Fisheries Newsletter

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Editorial

Welcome to this issue of the *Fisheries Newsletter*. In the article by Michel Blanc et al., the authors report on the outcome of a pilot project in Lifou, Loyalty Islands, New Caledonia, to turn fish waste into fish silage for use as a fertiliser and/or livestock food additive.

Antoine Teitelbaum and Sompert Gereva present the results of a small-scale anemonefish farming trial in Vanuatu. The main goal of this project is to determine whether anemonefish farming could be a viable activity in rural areas in Vanuatu. Anemonefish are among the most popular aquarium fish, and hatchery production is practised commercially on a routine basis in many developed areas.

William Sokimi, describes the deployment of two sub-surface FADs in New Caledonia, the design of the FADs being inspired (at a cheaper cost) from the Okinawa FAD.

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in This Issue

A small-scale anemonefish farming trial has started in Vanuatu. The photo shows the purchase of *A. clarkii* broodstock at an exporter's facility in Port Vila, Vanuatu.

SECRETARIAT OF THE PACIFIC COMMUNITY
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REEF FISHERIES OBSERVATORY

Staff of the coastal component of the EU-funded Pacific Regional Oceanic and Coastal Fisheries Development Programme (PROCFish/C) and the Coastal Fisheries Development Programme (CoFish) continued writing site reports, compiling and editing country reports, as well as providing management advice to Palau on its sea cucumber fishery. Auckland UniServices Limited has been contracted to provide statistical assistance with the regional analysis of the PROCFish/C dataset. The Live Reef Fish Trade Initiative has also been busy with surveys in Samoa, the Kosrae survey report, and an attachment from the Marshall Islands in Noumea to work on survey data.

Update on the compilation, finalisation and publishing of country reports

Sarah Langi and Celine Barre made good progress with compiling and editing country reports. The first three reports — Vanuatu, Nauru and Tuvalu — were published, and copies of these reports are on the PROCFish/C web portal[1]. Three other reports have been finalised (French Polynesia, Niue and Wallis and Futuna) and sent to the respective countries for comment and clearance. Two more reports (Samoa and Kiribati) have been fully compiled and are ready for editing.

Analysis of regional dataset

Staff of the PROCFish/C project are now analysing the regional dataset, which consists of more than 3000 variables in 254 tables, and 5700 additional variables in 425 views. Auckland UniServices Limited was contracted to provide assistance with the statistical analysis of the regional dataset. Associate Professor Brian McArdle of the University of Auckland will make three trips to Noumea to work with staff on the analysis during the last eight months of the project. The first two-week trip was made in September.

Dr McArdle worked with the senior scientists in each of the three disciplines (finfish, invertebrate, and socioeconomics) to review the datasets for statistical analysis on a regional basis. He also worked with staff in taking the first steps at data analysis across the disciplines.

His expertise validated current analysis undertaken by the scientists but also opened new avenues for examining and handling this intrinsically complex dataset. The outcome of this analysis will provide a better understanding of mechanisms that have a direct or indirect effect on fish and invertebrate resources and their use by local populations.

Technical assistance to Palau to develop sea cucumber fishery management plan

The Government of Palau requested SPC's Coastal Fisheries Programme to assist with facilitating a process to develop a sea cucumber management plan. The objective was to develop a more comprehensive plan for the management of this fishery in Palau for the foreseeable future. This plan will provide guidelines on how best to control activity in this multi-species fishery, which has over 24 species with potential for commercialisation.

Palau's sea cucumber fishery began in the early 1900s. Major harvesting in Palau occurred during the 1920s to 1940s. From then on until the 1980s, production of dried sea cucumber has been on an on-and-off basis for one to three years, separated by several years of no fishing.

The Palau Bureau of Marine Resources (BMR) recognised early on the danger to Palau's sea cucumber stocks, and judiciously put in place legislation in 1995 to ensure that the more valuable species were protected. Palau is among other island countries where sea cucumber features strongly in the local diet. Sea cucumber species consumed locally (Fig. 1) (referred to as "subsistence species") are not covered in the 1995 fishery ban. In an ongoing process of resource management, BMR is now canvassing input from Palau's fishers and community leaders in the development of a more comprehensive management framework for sea cucumber resources.

In support of the BMR's initiative, Kim Friedman and Kalo Pakoa from SPC's Reef Fisheries Observatory delivered stock status information developed through the cross-Pacific EU-funded PROCFish survey programme, and also shared their experiences of "what is" and "what isn't" working in management to a workshop held at the Palau International Coral Reef Center on 11 and 12 September. Etuati Ropeti, SPC's Coastal Fisheries Management Officer, facilitated the broad ranging discussions on developing management guidelines. After the work-

[1] http://www.spc.int/Coastfish/sections/reef/PROCFish_Web/default.aspx

shop, Kalo and Etuati remained in Palau for another week of consultations to allow stakeholders to give further input into the draft management plan. The draft plan has been completed and is being reviewed in Palau. Details of the Palau sea cucumber management plan can be found under the Coastal Fisheries Management Section's activities.

Figure 1: Ngimes (*Stichopus vastus*) is an important species in Palau's subsistence fishery.

Finfish presentation to the 11th International Coral Reef Symposium

In July, Silvia Pinca of SPC's Reef Fisheries Observatory attended the 11th International Coral Reef Symposium in Fort Lauderdale, Florida, to present some preliminary observations from the PROCFish/C and CoFish projects. The oral presentation was part of the Mini-symposium "Coastal Reef Associated Fisheries, Ecological Processes and Climate Change. Silvia's presentation — "Revealing patterns of impact of fishing on fish resources from a large scale regional program" — provided initial offered a preliminary analysis of assessments of underwater finfish resources and socioeconomic interviews carried out in most of the countries visited by PROCfish/C and CoFish. Values of biomass, size, trophic composition of food fish families, as well as catches and catch per unit of effort (Fig. 2) were used in reciprocal correlation analyses to try to extract information on the level of resource use at the different sites.

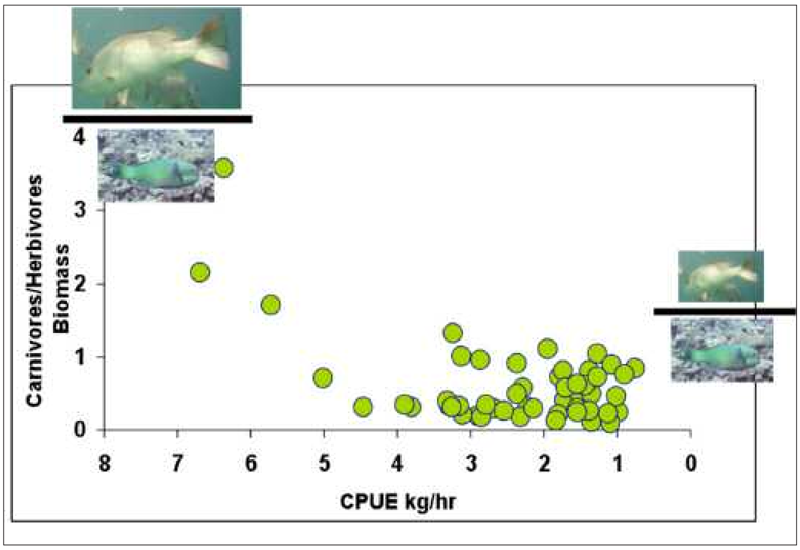


Figure 2: Decreasing relative importance of carnivores over herbivores with increasing fishing pressure.

Particular country examples of finfish biomass, size and carnivore percentage related to fishing stress measured by total catches, catch per unit of effort, percentage of export fishing, distance from market and human population density were given for Kiribati (Fig. 3) and Vanuatu. This presentation will be included in the proceedings of this four-yearly conference.

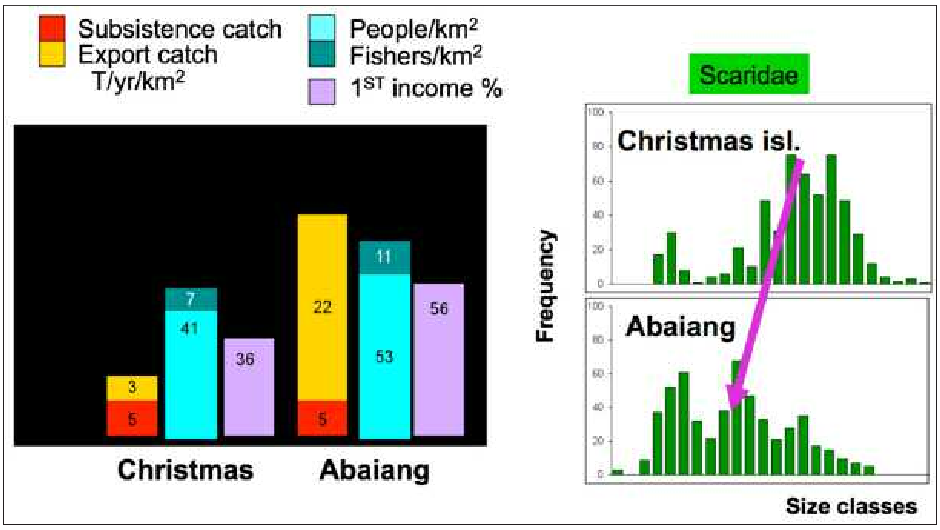


Figure 3: Reducing size structure in an herbivore family, Scaridae. Examples from two sites in Kiribati, where subsistence catches, export catches, density of people, density of fishers, and percentage of people receiving their principal income from fishing displayed very different values. Such descriptors suggest that Christmas Island has less fishing pressure than Abaiang, which is reflected by the healthier parrotfish size structure.

Many discussions in the fisheries mini-symposium focused on different coral reef fisheries problems, including the unreliability of reported catches as the number one problem in managing fishing activity throughout tropical countries. Other interesting reports analyzed trophic cascades and fish community responses to fishing pressure, the problem of baseline shifts in resource assessments, the effects of fishing from different gear use, the efficiency of management measures through gear restrictions, the effects of no-take areas on the number and size of fish, and the importance of protecting fish spawning aggregations. The symposium, which hosted about 4000 scientists from around the world, focused on the imminent risk of loss of world coral reefs and their associated fisheries due to global warming and overfishing, and on the unavoidable need to protect such delicate and productive environments in order to maintain sustenance for millions of people.

Some early socioeconomic findings

According to the joint data analysis approach, each dataset (socioeconomic, finfish and invertebrate resources) are explored first prior to combining data from the three different disciplines. Major questions for exploring the socioeconomic dataset are:

1) What is the current fishing pressure (i.e. catch per resource unit), how does it vary across the region, and which are the major variables that can explain the variation found?

2) What is the degree to which the communities studied are dependent on reef and lagoon resources, and what are the major reasons for the variations found?

3) What are the major socioeconomic drivers that determine the degree of current fishing pressure and that could be used to improve future coastal fisheries management?

Any of the above points comprise numerous data exploitation steps and statistical interventions. In the following, the investigation of seafood dependencies is chosen to provide a better understanding and insight of the complexity of the ongoing data analysis. Of course, the results presented here are far from being exhaustive, and must be understood as examples only.

In order to best characterise dependency in terms of seafood consumption, we have applied a simplified WHO approach[2] that allows for the correction of per

[2] Kronen M., Snowdown W. and Schultz T.J. 2004. The seafood nutrition-health paradigm of South Pacific Islanders. Pacific Health Dialog 11 (1):6–12.

capita consumption by gender and age groups. This is necessary in order to correct for a wide range of socioeconomic situations that occur within our regional survey. The range includes communities that are highly dependent on remittances. A considerable number of working-aged men (and to a lesser extent women) migrate to either national urban centres (as is the case in the Solomon Islands) or often overseas (e.g. New Zealand, Australia, United States of America) for better employment opportunities. These family members regularly send (or irregularly), money and commodities to support the livelihoods of women, children and older members of their family left behind.

The range of study sites also includes very traditional coastal communities with a high number of children, and also communities that have adopted a more urban lifestyle (i.e. less children and smaller household sizes). For instance, across 65 sites, the average household size is 6.2 people (standard error, SE 0.25), however, minimum and maximum sizes are 2.5 and 12.2 per site, respectively. We found that on average, 30% (SE 3.4) of all households in the communities studied receive remittances. However, again the extreme situations range from 0–96% of all households that receive remittances. The average amount of remittances received by benefitting households across all 65 sites amounts to USD 1091/year (SE 116), and the minimum-maximum range is USD 0–4404/year/household. The amount of remittances received in these rural communities is an important income source. This is demonstrated if comparing the influx of remittances to the overall basic household expenditure needs. On average, remittances account for 42.5% (SE 5.5) of the average basic household expenditures, while in extreme cases this can be 0 to double the amount needed for covering basic needs.

Calculating seafood consumption per capita and year confirms not only the overall fact that Pacific Islanders are among the highest seafood consumers worldwide, but also that communities in Pacific Island countries and territories depend to significantly varying degrees on finfish, invertebrate and canned fish (Table 1).

The average finfish consumption — amounting to 67.5 (SE 4.3) kg/piece/year — greatly exceeds the assumed regional average of 35 kg/piece/year (FAO 1996).[3] But again, this average figure encompasses communities that eat as little as 9.7 kg/piece/year to as much as 167.2 kg/piece/year. Similar situations are shown in Table 1 for invertebrate and canned fish consumption. It is noteworthy that in many cases, invertebrates are consumed while gleaning or fishing and thus not accounted for in family meals.

By converting the average per capita consumption of finfish, invertebrates and canned fish into kcal[4] and applying an average of 2100 kcal/day input to healthily sustain a person, it is possible to express our consumption figures as a percentage of average annual energy needs. Results show that on average, finfish and invertebrate consumption alone supply about 13% (SE 0.8) of a person's average energy need, and if adding canned fish consumption, this amounts to as much as 15% (SE 0.8) on average.

Input of all eligible study sites by the percentage of energy covered by fresh seafood (finfish and invertebrates) only into the distance based (log+1 transformed input data, Euclidean based resemblance matrix) Linktree procedure (PRIMER E 2007 software), shows groups of communities that are comparative by their energy supply covered by finfish and invertebrate consumption (Fig. 4).

The Linktree shows three major groups — C, H and N — and the outlier A (study site 56). Summary finfish, invertebrate and canned fish per capita consumption figures within these groups (and SE) are provided in Table 2. ANOVA (single factor) showed that groups are distinguishable.

This information can help to further determine how much pro-

Table 1: Annual per capita consumption of finfish, invertebrates and canned fish across PROCFish/C and CoFish survey sites

	Finfish kg/pc/year	Invertebrate kg/pc/year*	Canned fish kg/pc/year
Mean	67.5	7.4	8.8
Min	9.7	0.6	0
Max	167.2	27.1	47.2
SE	4.3	0.7	1.1

* Edible meat part only

3 FAO 1996. Demand and supply of fish and fish products in the Pacific Islands — perspectives and implications for food security. p 165–177. Report presented at the International Conference on Sustainable Contribution to Fish to Food Security, Kyoto, Japan.

4 FAO 2004. The Pacific Islands food composition tables. 2nd edition. Dignan C., Burlingame B., Kumar S. and Aalsberg W. Rome.

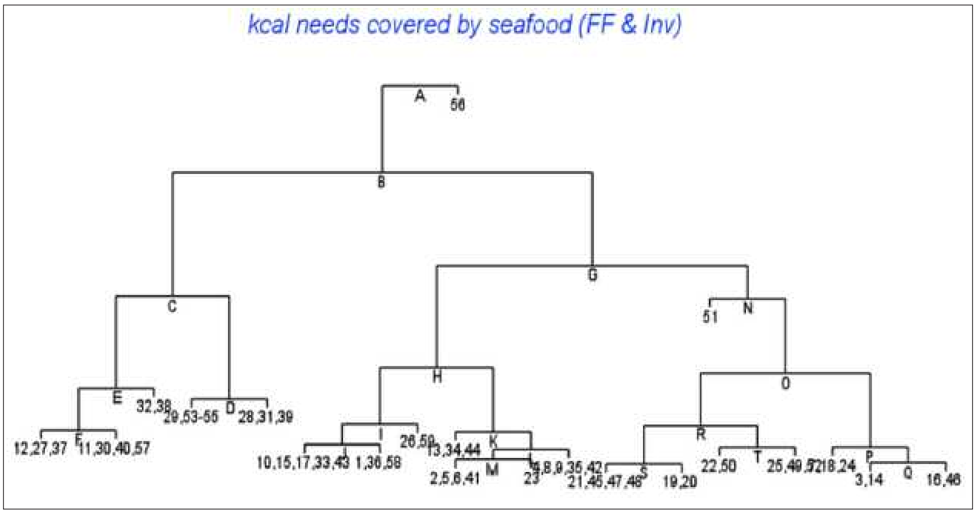


Figure 4: Linktree showing groups of communities that are comparative by their energy supply covered by finfish and invertebrate consumption.
[Note that numbers refer to particular study sites. For the sake of confidentiality, study site names are withheld.]

Table 2: Finfish, invertebrate and canned fish per capita consumption figures within groups A, C, H and N.

	Average finfish consumption kg/pc/year	SE	Average invertebrate consumption kg/pc/year	SE	Average canned fish consumption kg/pc/year	SE
Group A	9.72		3.21		4.62	
Group C	28.61	2.25	6.5	1.04	7.41	1.46
Group H	62.89	2.14	7.02	1.21	12.75	2.43
Group N	109.2	5.12	8.55	1.63	4.15	0.62

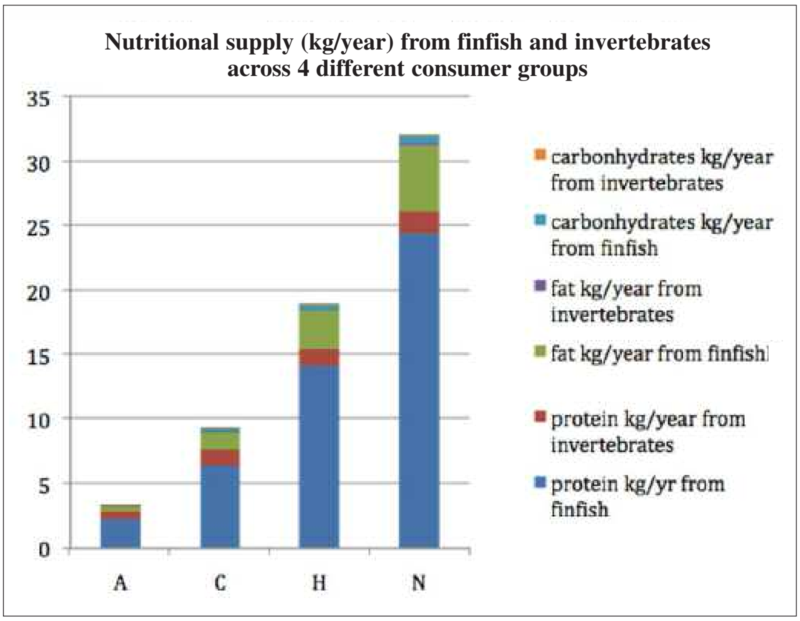


Figure 5: The amont of protein, fat and carbohydrates consumed by groups A, C, H and N (on average and on a yearly basis) by finfish and invertebrates.

tein, fat and carbohydrates people in each group on average consume on a yearly basis through finfish and invertebrate consumption only (Fig. 5). As seen in Figure 5, protein supply represents the most important nutritional contribution by finfish and invertebrate consumption, while fat and carbohydrates are low.

Further, we investigated reasons for the differences in seafood consumption attitudes. One reason is the availability of alternative food items, be it from the primary sector (i.e. agriculture) or from income and infrastructure that allows substituting traditional foods with commercial and often imported food items. The comparison between availability of agricultural land and regional seafood consumption supports the argument that access to alternative food items determines dependency on reef and lagoon resources.

Figure 6 demonstrates the significant relationship between agricultural land availability and seafood consumption patterns. Note, that this relationship is only one possible explanation. Also, in some countries, such as Nauru for example, agricultural land or garden areas may be available, and thus included in the dataset, however, people may not necessarily use this land but rather consume imported food items.

Furthermore, we can link consumption figures and the resulting fishing pressure as consequences. Figure 6 illustrates the highly significant relationship between the annual per capita consumption of finfish and invertebrates in kcal/km² of fishing area, and the annual subsistence catch in t/km² fishing area.

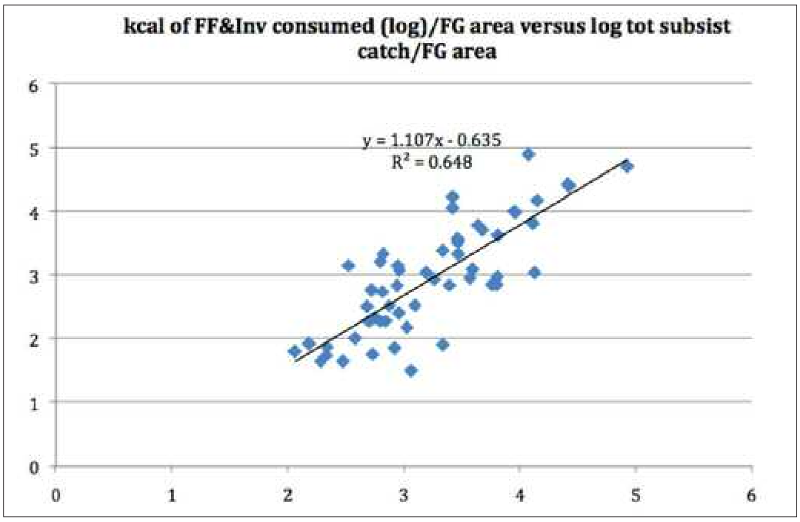


Figure 6: Relationship between agricultural land availability and seafood consumption patterns.

Pacific Islands Marine Data and Observations Training Workshop

A workshop to raise understanding and awareness about sources of marine data relevant to the Pacific Islands region was held from 22–25 September in Nadi, Fiji. The Pacific Islands Marine Data and Observations (PIMDO) training workshop was organised by the Pacific Islands Global Ocean Observing System and the South Pacific Sea Level and Climate Monitoring Project, and was funded by the East-West Center, the US National Oceanic and Atmospheric Administration, the Australian Agency for International Development, the Pacific Islands Applied Geoscience Commission (SOPAC) and SPC (through the EU-funded PROCFish/C project). The PIMDO training workshop was attended by professionals involved in the production and use of marine data specific to the Pacific (e.g. those from meteorological services, fisheries departments, regional organisations, etc.).

Workshop participants learned how to access various online data sources, using either near real time data — to measure changes in sea level and sea surface temperatures, and warn of coral bleaching events — or archival data — which examine long-term trends and anomalies. These data can then be used to monitor climate change and be correlated to biological data (e.g. coral bleaching events following the 1997/1998 El Niño).

The methodology used by PROCFish/C to produce a detailed bathymetric map for Aitutaki Atoll (Cook Islands) was presented by SPC's Reef Fisheries Information Manager, Franck Magron (see article on bathymetric mapping, using a combination of sonar data and satellite imagery in this newsletter). This method uses a QuickBird satellite image and existing sonar data (provided by SOPAC) to train an artificial neural network. The bathymetry will later be used by SOPAC to produce a hydrodynamic model of the atoll.

In addition to other presentations, a hands-on training was organised during the workshop to allow participants to access the data relevant to their country and to produce graphs and maps using web interfaces and freeware tools (Ferret).

Sub-regional underwater visual census finfish workshops

The first of four sub-regional underwater visual census (UVC) workshops was held in June and reported on in *Fisheries Newsletter* #125. The remaining three workshops were conducted in July and August, with 26 participants trained in the PROCFish/C UVC finfish methodology. The courses were run by PROCFish/C staff, Pierre Boblin, Silvia Pinca and Franck Magron. The course covered a presentation on the assessment methods and the equipment needed; classroom training courses on underwater fish census surveys at variable distances (fish and substrate); use of methods underwater with one to two diving sessions per day (Fig. 7) and data correction; classroom and practical training on how to use the RFID software for data entry, verification and cleanup; a short presentation on biases and the methods most likely to reduce them; and diver evaluation by means of a diving test at the end of the session.

The second course ran from 30 June–9 July and included eight trainees from four countries (Federated States of Micronesia, Bruno Ned and Curtis Graham; Marshall Islands, Candis M. Guavis and Frankie Harris; Palau, Gillian E. Johanes and Shalom E. Etpison; and Vanuatu, Sompert Gereva) and one SPC employee (Caroline Sanchez).

The morning of the first day was set aside for introducing staff, visiting the site and preparing the diving gear. In the afternoon, the first UVC methods class was given, mainly covering how to set up a transect and use a fish data sheet. A series of photos were projected on a screen to help trainees identify various fish species in New Caledonia. On the following day, the substrate data sheet was explained, together with the projection of photos designed to facilitate identification of various types of substrate, including corals, sessile invertebrates and algae. The afternoon was used to present the diving programme for the next day and to form teams. The remaining days of the course were used for dives around small islands and reefs classified as marine reserves in order to collect data. Once participants returned to SPC headquarters, they corrected their data. On the last day of the course, focused on biases and methods for reducing estimate errors and to verify and correct data that had been entered with the RFID software program.

The third workshop took place from 21–30 July and had nine participants (Fig. 8) from five countries and territories (French Polynesia, Yann Paureau and Michel Dhieux; Kiribati, Tuake Teema and Toaea Beiateuea; New Caledonia, Patrice Plichon and Christophe Glosset; Tuvalu, Simon Salesa and Tupulaga Poulasi; and Wallis and Futuna, Enelio Liufau). This training course was a bit unusual as it was given in SPC's two official languages, French and English.

The final workshop took place from 4–13 August, again with nine participants from five countries (Cook Islands, Ngametua Auaenau Tangatakino and Ngereteina George; Niue, Jamal Talagi; Papua New Guinea, Ian Liviko and Kilangis Erest Komet; Tonga, Mele Ikatonga Makasini and Elaona Vea Kava; and Samoa, Seleni Isaia Tiitii Matau and Mikaele Faamai). Three divers were identified as being suitable to participate in the upcoming PROCFish field activities.

Figure 7 (top): Recording substrate data during the practical session of the UVC workshop.

Figure 8 (bottom): Participants of the third UVC workshop.

Live Reef Fish Trade Initiative assistance to Samoa

Samoa was involved in the marine aquarium trade from the late 1980s until 1997 when a ban was placed on the whole industry because of public concern about the harvesting of live rock. In 2005, during the SPC Heads of Fisheries meeting, Samoa indicated interest in having SPC examine the status of its marine aquarium trade resources.

Given the increasing challenge of meeting the needs of local Samoan communities for alternative income generating opportunities and employment, Samoa officially requested SPC's assistance in June 2008, in assessing marine aquarium trade fish resources around Upolu. SPC's Senior Fisheries Scientist (Live Reef Fisheries), Being Yeeting, was assigned to liaise and plan the details of the work with Samoa's Fisheries Division. From 16 August to 2 September 2008, Being undertook several fieldwork assignments, the first of which was to train Samoa's fisheries officers in UVC methods (Fig. 9), which are used by SPC to conduct fisheries resource surveys. The second assignment was to conduct a marine aquarium fish resource survey around Upolu, using UVC methods and using the newly acquired expertise of the trained fisheries officers.

In-country UVC training for fisheries officers

The three-day training of local Samoan fisheries officers involved classroom sessions and in-water sessions. Ten participants registered their interest in the training, although only four were only able to take part in classroom sessions. Classroom sessions included lectures on methodology, a description of the forms and definitions used, fish identification exercises using fish photos, and an explanation and demonstration of how the entry and storage of data in the RFID database works. The in-water exercise consisted of training participants to estimate fish size and distance from the observer, and getting individual estimate errors to an acceptable margin of +2 cm. This session also focused on training participants to recognize and identify substrate types, identify fish species, and implementing survey techniques in order to build personal confidence in the use of the UVC method. Generally, after five or six in-water practice runs, trainees were able to conduct the survey with confidence.

Survey of Upolu's marine aquarium fish resources

Directly after the UVC training, a survey of Upolu's marine aquarium fish trade resources was conducted. Six sites were surveyed: two were fished, two were not fished, and two were reserves. At each site, six transects (50 m x 10 m) were laid out, resulting in a total of 36 transects around Upolu. To enable the team to survey the outer reefs, alias from the nearby villages were hired (Fig. 10). Data collected from the survey were collated and photocopied; the original data forms were left with the Samoa Fisheries Department, with copies taken to Noumea for processing and safe keeping.

Figure 9: In-water training of Samoan fisheries officers.

Attachment training in Noumea for Samoa Senior Fisheries Research Officer

A week after the marine aquarium fish survey, Samoa's Senior Fisheries Research Officer, Joyce Ah Leong, was attached to SPC's Coastal Fisheries Programme in Noumea for two weeks to be trained in using the RFID database. Joyce learned how to enter and "clean" the Upolu marine aquarium resource survey data, how to interpret and analyse the data using RFID queries, and how to write up the survey results into a technical report. At the end of the two weeks, Joyce became competent in the use of the RFID database, and was able to enter and clean all data, and run basic analyses. A report outline was prepared, which she could take back to Samoa, together with the analyses of the survey data. The results will be discussed and integrated into the technical report that Being is co-authoring with Joyce, and which is expected to be completed by the end of 2008.

Review of the Samoa Ciguatera Fish Poisoning Monitoring Programme

In addition to the Samoa marine aquarium fish resources survey, a review of the Samoan Ciguatera Fish Poisoning Monitoring Programme was also undertaken at the request of the Samoa's Fisheries Department. The Department had already collected algae samples to try to confirm the occurrence of the fish poisoning causative agent, the dinoflagellate *Gambierdiscus* spp. (Fig. 11). The samples collected show no sign that the dinoflagellate is present in the known infected areas and so the Fisheries Department wanted to make sure that the sampling protocols were done correctly.

Figure 10: Samoan alia used for transporting people to outer reefs for survey work.

Figure 11: Ciguatera dinoflagellate, *Gambierdiscus toxicus*.

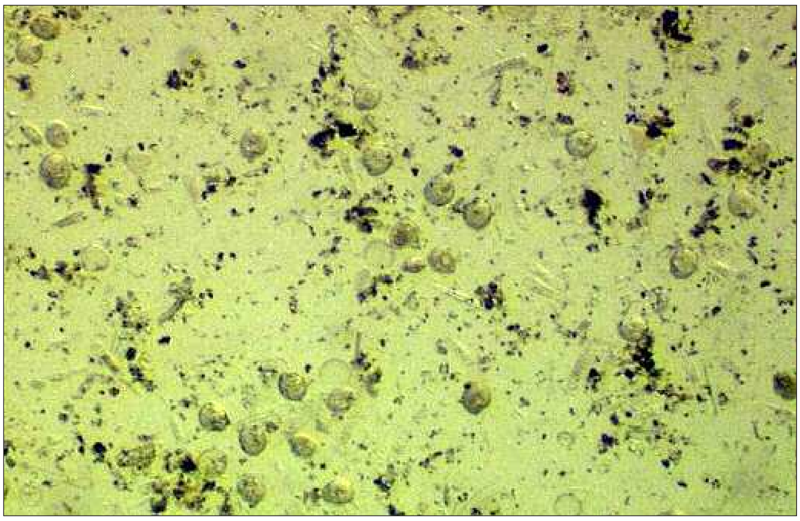


Figure 12: A view of a sample under a binocular microscope showing cells of *Gambierdiscus* spp.

Being was able to look at a few of the processed samples and confirm the absence of Gambierdiscus spp. In reviewing the sampling technique, he interviewed a number of the Samoan Fisheries Department staff to learn how the sampling was actually done. From the interview two things became obvious: first, the host algae samples were collected from reef areas that were too deep, and second, the samples, which were placed in containers, were not shaken long enough to get the dinoflagellate cells off from the algae which are then sieved out and counted under a microscope to estimate the number per weight of the host algae.

It was therefore recommended that new samples be collected and analysed. To identify *Gambierdiscus*, a processed sample from Niue (collected by SPC several years back), known to have the dinoflagellates,was given to the Samoa Fisheries Department for reference along with some photos (Fig. 12).

Attachment training for Marshall Islands Marine Resources Authority fisheries officer

Following the marine aquarium fish resources survey of Majuro Atoll (April and May 2008), there was a short-term attachment training of one of MIMRA's fisheries officers to learn how to use the RFID database for entering, cleaning and analysing survey, similar to the training provided for the Samoan fisheries officer. In late July, fisheries officer Candice Guavis was in Noumea to attend the PROCFish UVC training workshop, which also provided her an opportunity to stay on for an extra week to learn how to enter and process the survey data using the RFID database.

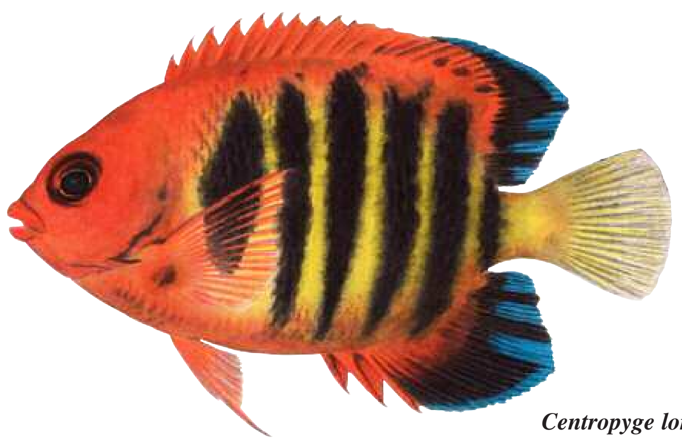
At the end of the week, all data from the Majuro survey were entered and analysed and she was able to take the results of the analysis with her back to MIMRA. While it was not possible to work on a technical report, an outline was developed for her to take back to the Marshall Islands for review and discussion with other survey team members, to help them draft their allocated parts.

Kosrae marine aquarium resources survey report

A draft Kosrae Marine Aquarium Resource Survey report has been sent to the Federated States of Micronesia (FSM) for comments. The results of the survey show that there are 153 species of interest to the marine aquarium fish trade, representing 16 main fish family groups. The most dominant family — in terms of number of species and number of individuals — was Pomacentridae, with *Chromis margaritifer* being the most dominant species with an overall estimated stock of 1.72 million individuals.

Based on survey results, the majority of fish species observed were low valued species. Also, all species observed were ones that are quite commonly found in other Pacific countries. Therefore, it would seem that the level of endemism and rarity for fish species in Kosrae is low, although some of these fish species are ones that are quite popular in the marine aquarium trade and form the basis of most Pacific aquarium trade operations. These include the two angelfish *Centropyge loriculus* and *C. vrolikii*, two damselfish *Dascyllus trimaculatus* and *Chrysiptera traceyi*, the dartfish *Ptereleotris evides*, two anthias *Pseudanthias dispar* and *P. pascalus*, three wrasses *Gomphosus varias* (bird wrasse), *Labroides dimidiatus* (cleaner wrasse) and *Thalassoma lutescens* (banana wrasse), and the green triggerfish *Balistapus undulatus*.

The status of live corals around Kosrae is very good, with an estimated live coral coverage of 60%. The massive and table



Centropyge loriculus

corals are the dominant types found on the outer reefs, with very little evidence of coral bleaching, and will provide a basis for coral farming.

The survey results provide a first estimate of fish stocks, which can be further improved with more surveys. It is recommended that at least two additional surveys be completed, if possible.

However, before allowing marine aquarium fish operations to go ahead (if the FSM government decides to do so), it is important to have a management framework in place. This framework should include a management policy and plan, with regulations and conditions that will ensure the sustainable use of resources. In addition, an economic feasibility study would also need to be conducted to work out the costs and benefits of having a marine aquarium trade industry. Such a study should look at all aspects of the chain of custody, from the suppliers to the market. This should be done to help provide the information needed to decide whether to have this industry or not.

COASTAL FISHERIES MANAGEMENT SECTION

Developing Palau's sea cucumber fishery's management plan

Palau's Bureau of Marine Resources (BMR) requested assistance from SPC's Coastal Fisheries Programme to develop a sea cucumber management plan. Etuati Ropeti (SPC's Coastal Fisheries Management Officer), Kim Friedman (SPC Senior Fisheries Scientist) and Kalo Pakoa (SPC Reef Fisheries Officer) attended to the request.

Unlike other Pacific Island countries, Palau possesses a sea cucumber fishery with over 20 marketable and commercially valuable species. Experiences from other countries reveal that the sea cucumber fishery is vulnerable to overharvesting, with most countries facing the difficulty of implementing proper management controls. Increased fishing, both over the years and across the fishery, means that fewer reef areas retain sea cucumbers at densities high enough to reproduce successfully, and the remaining adults are becoming too scattered to produce. Management systems have proven to be inadequate in controlling this decline in some countries. The tragedy is that sea cucumber fisheries have the potential to help boost village economies, but like falling dominoes, they have declined and collapsed in much of our region, as marine product agents move and open new areas when traditional fisheries become less productive.

BMR recognised early on the danger to Palau's sea cucumber stocks, and judiciously put legislation in place in 1994 (Marine Resources Act 1994), banning the export of sea cucumbers in an effort to ensure the more valuable species were protected. With declines in sea cucumber resources across the Pacific, it is foreseeable that the demand for sea cucumbers will continue to place increasing pressure on Palau's fishery. A sea cucumber management plan for Palau could not come at a better time because the export of sea cucumbers is banned and pressure from increasing market demands mounts.

Background

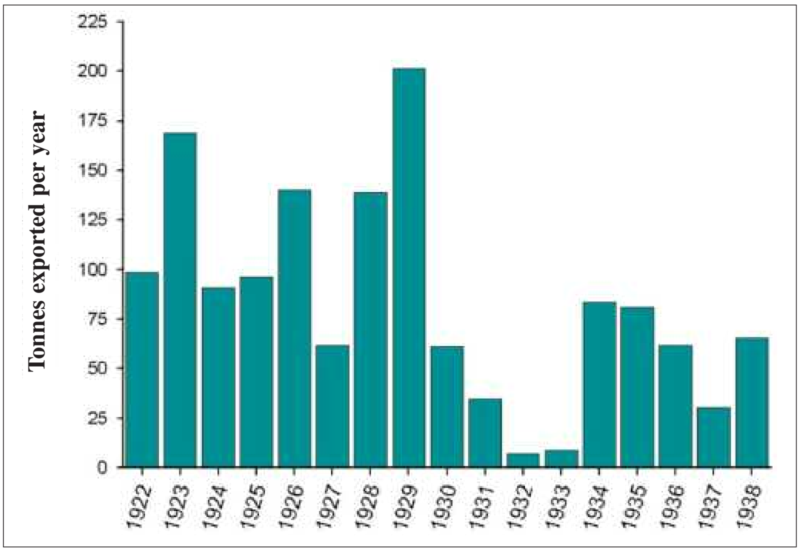
Palau's economy is dominated by the service sector, which contributes over 50% of Palau's GDP and employs half of the country's work force. Palau receives substantial aid money from the USA under the terms of the Compact of Free Association (this is likely to vary over the coming years). Tuna is the country's principle export commodity (2500 mt per year) although there has been a decline in the last few years.

Coastal reef fisheries are more important than pelagic fisheries for subsistence food security and domestic economy. Tourism is Palau's main industry, its major draws being its diverse and pristine marine and terrestrial environment.

Commercial fishing for sea cucumbers occurred before the 1700s, and is thought to have reached Palau and Micronesia in the 1800s. Commercial fishing for sea cucumbers is a traditional fishery in the Pacific region, although demand is low compared with the Asian (typically Chinese) market. The sea cucumber fishery can therefore be divided into two sectors: the subsistence sector, using certain species for domestic consumption; and the commercial sector, comprising species that are typically dried and sold to Asian markets. Atypically, there is also a small and growing sector for the sale of "export" quality species to local restaurants in Palau. This is likely to increase with increased tourism from China and the rest of Asia to Palau.

History and status of the sea cucumber fishery

Asian trade in sea cucumbers began very early, although historical records for Micronesia



Historical sea cucumber production from Palau.

indicate that it likely began during the Japanese presence (from the 1920s–1930s). These fishing records reveal that the islands of Micronesia were producing an average of 189 mt of dried sea cucumber per year for export to Hong Kong and China. Palau alone was a major producer in Micronesia, supplying on average 84 mt (of sea cucumbers (dry weight) in the Micronesian region during this period. Closer analysis of the data shows that by the 1930s, production had fallen from a high of around 150–200 mt to around 25 mt. Species of importance traded during these early days were *Holothuria scabra* (sandfish), *H. nobilis* (black teatfish), *H. fuscogilva* (white teatfish), *Actinopyga mauritiana* (surf redfish), *A. miliaris* (black teatfish) and *Thelenota ananas* (prickly redfish).

Fishing records after the Japanese occupation in Micronesia were patchy from the 1940s up to the 1960s, although some trading activities are known to have occurred in the 1950s. Trade resumed in 1970 with exports of 1400–2000 sacks of dried products per year.

While Melanesian countries experienced a surge in production in the 1980s and 1990s, Palau continues to export only small amounts. Low export rates of commercial species well into the 1990s, suggests that heavy fishing in the 1920s and 1930s may have largely depleted the fishery to a point where adults were only sparsely distributed, negatively affecting subsequent spawning success, and the fisheries' natural capacity to "bounce back".

Subsistence use of sea cucumbers

Subsistence use of sea cucumbers for domestic consumption is a long tradition in Palau. Ten of the 26 species of sea cucumbers present in Palau — *Holothuria scabra (molech)*, *Actinopyga* sp. *(ceremrum)*, *Stichopus vastus (ngimes)*, *H. impatiens (sekesakel)*, *Thelenota ananas (temtamel)*, *S. horrens* and *Bohadchia similis* and *B. vitiensis* — are featured in the subsistence fishery but the most commonly used ones are *molech*, *ceremrum*, *ngimes*, *sekesakel*. The viscera (guts) of *ngimes* and *sekesakel* (and sometimes *molech*) are consumed as a delicacy and the flesh from the body wall of *molech* and *ceremrum* is processed into an edible form and consumed raw or cooked.

Palau's subsistence sea cucumber fishery can be divided into three categories: home consumption, local market sales, and export for home use by families living abroad in Guam, Saipan and the USA. Landings of raw sea cucumber over a 10-year period from 1989–1998 by the subsistence sector, averaged 20 mt per year. Much of this production (40%) is exported for home use, 30% for local market sales, and another 30% for domestic consumption in Palau.

Development of the sea cucumber fishery management plan.

Local sales continue to be an important activity for women and an income generating activity for local communities.

Developing the management plan

The management actions recommended depict the collective view of community representatives, NGOs, State officials and representatives, government officials and various individuals in Palau. These management measures come about as a result of consulting with individuals who have engaged in the processing and export of sea cucumber products in the recent past, and interviews and stakeholder consultations during a two-day workshop in Koror, Palau. The management undertakings provide a framework to guide the development of relevant legislations and policies for potential commercialisation of the fishery.

The general vision for the management plan is:

> *Well-conserved and biodiverse sea cucumber populations in a clean and healthy coastal environment, that support a sustainable fishery, are linked to cultural heritage activities and whose biology and ongoing status is well understood by the Palauan population.*

The management plan's overall objectives are to:

- manage the sea cucumber fishery for now and future generations;
- provide guidelines for the development of national and State policies on the management of the sea cucumber fishery; and
- provide a framework for policy-makers to assist with their decision-making in regards to the management of the sea cucumber fishery in Palau.

The recommendations highlighted in the plan include, among others, species controls, limited entry (i.e. restrictions on the number of fishers), fishing seasons, gear restrictions, maximising benefits through the export of premium products, limiting the number of processors/exporters of premium species, terms and conditions of licences (processors/exporters), and monitoring of the fishery.

AQUACULTURE SECTION

Training for seaweed farmers and project field-men in Fiji Islands

Fiji's Department of Fisheries and SPC's Aquaculture Section recently collaborated on an advanced-skills training in *Kappaphycus* seaweed farming for seaweed project field men in Fiji. Organised jointly by Department of Fisheries staff Lorima Hansen and Sam Mario and SPC's Tim Pickering (10–12 September), the emphasis was on seaweed nursery techniques (floating raft and floating long-line construction), seaweed biology and ecology (to understand culture and processing methods), an update of current trends in world markets, and a full-day practical session (at Nukulau Island near Suva). SPC contributed to the training by providing each field man participant with a copy of a seaweed farming manual in English, seaweed "comic books" for distribution to farmers, seaweed training DVDs in both the English and Fijian lan-

"This deep." Sam Mario of Fiji's Department of Fisheries shows Kabariki farmers the correct level for spreading harvested *Kappaphycus* seaweed on drying platforms in order to optimise the sun-drying process and avoid loss of quality.

guages, and a soft-copy Fijian translation of the seaweed farming manual.

A second workshop was held on Kadavu Island, Fiji, this time aimed at rural villagers who are considering taking up seaweed farming as a new livelihood. Held at Kabariki Village in southern Kadavu, participants also attended from the neighbouring villages of Levuka and Nukubalavu. This workshop was run by Sam Mario with Tim Pickering and Kadavu-based fisheries staff Rabo and Keni. Explanations were given about basic techniques to farm seaweed and how to choose appropriate farm sites to avoid culture problems. As a practical demonstration of nursery techniques and alternatives to the standard off-bottom culture method, a seaweed longline and a raft was constructed by participants, seeded with seaweed and deployed in the lagoon in front of the village. Evenings were spent in informal discussion sessions, talanoa, about seaweed and other fisheries topics. Farmers provided feedback about the training, which they greatly appreciated because it had filled gaps in their knowledge about the purposes and processes of seaweed farming in Fiji.

Southern Kadavu is one of three locations where seaweed farming is currently being encouraged by the Fiji government and by the main seaweed buyer, Agro-Marketing Authority, through focused assistance in farmer training, seedstock culture for planting, and marketing assistance. The other two places are Namuka Island and Ono-i-Lau Island, both in the southern Lau group. Seaweed farming is undergoing a renaissance in Fiji due to recent increases in global seaweed prices fueled by the high demand in China, and due to the continued interest in sustainable alternative livelihoods by people in Fiji's maritime provinces.

NEARSHORE FISHERIES DEVELOPMENT AND TRAINING SECTION

Review of the WWF pilot fish aggregating device in the Galapagos Islands

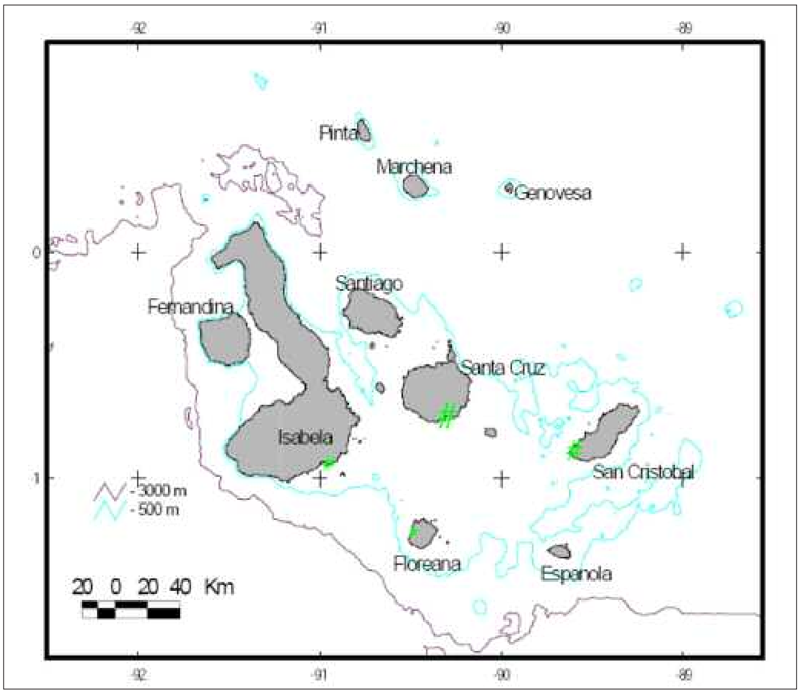
During July 2008, SPC's Fisheries Development Officer, Steve Beverly, conducted a project review in the Galapagos Islands, Ecuador in South America. The two main objectives of the review were to 1) evaluate a pilot fish aggregating device (FAD) project that the World Wildlife Fund (WWF) and Galapagos National Park (GNP) are currently implementing in the archipelago in coordination with the fishing sector, and 2) to work with local technicians to evaluate and improve the performance of the anchored FADs, the fishing techniques used, and the monitoring system in place. The objective of the pilot FAD project, which only allows the use of handlines in fishing, is to provide an economic alternative for artisanal fishermen, allowing them to spend less time and money in catching more valuable species such as bigeye and yellowfin tuna, and to reduce fishing pressure on other resources, such as sea cucumbers and lobsters. The pilot FAD project is a first for the Galapagos so they called on the expertise of SPC's Nearshore Fisheries Development and Training Section for assistance. The Galapagos Island's fishery was experiencing the same problems that have beset fisheries in many Pacific Island countries. The review was funded by WWF Galapagos.

The Galapagos Islands (Fig. 1) is an archipelago of volcanic islands that straddle the equator in the eastern Pacific Ocean about 1000 km west of continental Ecuador. The archipelago comprises 128 islands and islets, the largest of which are Isabela, Santa Cruz and San Cristobal. The total land area is 7880 km^2 with a coastline of 1800 km. The archipelago sits on a submarine platform with depths ranging from 1000 m to 3500 m, but the main islands sit on a central platform with depths generally less than 500 m. The islands are affected by three oceanic current systems: the Panama Current from the northeast, which is warm and nutrient poor; the colder Humboldt Current from Chile and Peru; and the nutrient-rich equatorial Cromwell Counter-current from the west. Because of the upwellings caused by the latter of these currents, the waters around the Galapagos Islands are rich in flora and fauna.

Of the 100 or so marine species caught in the Galapagos artisanal fisheries, only a small number are actually targeted. Among these are sea cucumbers (pepino de mar – *Isostichopus fuscus*), two species of spiny lobsters (*Panilurus pencillatus* and *P. gracilis*), several bottom and demersal fish species (e.g. *Mycteroperca olfax* and *Epinephelus mystacinus*), and pelagic species such as yellowfin and bigeye tuna (*Thunnus albacares* and *T. obesus*) and billfish (*Xiphias gladius*). Recently (2002–2003), the most lucrative of these fisheries has been sea cucumbers (worth USD 3.7 million/year), followed by lobsters (USD 1.1 million/year), and finfishes (about USD 0.7 million/year). Because of the lucrative nature of the sea cucumber and lobster fisheries, there was a heavy influx of fishermen and boats in the Galapagos during the late 1990s (Fig. 2). However, from 2002 to 2006, sea cucumber revenues dropped by 83% and lobster revenues by 43%. In 2002, the average artisanal fishing boat earned around USD 8000 annually, but this dropped to around USD 3400 annually by 2006.

The collapse of the sea cucumber fishery and the depletion of lobsters raised concerns of both local and national authorities as well as non-governmental organisations (NGOs) about the sustainable use of fishery resources and the conservation of the Galapagos Marine Reserve. The use of anchored FADs to help artisanal fishermen target pelagic species such as bigeye and yellowfin tuna was identified as the most probable viable alternative. With the advice of the fishing sector, GNP authorities selected appropriate sites to locate the FADs. The chosen positions were near Isabela, Santa Cruz and San Cristobal islands, where there are established fishermen's cooperatives. Since 2006, WWF has been supporting the GNP and the fishing sector in the implementation of the FAD project. GNP authorities deployed three FADs: one southeast of Isabela, one south of Santa Cruz, and one southeast of San Cristobal (Fig. 3).

Workshops were then held for fishermen on Isabela and Santa Cruz on FAD maintenance, project



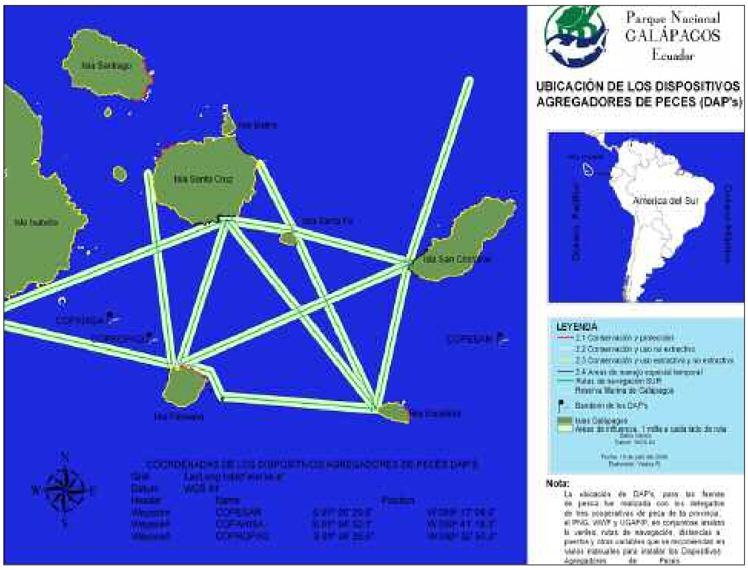


Figure 1 (top). Galapagos Islands. Blue line is 500 m isobath, purple line is 3000 m isobath. Green hash marks are main population centers and sites of the fisheries cooperatives .

Figure 2 (middle). Typical Galapagos fishing boats.

Figure 3 (bottom). Galapagos Islands, showing FAD positions and tourist boat routes.

regulations and management plan, FAD fishing techniques, and monitoring and data collection.

The Galapagos FADs have very robust cylindrical buoys made from fibreglass and foam with inner steel spars (Fig. 4). They are equipped with lights, batteries, solar panels, radar reflectors, and padeyes for attaching boat mooring lines. Galapagos fishermen refer to FADs as plantados (planted), and the FAD buoys with lights and radar reflectors are called cabezas (heads). Aggregators are called pantallas (screens) or cuerpos agregadores (aggregating bodies). The mooring line is called línea de anclaje (anchor line) and the anchor block is called durmiente (sleeper) or muerto (dead).

Steve went on a fishing trip to one of the FADs on a 7-m fiberglass boat powered by a 75 HP outboard motor. As soon as they reached the FAD they began trolling, using handheld 100 m x 3.5 mm braided nylon lines with 10 m x 1.0 mm nylon monofilament sections and 0.5 m wire traces, ending with Rapala Magnum lures. The catch on the trolling lines was 20 small yellowfin tuna (Fig. 5) and 2 small mahi mahi. At dusk, they tied to the FAD and had dinner while waiting for the waning full moon to rise. When the moon came up they started fishing with the same lures they trolled with, jigging these about 15–25 m behind the boat, in the current but not on the surface (sinking them to 15–20 m). The catch was seven larger yellowfin tuna of

Figure 4. Galapagos FAD.

Figure 5. Small yellowfin tuna caught on a Rapala Magnum lure while trolling near the FAD.

Figure 6. Large yellowfin tuna caught on the same Rapala Magnum lure while the boat was tied to the FAD.

about 15 to 25 kg each (Fig. 6). Total catch was 29 fish, weighing 170 kg, which were sold the same morning for USD 2.00/lb (USD 4.40/kg). The captain said that they usually get catches like that around the full moon. He also said that his break-even point for a one-day trip was around 182 kg (400 lb) of fish,

Galapagos fishermen use three FAD fishing techniques (artes de pesca en asociación con plantados) aimed at capturing pelagic species. These include vertical longlining (empate oceanico), handlining (línea de mano), and trolling (línea de arrastre, or troleo). It has been suggested that the law should be changed to allow alternative fishing techniques, using mechanized reels — either hand reels or electric reels — but use of these devices would require a revision of the Galapagos Special Fishing Law. The Galapagos Special Fishing Law specifies the types of fishing gear that can be used by artisanal fishermen in the Galapagos Marine Reserve, but there are no regulations limiting the number of lines or hooks that each boat can use.

Steve provided a comprehensive report to WWF, making several recommendations to improve the FAD project, including:

- A FAD project manager should be selected to oversee all project activities, including keeping an inventory of FAD materials, coordinating FAD monitoring, catch and effort data collection, data analysis, economic analysis, and ongoing FAD maintenance;
- The FAD design should be reviewed and some changes should be made. Indian Ocean type FADs equipped with radar reflectors and lights would result in a substantial cost savings although they have disadvantages in comparison to a spar buoy design (lower visibility and boats cannot tie to them);
- A FAD maintenance check list should be written and distributed to all e fishing cooperatives. A check list will not only serve as a reminder for all of the components that need to be inspected, cleaned, and repaired, it will serve as a record for the FAD project manager to assist in ordering new materials and conducting more vigorous maintenance visits;
- The FAD project should adopt a simple form to collect data directly from the fishermen — something similar to SPC's Canoe/FAD Monitoring Logsheet — and avoid complicated forms that fishermen are likely to ignore. Logsheets should concentrate on catch and effort, fishing techniques, sea conditions, trip expenses, gross and net revenue, and bycatch;
- A port sampler project should be initiated in order to obtain more detailed data on catch, including species, fork length, weight, deposition, revenue, etc. Port samplers could interview fishermen upon returning to port in each of the three fishing centres in order to collect relevant information. All fish could be measured (fork length) upon unloading and a value could be placed on the catch based on observed sales or based on interviews or market trends;
- WWF should lobby the government to allow small-scale reels into the FAD fishery, such as the FAO wooden hand reel;
- Vertical longlines should be rigged so that there are no hooks in the upper 50–100 m of the water column, circle hooks should be used on longlines, and de-hookers should be carried by all boats; and
- WWF and GNP should initiate more workshops on FAD fishing techniques and proper fish handling for the fishing cooperatives, and include topics such as making your own FAO wooden hand reel, vertical longline fishing, palu ahi and other handline fishing methods, on-board handling of sashimi grade tuna, and tuna grading.

Assistance to a domestic longline company in the Cook Islands

In September, Steve went to Rarotonga, Cook Islands to offer assistance to a domestic longline company and to make two presentations to the Cook Islands Tuna Industry Conference, which was organised by the Cook Islands Marine Institutional Strengthening project.

Last year Steve was in the Cook Islands for two months assisting the Rarotonga-based domestic longline fishery (see *Fisheries Newsletter* #122). One of the outcomes of that project was a suggestion that larger boats may do better as they were able to fish more of the EEZ in the southern Cook Islands. The domestic fleet at the time averaged just 14 m in length, and all were conducting shallow sets without using a line setter. One operator, Land Holdings, purchased a larger (18 m) longline vessel in 2008, but was still experiencing difficulties. They asked the

Ministry of Marine Resources (MMR) to request further assistance from SPC.

Steve went on one longline trip on the new vessel, F/V *Gold Country* (Fig. 1), and determined that the boat was fishing the same way the smaller boats were fishing during his 2007 visit: short trips in close proximity to Rarotonga. Figure 2 shows the Argos track of the fishing trip. Note that the trip was brief — only four sets were made — and that all sets were made within a range of about 75 nm from Rarotonga. Even though F/V *Gold Country* had an operating range greater than the other vessels in the Rarotonga-based fleet, it was not taking advantage of this capability. In addition, the boat was not using a line setter (shooter), even though the company had purchased one when they bought the boat in early 2008. Steve recommended that Land Holdings mount the line setter on F/V *Gold Country* and then begin a campaign of expanding their range so that they could explore the rest of the southern Cooks fishery and better target bigeye and albacore tuna.

The first presentation that Steve gave to the Cook Islands Tuna Industry Conference was titled "Improving fishing performance in the domestic longline fishery". The presentation outlined three themes: increasing fishing effort, improving CPUE, and increasing revenue. The second presentation was given jointly with Pam Maru of MMR and Dr Yonat Swimmer of the US National Marine Fisheries Service in Hawaii, and introduced a planned hook exchange programme that will likely take

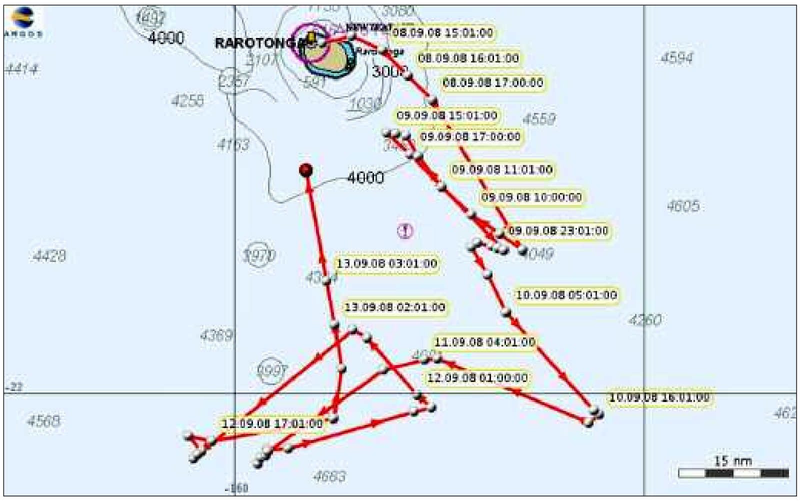


Figure 1 (top). F/V *Gold Country*.

Figure 2 (bottom). Argos track of F/V *Gold Country*'s longline fishing trip from 8–13 September 2008.

place in the Cook Islands during 2009. The plan is to replace all of the longline hooks currently being used by the domestic fishery, with standardised stainless steel tuna circle hooks, probably 16/0 hooks without the ring. These hooks have been found to help mitigate the capture of some bycatch species, especially sea turtles, and to help with post-release survival if these species are hooked. Data will be recorded on all fishing trips, and results will be compared with past data from trips where hooks were not standardised.

FAD fishing methods and small boat safety workshop in Suva, Fiji Islands

Background

Fiji's Department of Fisheries' Capture and Development Section are tasked with maintaining the development of safe and sustainable small fishing boat operations to ease the burdens of operational costs on artisanal and small-scale commercial fishermen throughout Fiji. Rising fuel costs and declining catch rates have significant adverse effects on the fishermen's capabilities to return home with a profitable catch; therefore, any intervention by Fiji's Department of Fisheries to alleviate these burdens are very much welcomed by the fishermen.

The fishermen are categorised into four groups:

- Fishermen who troll for pelagic species around FADs and running schools.
- Inshore and offshore fringing reef slope fishermen using hand-lines and nets.
- Night divers for reef fish.
- And fishermen who carry out a combination of these fishing activities.

While contemplating assistance to these fishermen, the Fiji Department of Fisheries had to keep in mind the declining inshore reef stocks that are evident in areas adjacent to most of the heavily populated urban coastlines.

The current preliminary solution is to implement FAD programmes in strategic areas to encourage fishermen to fish for pelagic species — as an alternative to reef fish — so that reef species are given an opportunity to recover. Fishermen will need to be taught several basic, but effective, FAD fishing methods that will enable them to use FADs fully and enhance their chances of returning with a payload catch. Most FAD fishermen only troll around FADs, which consumes considerable amounts of fuel.

The FADs are not being used to their full capacity, as very few fishermen went midwater fishing for the larger yellowfin tuna that can be found at deeper depths than the one's caught during trolling. Midwater jigging for skipjack tuna and other pelagic fish can also result in big catches if it is done right. The fuel consumption will be an affordable fraction compared to trolling, because midwater jigging requires long periods of drifting with periodical use of the engine to return to the vicinity of the FAD.

In support of this, the Fiji Department of Fisheries requested SPC's assistance with implementing a FAD fishing methods workshop targeted at training select fishermen from the Suva–Nausori area as well as Department of Fisheries officers, to acquire the skills to replicate this training in other centres around Fiji.

SPC's Fisheries Development Officer, William Sokimi, was assigned to conduct the FAD fishing methods and small boat safety workshop in Suva from 12 July–2 August, focusing on safe and sustainable fishing operations for small boat, offshore fishermen.

While fishing methods application was an important part of this workshop, equally important was:

- dissemination of information on the safety aspects of handling small boats and conducting small-scale fishing operations;
- care and handling of fish onboard as well as during processing;
- processing the catch for local and export markets;
- keeping records of all aspects of the fishing operations; and
- basic financial management of small-scale commercial fishing operations.

William worked with and advised the selected Fiji Department of Fisheries Capture and Development Section staff in all aspects of conducting the workshop, including planning, preparation, briefing on safety and small boat operations, briefings on fishing methods, constructing fishing gear, implementing Safe Operation Plans (SOPs), pre-fishing trip procedures, practical fishing trips, anchoring procedures (using grapnel anchor and sea anchor), post fishing trip procedures, care and handling of the catch, fish processing, stowing fishing gear and equipment, record keeping using logbooks, and basic small fishing operations financial management.

Workshop brief

Classroom sessions were carried out over two days to brief participants on:

- Safety aspects of handling small boats at sea. Emphasis was placed on this topic to highlight the importance of implementing SOPs and basic safety awareness when fishing or operating boats.
- Fishing methods that would be used during the workshop.
- FADs: what they are and how they function.
- Fishing gear components and tools.

- Fishing gear for various types of midwater fishing methods.
- Care of fishing gear, unused components and tools.
- Basic onboard hygiene.
- Care and maintenance of fishing boats.
- Proper onboard handling of fish and icing the catch.
- Handling and processing of fish for local and overseas fish markets.
- Maintaining catch records.
- Maintaining operations records and financial records for small commercial fishing operations.

A four-part PowerPoint presentation was given, covering all of the workshop topics. Notes on the PowerPoint presentation, handbooks and pamphlets were issued to participants to encourage them to keep up with the presentation. A display of the tools and several fishing gears were presented for the participants' perusal (Figs. 1 and 2).

DVDs were used to illustrate safety, fish handling, fish markets, hygiene and small commercial fishing business requirements.

Two days were dedicated to constructing fishing gear and setting up the boats for fishing trips (Fig. 3).

Figure 1 (top). Fishing gear used during the workshop.

Figure 2 (middle). Manuals and DVDs used during the workshop.

Figure 3 (bottom). Participants constructing fishing gear.

Gear for six types of fishing methods were constructed for the practical fishing sessions; however, other FAD fishing methods were discussed and notes were delivered on the construction methods for these.

The six methods focussed on were:

- Chum bag scatter bait weighted jigging rod
- Bait jigging
- Live bait fishing
- Mahi mahi line, and
- Trolling (with multiple lures on one mainline to maximise catch effort).

Four days of the workshop were spent in practical fishing operations, using the six fishing methods. On the last day, certificates were issued.

Subsurface fish aggregating devices and fishing grounds used during the workshop

In late 2007, two subsurface FADs were deployed off Suva as part of the Japan International Cooperation Agency (JICA) course on community-based fisheries diversification in Pacific small island states (Fiji study). One subsurface FAD was deployed of Nukubutho sandbank in position 18°13.49'S; 178°27.13'E, while the other subsurface FAD was deployed off Naqara Island in position 18°13.47'S; 178°18.52'E.

Although the subsurface FADs could not be seen, large schools were sighted in the vicinity and so these FADs were used as the primary fishing grounds during the workshop. Additionally, a surface FAD, which was deployed three weeks prior to the commencement of the workshop, 2 nm east of Suva Harbour passage, had drifted to only 0.5 nm from the passage, and about the same distance offshore. This FAD was used during bad weather but, because it had drifted close to the passage, the Harbour Master requested that the surface bamboo aggregator be removed to prevent merchant ship captains from mistaking it for a manned small craft..

Fishing methods used during the project

Chum bag scatter bait method. This method is an advanced modification of the drop stone method that was traditionally used in the Pacific region in earlier years. Although some Pacific Islanders still use the drop stone method in its basic form, its capabilities are limited for small-scale commercial use.

With the drop stone method, fishing duration is dependent on the amount of stones a fisherman takes with him. Once the line is sunk, frees the chum and baited branchline, the stone and wrapping leaf drop free and the baited branchline is allowed to drift with the current while the chum attracts fish. Once he runs out of stones, the fisherman must switch methods, usually to either rod and sinker jigging, live bait fishing or trolling.

With the chum bag method (Fig. 4), the full gear is permanently attached to the mainline. The chum bag replaces the leaf that wraps the chum, and the 1-kg sinker replaces the stone. A winding board is included to make it easier to coil the 20-m branchline. The whole parcel is packed into the bag and secured by a flexible wire that is worked loose when the required depth is achieved. The fisherman can fish for as long as he has bait to do so.

Weighted jigging rod method. This method requires a weighted jigging rod attached to the end of a mainline and a branchline of 2–10 m attached to the other end of the rod. It can be used with either a baited hook or with a hook and feather lure (Fig. 5).

Bait jigging method. The bait jigging rig is a simple 20-kg test line with four to six hooks on the branchline (Fig. 6). The lures on these hooks were white drinking straws cut to the length of the hook shank. While this rig is effective in jigging for

Figure 4. Tekata Toaisi preparing to deploy a chum bag.

bait, it is also effective in jigging for frigate mackerel and other small pelagic fish species.

Live bait fishing method. This method is straight forward and involves hooking fresh-caught live bait onto a mainline, and slacking it to a depth where large pelagic fish can find it.

Trolling lines with two lures. These trolling lines are constructed as is normally done for conventional single hook trolling lines, using red and white squid skirt lures with double hooks. The only difference is the addition of a second, shorter branchline at the swivel end. The length of the shorter branchline can be anything from 1–3 m or more depending on the fisherman's preference. Some fishermen prefer to have short second branchlines to make it easier to remove fish when the line is hauled in; others prefer longer second branchlines because they feel this is more effective than shorter ones. During the workshop both the short and long second branchlines proved equally effective.

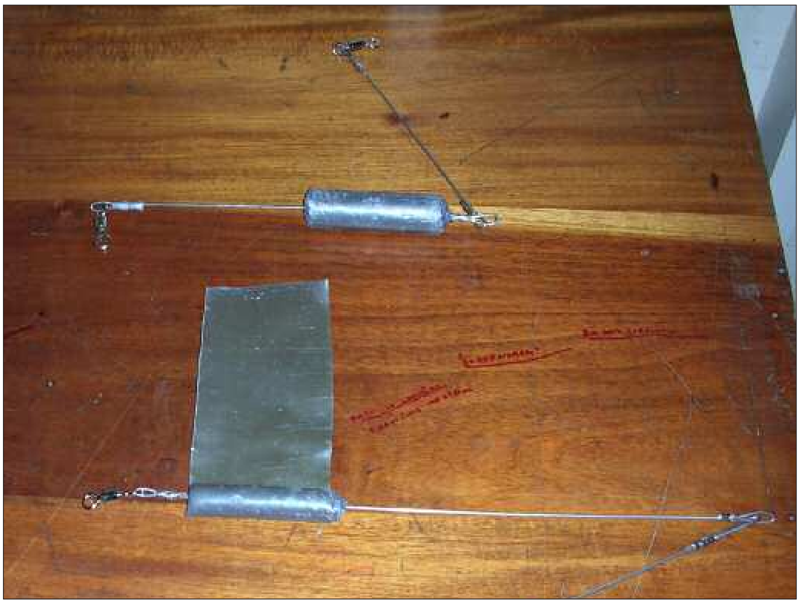


Figure 5. Jigging rods under construction.

Figure 6. Bait jigging rigs coiled on wooden slats.

Fishing trips

Participants were divided into three teams of five and tagged according to the colour of the reels they used (yellow team, blue team and red team). This encouraged a coordinated effort in constructing fishing gear and setting up individual boats for fishing. It also inspired the mood for friendly competition to see which group would do well during the fishing trips.

The two final days of fishing resulted in good catch rates. The improvement in weather conditions allowed the boats to fish the subsurface FAD at Nukubuco and troll the fringing reefs towards Beqa, Nukulau and Makuluva Islands. Fishing had to be limited in accordance to the ice that was carried on board. The Nukubuco subsurface FAD area was packed with a large Frigate Mackerel school that took anything that went overboard (Fig. 7). It took very little effort to catch this fish as the school was very slow moving and rotated in the same area. Either the yellowfin and skipjack tuna never had a chance to get the hooks, or they were not in the area. However, this was good practise for the fishermen and it was decided not to risk further scouting for yellowfin tuna in case there wouldn't be another good opportunity to practise the fishing methods. The main thing was to demonstrate how the methods worked so that the fishermen could have confidence to use them later during their fishing operations.

A surface FAD marker would have greatly facilitated effective implementation of the bait jigging and scatter bait method; however, the practise undertaken was sufficient to demonstrate the potentials of the methods for future development.

A total of 74 fish were caught over the two days, comprising 68 frigate mackerel, 1 skipjack tuna, 1 mahi mahi, 1 dogtooth tuna, 1 trevally, 1 barracuda, and 1 wahoo.

Workshop closing

The workshop was closed by the Fiji's Director of Fisheries, Sanaila Naqali, and laminated certificates were issued to participants to acknowledge their attendance. A buffet lunch, hosted by the Coastal, Extension and Development Section, followed and consisted entirely of the fish caught during the workshop.

Discussion and conclusion

The organising and implementation of this workshop went very well despite discouraging weather conditions at the start of the practical fishing sessions.

Interviews with small-scale commercial fishermen who attended the workshop, and with those who couldn't attend, revealed that most fishermen knew only a few basic methods of offshore commercial fishing and almost all offshore FAD fishermen only ever engaged in trolling. Only a few had tried drop stone fishing or midwater jigging (with limited success). It seems that this generation of fishermen have fully customised themselves to fishing from fibreglass banana boats but have not adapted canoe fishing methods to these boats. Trolling is their main offshore fishing method. Very few know what a sea anchor is or its potential to offshore and FAD fishing so the Fiji Fisheries Department's timing to revive assistance to small scale commercial fishing operations is opportune and should be encouraged.

Subsurface FADs. The two subsurface FADs have large schools in the surrounding vicinity. On the first day of fishing a big school of large yellowfin tuna was engaged at the Nukubuco subsurface FAD area but the three large yellowfin tuna that was caught all escaped due to the inexperience of the fishermen in handling big fish. Other schools of skipjack tuna and frigate mackerel were in the area. The subsurface FAD off Naqara Island also had large schools but these were slightly away from the initial deployment position leading to suspicion that the subsurface FAD had shifted position.

Figure 7: Fish caught during the double lure trolling exercise.

Observations of these subsurface FADs suggest that:

- subsurface FADs are very effective at aggregating large schools of fish;
- if there are no surface markers, subsurface FADs are only good for trolling in the early morning hours, until the schools start forming and begin to run, and in the late afternoon;
- in order for other fishing methods to be used effectively at subsurface FADs, a surface marker should be included at each FAD so that the fisherman can drift close to the subsurface FAD to jig for baitfish and tuna. The surface marker would enable fisherman to maintain an effective fishing distance from the subsurface FAD; and
- if the surface marker is connected to the subsurface FAD by a strong rope, then the fishermen can tie their vessel to this and jig at this spot to save fuel. It is possible to attach a 12–22mm rope to the subsurface FAD for the surface marker. This modification would allow fishermen to fish the subsurface FADs to their full potential.

In all, the workshop was a huge success and the results from this will be indicators for the Fiji Department of Fisheries to restructure their assistance and training programs for small-scale commercial fishing operations.

Second Pacific Island fisheries evidence training and investigation course

Following the inaugural course in 2007, this is the second time SPC has co-sponsored this Pacific Island Fisheries Evidence Training and Investigation Course (FETIC) with the Pacific Islands Forum Fisheries Agency (FFA).

From 13–29 August 2008, a group of fisheries officers (1 female and 14 males) from 14 Pacific Island countries and territories attended this training programme, which was run at the National Fisheries College in Kavieng, Papua New Guinea. The three course facilitators were from the Primary Industries and Resources South Australia (PIRSA).

The FETIC programme is adapted from the Australian Basic Evidence Training and Investigation Course (BETIC) programme, which is a major component of the nationally accredited Certificate III in the Seafood Industry (Fisheries Compliance). FETIC was developed by PIRSA on behalf of the Australian Fisheries Academy, FFA and SPC in 2007.

The course objective was to enhance Pacific Island fisheries officers' skills in:

- fisheries management principles and legislation;
- monitoring fish catches;
- patrol operations, including methods and resources;
- investigation techniques, including evidence gathering, note taking, chain of evidence, interviewing; and
- statement taking, brief preparation, and court procedures.

The course facilitators made the following recommendations to both FFA and SPC:

- Course sponsors continue to give consideration to supporting the annual facilitation of the Pacific Island Fisheries Evidence Training & Investigation Course.
- Future courses continue to be delivered and assessed against a Competency Based Training methodology.
- Consideration of any future course venues be based on the capacity to facilitate a marine platform to facilitate practical exercises with a marine component.
- Prior to any future course being facilitated a Training Needs Analysis and review of past course evaluations be conducted to ensure the relevancy and appropriateness of the course content, venue and delivery.
- Course Sponsors give consideration to developing a recognised process and pathway to support participants to achieve full accreditation of the Certificate III Seafood Industry (Fisheries Compliance) or Higher through the approved Recognition Process.

Original text: English

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COASTAL FISHERIES IN THE PACIFIC ISLANDS REGION

Identification of candidate fisheries for Marine Stewardship Council (MSC) certification

The following is a summary of a report written by Bob Gillett in March 2008 for the World Wide Fund for Nature (WWF).

The study

In early 2008 a fisheries specialist was employed by WWF to identify coastal fisheries in the Pacific Islands that may be appropriate for starting on a process toward Marine Stewardship Council certification and those fisheries that would benefit from WWF engagement.

MSC candidate coastal fisheries in the Pacific islands

Important features that would readily separate candidate and non-candidate fisheries are whether:

(1) the concerned fishery produces a commercially exported product,
(2) the value of the exported product is substantial and
(3) the product is imported into a country where MSC has achieved considerable recognition, resulting in a higher price for the product. In addition, candidate fisheries should be small scale, or at least not industrial fisheries.

The most appropriate candidates for MSC certification

Based on the above criteria, fisheries for trochus and deepwater bottomfish appear to be the most appropriate MSC candidates among the coastal fisheries of the Pacific Islands. In addition:

- Fisheries for these species presently operate (or considerable commercial potential exists) in many countries of the region.
- Several of the trochus and deepwater bottomfish fisheries are relatively well-managed — and among the best managed coastal fisheries in the region.
- There is a considerable amount of information on both fisheries, in some cases going back several decades. This includes stock assessment work.
- There has been recent interest in some form of environmental certification on the part of commercial interests for both types of fisheries.

The way ahead

In many respects, the next steps in making progress towards MSC certification are best known to MSC staff. Nevertheless, there may be some value of providing the consultant's perspective on furthering the process. The present report was undertaken as a desk study — and there are obvious limitations as to what can be accomplished with respect to gauging interest in MSC of those people involved in a fishery, especially those located in a relatively isolated community. The immediate task is to engage in a dialogue with the major stakeholders. If the present study is considered Phase 1, Phase 2 could be considered as getting the fishery participants to the point of where they are able to make an informed decision whether to proceed with the MSC certification process.

NGOs and fisheries in the Pacific Islands

Some important issues associated with NGOs and fisheries in the Pacific Islands are:

- The proper role of the NGO.
- The food aspect.
- Working with the regional fisheries agencies.

It is suggested that an important niche for NGO involvement in fisheries in the Pacific is to alert national governments to developments that represent new or growing threats and take some initial action that may catalyse more comprehensive action on the part of government fisheries agencies. Another type of fishery issue that may benefit from NGO attention is, ironically, the opposite situation, old and chronic problems that persist despite years or decades of attention by governments and/or SPC.

Fisheries that could benefit from NGOs

Although there are many fisheries that could benefit from NGO engagement, two that may be especially appropriate for NGO attention are spearfishing and beche-de-mer fishing.

BOATS SHED THEIR OLD SKIN

The conventional way to deter aquatic organisms from colonising underwater equipment is to poison the offending organisms. Bacteria, unicellular algae, green algae, barnacles, sponges and marine worms are among the more than 2,500 species identified by experts as contributing to the process known as "fouling". One European project is counting on nanotechnology to revolutionise the sector.

Fouling is a scourge of all underwater structures (including boat hulls and industrial and scientific installations). In the case of ships, it increases fuel consumption by as much as 40%, incurring an estimated additional cost of Euros 4.8 billion per year. The annual cost of maintaining underwater installations is more than Euros 9.7 billion. Although biocide paints are proving effective, they are now recognised as ecotoxic and increasingly they are being banned from use. Europe is the market leader for antifouling paints and is keen to boost its research to design effective new coatings, which are also environmentally friendly.

Toxic or hydrophobic surfaces

The Phoenicians, Greeks and Romans coated the hulls of their ships with copper or lead because these metals produce oxides or sulphates that are toxic to marine organisms. Nothing has changed since then and the conventional method for preventing fouling today is to cover surfaces with a biocidal coating that releases a continuous stream of toxins.

The most commonly used antifouling paint nowadays releases tributyltin (TBT), a tin-based organic compound that is known to be a powerful endocrine disrupter. Although highly effective, TBT is so ecotoxic than many countries have banned it. A worldwide ban is expected to be introduced in 2008.

As it is no longer permitted to poison colonising organisms, a new range of coatings has been developed with smooth, hydrophobic surfaces that reduce the adhesive properties of the organisms. All that is needed then is a flow of water to dislodge intruders. The silicone elastomers used today are proving highly effective in repelling macro-organisms (such as green algae and barnacles), whose adhesion power is not strong enough to withstand a flow of between 12 and 15 knots (22–28 kilometres per hour). However, silicone elastomers are not effective against microflora, which accumulate to form a thick biofilm on hulls, disrupting water flow and slowing down ships. Other drawbacks of silicone elastomers are that they are still expensive and not as robust as traditional biocide paints.

A matter of compromise…

"There is no such thing as a coating that is effective against all marine organisms. We need to find a good compromise between the type of organism and the navigation context", explains James Callow, coordinator of the European project AMBIO (Advanced Nanostructured Surfaces for the Control of Biofouling). The aim of the project is to design clean and effective antifouling coatings, taking into account different parameters such as navigation areas, frequency of use and ship speed. The candidate coatings are being studied and nanostructured to endow them with suitable properties in terms of surface energy (the interface tension between two substances), porosity, morphology and chemical and physical reactivity. Not forgetting, of course, compatibility with marine organisms. "Although we know that cells react to textures, we have yet to determine the precise influence of the different nanostructures and to formulate a set of design rules", explains James Callow. The "optimal" surface will need to be a compromise between these different rules, geared to the colonisation strategies and chemical resources of marine organisms.

… for composite surfaces

The coatings currently being developed are a mixture of hydrophobic and hydrophilic polymers. The morphology and topology of hydrophobic polymers have been designed on a nanometric scale to reduce algae's foothold to a minimum, while hydrophilic polymers contain enzymes that absorb and destroy the biological "glue" secreted by marine organisms. Other ideas are also being studied, including polymer/metal nanocomposites that prevent the formation of biofilms. A silicone elastomer incorporating a carbon nanotube structure is expected to come onto the market shortly. This silicone elastomer coating limits colonisation as its surface is rough on a nanometric scale, making it inhospitable to organisms, whilst silicone's low surface energy weakens their adhesive properties. In addition, the carbon nanostructure reinforces the coating, making it very tough and easy to apply.

As no single solution exists, AMBIO research teams are combining materials and nanostructures to make surfaces as inhospitable as possible to invasive marine organisms and to minimise surface energy to limit their adhesive power. This has resulted in antibacterial or enzymatic chemical reactions that are able to dissolve the biological glue.

Although copper- and zinc-based biocide paints are still authorised at present, James Callow believes that environmental legislation is evolving rapidly and that alternatives must be found. With the products developed by AMBIO, "no particle or product is released into the ecosystem" says Philippe Dubois, from Mons-Hainaut University in Belgium, who is responsible for developing silicone coatings containing carbon nanotubes. What is more, the programme is one of the few to have been commended by the European Parliament study to evaluate the use of nanotechnology as a substitute for chemicals.

Source: research'eu, No 56, June 2008; http://ec.europa.eu/research/research-eu

BATHYMETRIC MAPPING USING A COMBINATION OF SONAR DATA AND SATELLITE IMAGERY

In *Fisheries Newsletter* #120 the various methods available for determining shallow water bathymetry, using either active sensors (sonar, LiDAR) or passive multispectral imagery (Landsat, QuickBird) were described. This article discusses recent work conducted in collaboration with the Pacific Islands Applied Geoscience Commission (SOPAC) to produce a high-resolution bathymetric map of Aitutaki Lagoon (Cook Islands), using a combination of single-beam sonar data, reef crest points and a QuickBird satellite image.

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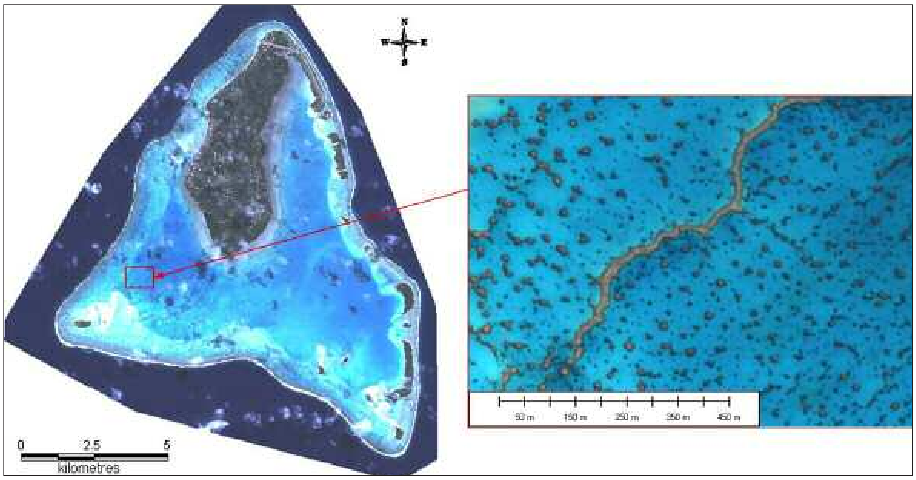
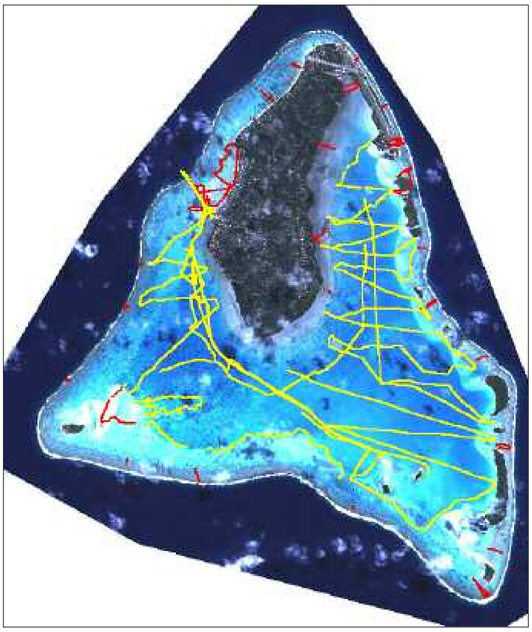
Aitutaki Lagoon has a surface of around 80 km² and depths mostly between 1 m and 7 m, not exceeding 12 m. Hundreds of patch and ribbon reefs — no deeper than 1 m — are scattered throughout the lagoon (Figure 1) and have a high influence on the lagoon's hydrology and ecosystem These structures appear clearly on a QuickBird satellite image (2.4 m resolution), yet they are costly to survey using sonar bathymetry alone, and navigation around patch reefs is hazardous.

In early 2008, SOPAC's Ocean and Islands Programme surveyed the lagoon, using a single-beam echo sounder (white tracks on Figure 2) and a real time kinematic (RTK) GPS, which provides very accurate positioning. Points were also surveyed on reef crests using RTK GPS alone (dark tracks). All depths were subsequently corrected for tides.

A QuickBird satellite image was bought by SOPAC's GIS unit and rectified so that it matches





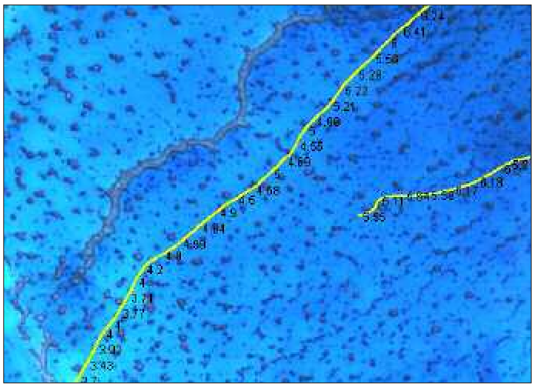


Figure 1 (top). Aitutaki Lagoon.

Figure 2 (bottom). Single-beam echo sounder (left, yellow) and reef crest RTK soundings (right, red).

RTK data. An atmospheric correction was applied to remove haze and other atmospheric effects.

The availability of the rectified image and soundings for various locations made it possible to determine the relationship between the colour observed on the satellite image and the measured depth, and use it to build a bathymetric map for the whole lagoon.

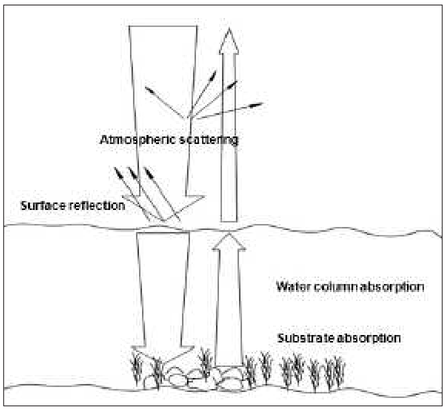
Predicting bathymetry from a satellite image

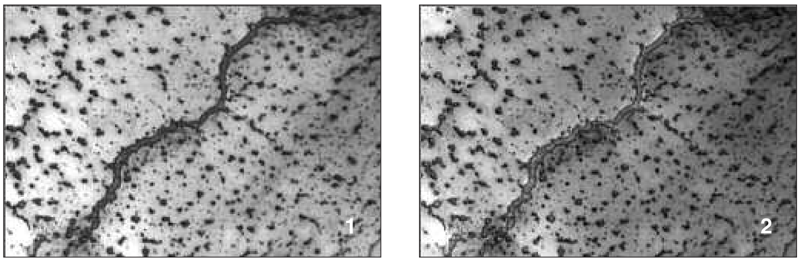
A QuickBird image is composed of three visible bands corresponding to blue, green and red wavelengths. Only a fraction of the sunlight illuminating the area is received by the satellite sensors due to absorption, reflection and scattering by the atmosphere, the air-water interface, the water column and the bottom substrate. In particular, light is absorbed exponentially with depth, more quickly for green and red bands than for blue bands (Shifrin 1988). The green and red bands appear darker (when viewed separately) than the blue band as shown in Figure 4.

Several papers suggest using the relative absorption of two bands to determine the depth from the reflectance, and a good correlation can then be found between log (blue)/log (green) and depth (Philpot 1989; Stumpf and Holderied 2003) (see Fig. 5).

This approach gives a good approximation of depth. It can be improved using a more complex model that uses the three visible bands and is fitted using the available sonar and reef crest data. For that purpose, we used a multi-layer perceptron (artificial neural network) to model the depth from colour: the available soundings and corresponding colours were initially used to train the neural network, and then the model was applied to the whole image to predict the depth of the whole lagoon.

After training, the artificial neural network was able to predict depth with an average error of less than 1 m on the training data set (a fraction of the data is actually used for training and the rest used to test the result). The model was also able to spot some errors in the sonar data (due to multi-reflections of the sonar signal), which were sub-





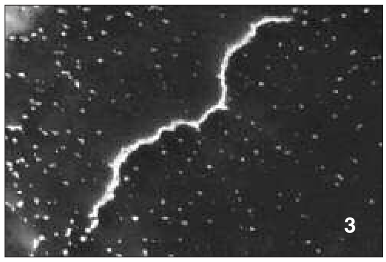


Figure 3 (top). Effects contributing to the colour observed on a satellite image.

Figure 4. QuickBird blue [1], green [2] and red [3] bands for a reef area.

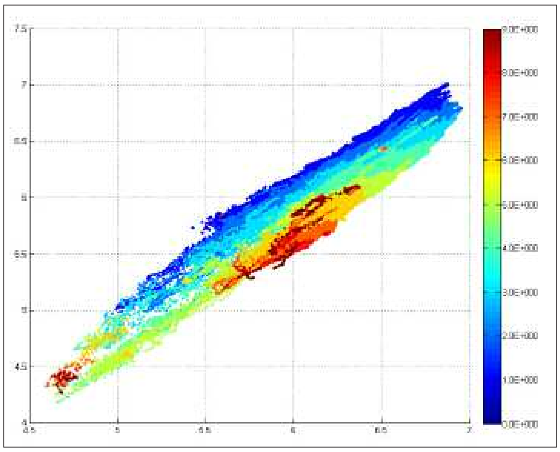


Figure 5. Measured depths for values of log (blue) and log (green).

sequently removed from the training data. Once applied on the whole image, it was possible to obtain a bathymetric map for the lagoon (Figure 6), on which emerged areas and thick clouds have been masked and coloured in purple.

Conclusion

The availability of both a high-resolution satellite image and sonar data for various depths and substrate made it possible to produce a detailed bathymetric map for Aitutaki Lagoon. This map will be used in the near future by SOPAC to build a hydrographic model of the lagoon.

The same methodology can be used for other shallow lagoons for which satellite imagery and shallow water soundings for various depths and substrates are available.

References

Philpot W.D. 1989. Bathymetric mapping with passive multispectral imagery. Applied Optics 28:1569–1578.

Shifrin K.S. 1988. Physical optics of ocean water. American Institute of Physics, New York.

Stumpf R.P. and Holderied K. 2003. Determination of water depth with high-resolution satellite imagery over variable bottom types. Limnological Oceanography 48:7–556.

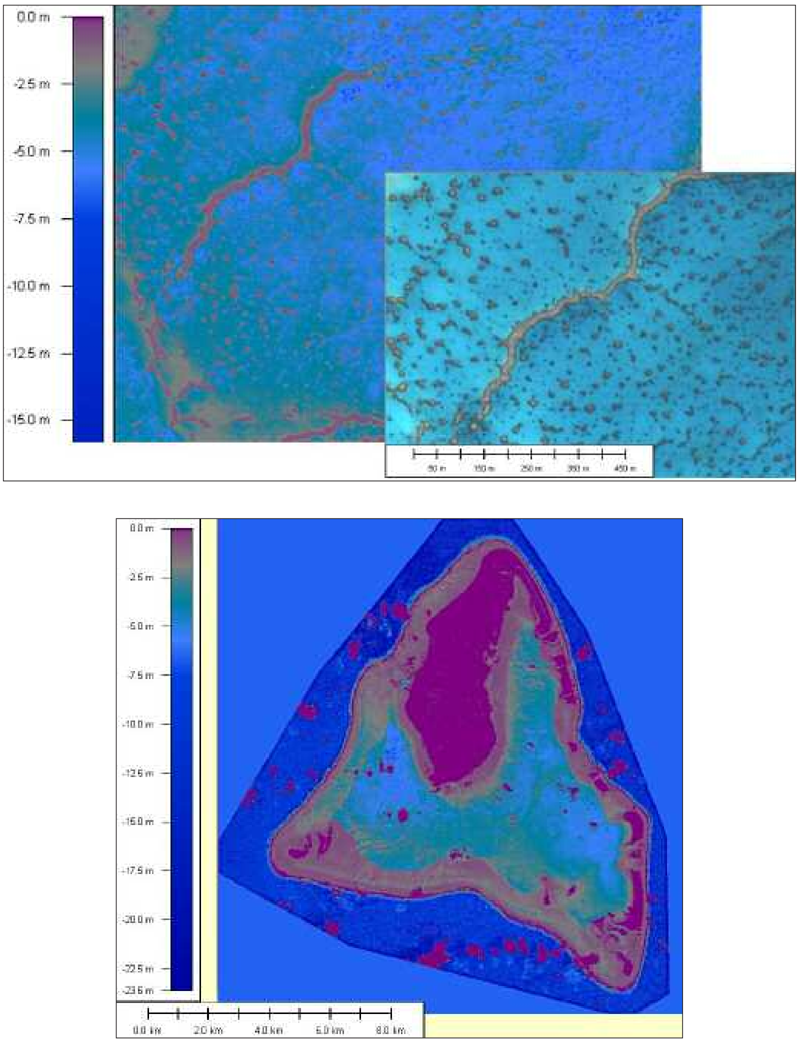


Figure 6. Predicted depth of Aitutaki Lagoon.

FROM SEA TO SOIL: ADDING VALUE TO FISH WASTE

Angus McNeill[1], Michel Blanc[2], and Kim Des Rochers[3]

Every year across the Pacific, thousands of tonnes of fish waste are either discarded at sea by fishing vessels, or buried in landfills where the stench from the rotting waste attracts flies, rats and other pests. Turning this waste into useful silage adds value to an otherwise untapped and unused resource, and can provide island communities with an inexpensive source of organic fertiliser.

With this in mind, the Nearshore Fisheries Development and Training Section of the Secretariat of the Pacific Community (SPC) facilitated a pilot project to turn fish waste into fish silage for use as a fertiliser and/or as a livestock food additive. The project took place at Wé on Lifou Island in New Caledonia's Loyalty Islands group, where the local seafood retail shop processes several tonnes of fish every month.

The practice of dumping waste from processed fish in the municipal landfill has raised concerns in Lifou communities. Subsequently, in 2007, the Loyalty Islands provincial fisheries department sought SPC's assistance to turn local fish waste into a commercially valuable byproduct. Fish silage was quickly identified as the most suitable option, due to the presence in Lifou of a number of organic farms. Farmers there import large amounts of fertilisers, including fish silage (4400 litres sold at XPF 1000 per litre in 2007).[4]

The primary goals of the project were to source and supply the equipment and materials needed to carry out the trial production of silage, produce silage that was liquid enough to be mechanically sprayed onto food crops, and advise the Poisson-nerie de Lifou and the Loyalty Islands provincial fisheries department on the specifications of a fish silage facility, including processing equipment, and the procedures required for medium-scale commercial production of fish silage.

Initial funding for the project came from the French Pacific Fund, the Loyalty Islands Province and SPC. Local stakeholders included the Loyalty Islands provincial fisheries department, staff of Poissonerie de Lifou, and local farmers

What is fish silage?

Fish silage is a liquid organic product made entirely from ground up fish waste (e.g. heads, guts, skin and cartilage). The waste, which contains minerals, trace elements, complex nutrients and amino acids, can be used as a fertiliser for soil or as a supplement to animal food.

Making and storing silage

Silage production begins with chopping or mincing fish waste into small particles. In the pilot project, two types of "cutters" were used: one for processing the heads and skeletons of large pelagic fish such as tuna, mahi mahi and marlin, and a smaller cutter for use on reef fish.

The large cutter used during the trial was a machine regularly used on New Zealand toothfish longline vessels as a preparatory step for making fishmeal, or as a way to minimise the volume of waste on board when vessels are fishing in seas where waste and offal cannot be discharged directly overboard (e.g. the Southern Ocean).

The smaller, hand-operated cutter can be used by a single person and can be fitted with a small motor to increase its power and efficiency. The cutter was designed to process split heads but there was no equipment on hand during the trial to break down the heads prior to loading into the cutter. The cutter has since been returned to New Zealand for modification. In addition to increasing the gearing ratio and making it more robust, the small cutter will be fitted with a fish head breaking device.

After the fish waste was cut up, it was placed in several plastic tubs, of either a standardised volume or a standardised weight. Formic acid was then added to each tub to aid in the liquefaction process; the entire mixture was then thoroughly mixed so that all of the material came into contact with the acid, otherwise, any untreated fish particles would putrefy. The proportion of acid used was 3.5% by volume (i.e. 350 ml acid to 10 kg of fish waste). The acidity of the mixture was kept at pH 4 or lower to prevent bacterial action. The natural silage process then began.

The rate of liquefaction depends on the type of fish, the parts used, freshness of the raw mate-

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[4] USD 1 = XPF 95

Top. The large fish cutter; typically used in New Zealand's longline fishery in the Southern Pacific Ocean. This model was purchased second-hand and was reconditioned prior to its shipment to Lifou. The inside view of the cutter shows the steel shaft that is made of a series of hammers, which pre-breaks fish waste on a corresponding series of anvils.

Bottom. The manual fish cutter is aimed for use by small-scale reef fishing operators.

rial, and the temperature of the mixture. In fact, the warmer the mixture, the faster the silage process. According to an FAO report,[5] silage made from fresh white fish viscera takes two days to liquefy at 200°C, but takes 5–10 days at 100°C, and even longer at colder temperatures.

During the Lifou trial, the time allocated for on-site silage production was only 10 days, but within this period, the conversion of fish waste (from tuna, marlin and mahi mahi) into stable silage was successfully accomplished.

Most kinds of fish can be made into silage, but the parts used for processing should be fresh; thawed, previously frozen fish can also be used. Sharks and rays are difficult to liquefy and so should be mixed with other fish species.

The inclusion of fish guts in the mixture is very important for speeding up the process, as the viscera contain enzymes that aid in liquefying the fish. During the trial operation, very little viscera were available as the raw material originated from longline-caught fish, which are typically gilled-and-gutted at sea. However, the effect of the low ratio of enzymic material on the overall quantity of raw product was dealt with by working with small control batches. In the future though, it will be necessary to encourage fishermen not to dump viscera at sea, but to bring it back to port for processing.

Due to a lack of adequate testing equipment during the Lifou trials, it was not possible to finely control the pH of the mixture. However, if the proper pH level is maintained, then the silage should keep at room temperature for about two years.

5 http://www.fao.org/wairdocs/tan/x5937e/x5937e00.htm

Fish silage processing

Preparation

- Decant the acid into a small easy-to-use container. Wear gloves and eye protection.
- Minced product should be placed in containers with a standardised volume or a method of weighing batches.
- A non-ferrous stirring pole should be available.
- A pH meter should be ready for use.
- The cutter equipment should be ready and clear of residue from previous processes or any other material. (See below for routine maintenance.)
- The fish parts used for processing should not be stale. Thawed, previously frozen fish is acceptable. The inclusion of guts is important to speed the liquefaction process. Batches should not be made up of only sharks or rays.
- Ensure there are no hard foreign materials among the fish parts, such as hooks or stones.

Process

- Lift the fish parts into the cutter ensuring hands, loose clothing and personal effects are kept well away from the moving parts. Do not place any uncut parts in with the cut product. The action of cutting/mincing allows the natural enzymes and acid to make contact with the greatest amount of product as quickly as possible. Where possible, batches should consist of different fish parts (i.e. be a homogenous mixture).
- The chopped fish is collected in small batches of either a standardised volume or weight. The required amount of formic acid is added and the batch is well mixed. There will be a change in the product's texture when the acid has made good contact. There will also be a colour change throughout the batch. The amount of acid to be added is 3.7% by weight (370 g to 10 kg of fish waste) or 3.5% by volume (350 ml to 10 L or kg of fish waste).
- Batches should be stirred and tested daily for acidity (pH). The pH of the mixture should be between 3.5 and 4. If the pH is above 4, then thoroughly stir the mixture before adding more acid.
- When the batches become more liquid, brown and easy to stir, they can then be transferred to a non-ferrous storage vessel.
- Until experience is gained, the pH of the product in the storage containers should be tested daily for the first three days, or until it is used or full.
- Clear the machine of material after processing. Two full buckets of water are better than a hose. Remove top and bottom orifice plates to aid.

Notes

Fish silage will reduce in quality and become unpalatable if it is stored in hot conditions, has a high oil content, or is exposed to sunlight.

1. Fish silage is high in nutritional value. After processing, the higher the temperature of the product, the greater the reduction in high value amino acids.
2. The silage should be in a liquid form after four days in warm weather.
3. Silage made from fish with a low oil content should be stirred before decanting from the storage container.
4. In its liquid form silage can be stored for several months.
5. In fisheries where the gills and gut are removed at sea these should be kept chilled or frozen and brought ashore to assist in the process (autolysis).
6. Cutter maintenance should be performed every five days of operation or when there is likely to be a period of idleness. Check for loose nuts and bolts. Grease the front and rear bearing nipples. Overhauls, including the replacement of knives and anvils, will be required after a year of frequent use or as inspection dictates.

Silage processing facility needed

The pilot fish silage trial was carried out in a workshop adjacent to the Poissonnerie de Lifou at Wé. The Poissonnerie de Lifou operates under HACCP protocols, which do not permit a product that is unfit for human consumption (i.e. fish waste) to be processed in the same environment as fish being processed for markets. Because the processing could not be accommodated in a controlled environment, it was carried out in a nearby workshop.

However, this makeshift facility proved to be less than ideal because of the lack of working surfaces, and a floor that sloped away from the nearest drain, which made the cleaning of equipment and the facility difficult. The makeshift premises highlighted the need for a purpose-built fish silage plant. Rough specifications for such a processing plant on Lifou have been developed, although the shape and design of any supplementary equipment will need to be incorporated into the overall building design (see box below).

Basic requirements for a silage plant on Lifou

Easy to clean interior surfaces with a good fall in the floor to drains (both sides), with solid drain traps and vermin-proofing all leads to the sewer.

- **Easy access from the waste storage area of the fish processing building to two holding rooms: one for freezing and the other for chilled storage of fresh, ready-to-use product.**
- **The door opening to the main processing area should allow fork lift access, although the regular lifting of heavy drums could be done with an overhead gantry.**
- **3 Phase and single phase power should be available from an overhead supply to avoid cables lying on the floor.**
- **A separate mechanically ventilated room to accommodate the storage and handling of formic acid. This could also act as a laboratory/records office.**
- **The upper part of the building (loft) could serve as a storage area for empty containers.**
- **There should a place for staff to hang their outside clothes and to be able to shower in case of acid contamination.**
- **The general working space must accommodate the large cutter, a mechanical mixer, storage of batch buckets, holding drums or storage tanks, a blender/mill/filter as dictated by final product form and client requirement.**

Left. The remains of a large opah (*Lampris guttatus*) are fed into the fish cutter.

Right. Ground up waste is collected after the passage through the orifice plate.

Benefits and use of fish silage

The benefits of fish silage production include:

- Value is added to an otherwise untapped and unused waste product. Adding value and using often discarded fish waste would contribute towards a more sustainable use of scarce fisheries resources.

- The amount of imported fertiliser and animal feed is reduced. Currently, local farmers on Lifou and elsewhere in New Caledonia and the Pacific rely on expensive imported fertilisers to improve soil condition, particularly on atolls, which have impoverished soils.

- Fish waste disposal costs are reduced. In New Caledonia, fish market vendors are responsible for and bear the cost of the proper removal and disposal of fish waste.

- Fish waste dumped in landfills is greatly reduced. The current practice of disposing of fish waste in landfills results in the attraction of flies, rats and other pests, which can affect human health through diseases and water contamination.

- Relatively low technology equipment and facilities are needed to carry out the production of fish silage. This means that operating costs are relatively low and any necessary repairs are simple to carry out.

- Skilled or specialised labour is not required, so silage production can be done in most Pacific Island communities. It may also be an area of income generation for women.

- Additional income generation opportunity is possible for processors.

Top. Formic acid is carefully added to the grinded fish waste, its role is to stabilise the resulting silage by avoiding bacterial spoilage.

Bottom. After the addition of acid, the grinded fish waste is transferred into plastic buckets with lids.

In addition, the making of fish silage has virtually no negative environmental impact because the only input other than fish waste and manpower is a small quantity of organic acid.

Future silage production needs

In order to determine the composition of the silage produced during the Lifou trials, laboratory analyses were carried out (see figure below). The proportion of nitrogen, water, protein, minerals and other substances will determine how suitable the silage is as a fertiliser or as animal food. It may be necessary to adjust the ratios, depending on the end use. At the time this article went to press, advice was being sought from staff of SPC's Land Resources Division on the suitability of the Lifou silage as fertiliser and animal feed.

Another aspect of the process that needs refining is producing a liquid fertiliser that is fine enough to be broadcast from a sprayer onto plant foliage. The silage produced during the trials contained many particles that were large enough to clog the nozzle of a sprayer, although it was suitable for pouring underneath plants directly onto the soil. Future trials will need to investigate and source equipment that will break down and emulsify the solid particles even further.

The mixing of the acid with the cut fish needs to be mechanised to ensure a thorough coating of all fish parts in what should be a homogenous batch and to reduce the manual effort used during the trials. Experiments are also underway to find a suitable enzyme that could be used to supplement the natural fish enzymes in achieving a better liquefaction, should the fish continue to be landed without the gut enzymes.

After 24–48 hours, the product is transferred into large holding containers where the silage will mature for another 3–4 days, depending on temperature and the amount of natural enzymes in the fish waste.

Conclusion

A fish silage plant can be readily built on other islands as well, meaning the success of this project will be of value to both the Lifou community and other Pacific Island countries. Such plants add value to fish waste that would otherwise be discarded, and reduce adverse environmental impacts. Fish silage can also be produced at a smaller scale through the use of a manually operated fish cutter, a prototype of which was successfully trialled in Lifou. This scale of production appears suitable to individual fishers or small fishing cooperatives on islands (especially atolls) where the lack of fertile soil constrains the development of agriculture.

Pacific Island countries are looking for ways in which they can balance the growing nutritional and livelihood requirements of their rapidly increasing populations with the production capacity of their terrestrial and coastal fisheries ecosystems, while at the same time maintaining the integrity of their island environments. Fish silage production may be one small step towards achieving this.

Sample	Nitrogen (g/m^3)	Phosphorus (g/m^3)	Potassium (g/m^3)	Calcium (g/m^3)	Protein (g/100 ml)	Fat (g/100 g)	Carbohydrate (g/100g)	pH
"Combo" (commercial fertiliser imported and used in Lifou)	4719	280	73					3.84
Reef fish silage	6062	140	120			1.7		3.29
Pelagic fish silage (filtered)	5201	130	95	210	16.3	3.3	0.4	3.81
Pelagic fish silage (unfiltered)	7227	200	85	320	69.6	3.5	1.2	3.8

Laboratory analysis of the Lifou fish silage

VANUATU'S FIRST ORNAMENTAL ANEMONEFISH (*AMPHIPRION* SPP.) HATCHERY TRIALS

Antoine Teitelbaum[1] and Sompert Rena Gereva[2]

As part of the Australian Centre for International Agricultural Research (ACIAR) project "Development of aquaculture based livelihoods in the Pacific Islands region and tropical Australia" (FIS2006/138), Vanuatu's Fisheries Department, the Japan International Cooperation Agency (JICA) and the Secretariat of the Pacific Community (SPC), will launch a small-scale anemonefish farming trial in Vanuatu. The aim of this project is to determine whether anemonefish farming could be a viable activity in rural areas of Vanuatu. It is hoped that with technological advances becoming more accessible, such activities could extend to other part of the Pacific Islands region where the aquarium trade is active.

Background

The global demand for aquarium fish has been estimated to worth USD 200–330 million per year (Wabnitz et al. 2003). The ornamental trade is a significant source of income for over 10 Pacific Island countries, and it was recently determined that over 1000 households are involved either fully or on a part-time basis in the trade. The need for income generating opportunities, which in the rural Pacific often involve coastal resources, is growing rapidly given the region's increasing human population growth (especially in Melanesia) (Bell et al. 2008). Sound management of the wild-capture fishery and the promotion of mariculture appear to be sustainable options for trade in the Pacific region.

Maricultured commodities such as giant clams and corals have proven to be reliable sources of cash in rural areas (Teitelbaum and Friedman 2008; Lal and Kinch 2005; Vanuatu Fisheries Department 2008). Although the aquaculture of marine ornamental fish is in its infancy, it holds great promise as an alternative livelihood option for fishers in the region (Job 2005). Full-cycle aquaculture currently accounts for only 1% of the global trade in marine aquarium fish (Wood 2001), with approximately 50 species routinely produced commercially. These species are primarily anemonefish, dottybacks, gobies and seahorses (RCT 2006). In order to be competitive with wild-caught products, maricultured products need to be of high quality, in high demand, and produced reliably in sufficient numbers to be economically viable.

Globally, anemonefish (*Amphiprion* spp. and *Premnas* spp.) are among the most popular marine aquarium fish. Hatchery production of anemonefish is practiced commercially on a routine basis in many developed areas (e.g. USA, Europe, Australia and Asia). However, grow-out of

Plankton collection trials at night using a spotlight and a 50µm scoop net.

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those fish in open cages in rural areas of the Pacific is a new concept, but could provide communities with livelihood incomes while also reducing the pressure on wild-caught animals. Anemonefish are highly sought after in Vanuatu, and are caught by professional divers and exported by private companies. The average number caught annually is between 5000 and 10,000 fish (VFD 2007, 2008). The uncommon colour morph of *Amphiprion melanopus* can fetch between USD 4 and USD 5 per fish, export price.

Forecasted hatchery and grow-out phases of the project

In July 2008, SPC's Aquaculture Officer went to Vanuatu to begin organising the hatchery, including setting up broodstock and larval rearing areas, purchasing broodstock from local ornamental fish exporters, preparing specific broodstock feed, and performing plankton collection trials.

Vanuatu's Fisheries Department has suitable facilities for running a small-scale aquarium fish mariculture project. Their newly renovated hatchery has a laboratory, raceways/production units, and access to open ocean sites with boats. Four small concrete raceways (1000 liters) were set up as broodstock tanks. A total of 35 different sized *A. melanopus* were placed in three of the four raceways, together with bubble anemones (*Entacmea quadricolor*) that were collected on the reef off Efate's northern coast. Similarly, 18 *A. clarkii* were placed in a raceway together with their host, the long tentacle anemone, *Heteractis crispa*.

Anemonefish are pair mating and protandric hermaphroditic fish (i.e. males change into females). They lay demersal sticky eggs, which are looked after until hatching. Under optimum conditions, a mating pair will spawn every two to four weeks during summer when the water temperature reaches 27–28°C.

Larval rearing, nursery culture will be undertaken at the facilities using established techniques. Once the fish reach 2 cm they will be transferred to ocean grow-out sites.

The grow-out sites will be located on the reef near a community on Efate's north coast (half an hour's drive from Port Vila), where there is already a giant clam grow-out station and where aquarium fish collection companies have operating licenses. Vanuatu Fisheries Department staff will be in charge of introducing the anemonefish grow-out project to villagers and selecting key operators in the village, prior to initial trials.

Once juvenile clownfish can be produced routinely from the hatchery, a trip will be undertaken by SPC's Aquaculture Officer, Vanuatu's Fisheries Department staff, and JICA personnel to introduce farming techniques in floating cage systems. Initial trials will determine growth and survival of clownfish in the simplest possible cage set up. Low cost, readily available feed (e.g. minced shrimps, fish or crushed shellfish) will be identified with the villagers.

Top. One-tonne raceways used at Vanuatu Fisheries Department for the project.

Bottom. *Amphiprion melanopus* and *Amphiprion clarkii* at an export facility.

How will farmers benefit from farming anemonefish?

A. melanopus (Vanuatu clownfish) are exported at USD 4–5 per fish. It is likely that village farmers could expect to receive around USD 2–2.5 per fish, farm-gate price. It is anticipated that farmers will have the capacity to produce several batches per year, with each batch composed of 100 clownfish of 3-4 cm, according to market demand. Thus, a clownfish farmer could expect to make between USD 200 and USD 250 per shipment, repeating the process several times a year. This activity could complement other activities such as giant clam farming.

Previous experiments were shown to be profitable in other areas of the Indo-Pacific such as the Philippines (Pomeroy and Balboa 2004). If the hatchery technology for anemonefish is successful in Vanuatu, there should be attempts at transferring it to the private sector. Aquarium fish exporters could supply clownfish juveniles and buy back commercial size anemonefish (on the same model as giant clam farming).

References

Bell J.D., Kronen M., Vunisea A., Nash W.J., Keeble G., Demmke A., Pontifex S. and Andréfouët S. in press. Planning the use of fish for food security in the Pacific. Marine Policy.

Job S. 2005 Integrating marine conservation and sustainable development: Community-based aquaculture of marine aquarium fish. SPC Live Reef Fish Information Bulletin 13:24–29.

Lal P. and Kinch J. 2005. Financial assessment of the marine trade of corals in Solomon Islands. A report prepared for SPREP, FSPI, DFMR. 31 p.

Pomeroy R.S. and Balboa C. 2004. The financial feasibility of small-scale marine ornamental aquaculture in the Philippines. Asian Fisheries Science 17:365–376.

Reef Culture Technologies. 2006. http://www.rcthawaii.com/cvb/5.htm

Teitelbaum A. and Friedman K. 2008. Resurgence of cultured giant clams from the Pacific. Current status and prospects for the aquarium market. Australasia Aquaculture conference. Brisbane, Queensland.

Vanuatu Fisheries Department. 2007. Fisheries Department 2006 Annual Report. Vanuatu Fisheries Department, Ministry of Agriculture, Livestock, Quarantine, Forestry and Fisheries. 28 p.

Vanuatu Fisheries Department. 2008. Fisheries Department 2007 Annual Report. Compiled By Jason J. Raubani. Vanuatu Fisheries Department, Ministry of Agriculture, Livestock , Quarantine, Forestry and Fisheries. 46 p.

Vanuatu Fisheries Department. 2008. Vanuatu Aquaculture Development Plan 2008–2013. A collaborative work of Vanuatu Fisheries Department, Ministry of Agriculture, Livestock, Quarantine, Forestry and Fisheries, and SPC Aquaculture Section. 35 p.

Wabnitz C., Taylor M., Green E. and Razak T. 2003. From ocean to aquarium. Cambridge, UK: United Nations Environment Programme — World Conservation Monitoring Centre. 67 p.

Wood E.M. 2001. Collection of coral reef fish for aquaria: Global trade, conservation issues and management strategies. UK: Marine Conservation Society. 80 p.

A dark phase of *Amphiprion clarkii* in *Heteractis crispa*.

DEVELOPMENT OF SUBSURFACE FADS IN THE PACIFIC ISLANDS REGION, INCLUDING DEPLOYMENT OF TWO SUBSURFACE FADS IN NEW CALEDONIA

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Introduction

The introduction of fish aggregating devices (FADs) to the Pacific Islands region through the pole-and-line tuna fishery has, in some Pacific Island countries, improved the operational costs for small-scale offshore fishermen.

The commercial use of FADs, or *payaos*, originated in the Philippines, but the FAD concept is not new to the Pacific. In earlier days, some Pacific Islanders used bunches of bamboo, palm fronds, or mature coconuts anchored by large rocks in lagoons or on the ocean side of reef drop-offs to make it easier for canoe fisherman to catch the family's meal for the day; especially when the fisherman preferred one of the common pelagic fish normally found around drifting logs or debris. These types of basic FADs worked very well for subsistence fishermen. However, nowadays, with the increased number of powered craft found throughout the Pacific, particularly near major population areas, these basic types of FADs are now very rarely seen, except in remote areas.

The commercial use of FADs came about when their potential to aggregate pelagic fish proved effective for small-scale, offshore fishing operations, and subsequently, large-scale operations. On the other hand, the costs of maintaining sustainable FAD programmes in the Pacific Islands region can be expensive as some FADs must be replaced almost annually, due mainly to the effects of adverse weather conditions that place significant strains on the middle mooring and anchor systems.

Ever since this problem was identified, FAD designs in the Pacific have undergone a transition from weather-resistant flotation buoys, to surface flotation sections less resistant to the forces of nature. While in most cases this has improved the longevity of FADs in the water, there is still room for improvement in order to justify the cost of putting FADs in place. Other major problems that reduce the lifespan of FADs are vandalism and collision accidents.

FADs are also important to local fishermen in Japan. FAD problems there were similar to those in the Pacific Islands. To address these issues, several subsurface FAD programmes were implemented in Japan's fisheries prefectures. These programmes tested the performance of subsurface FADs, and determined their overall longevity. These trials proved to be very successful, with some FADs lasting up to 10 years and still functional. Now, more subsurface FADs are being deployed around Japan.

The Okinawa subsurface FAD programme is a good model to base subsurface FAD ideas on. Even though their subsurface FADs are too expensive for most Pacific Island programmes, the concepts and results of these subsurface FADs can be made simpler and cheaper for practical use in the region. Two cheaper versions of subsurface FAD designs were developed and trialed in Nauru and Fiji by SPC and the Japan International Cooperation Agency (JICA) on separate programmes.

Subsurface FAD activity in the Pacific Islands region

Two subsurface FADs were deployed off Suva, Fiji in 2006 by JICA adviser Takayuki Kai, working with the Fiji School of Maritime and Fisheries (FSMF). Another subsurface inshore FAD (of a simpler design) was deployed off Nauru by SPC's William Sokimi in early 2007, and two more subsurface FADs, similar to the FSMF design, were deployed off Suva in late 2007 with SPC's assistance under a JICA course for Pacific Islands Fisheries Officers. This project was coordinated jointly by Takayuki Kai and William Sokimi (Fig. 1).

Inconclusive data were obtained from the Nauru and FSMF subsurface FADs due to incomplete data feedback, although one of the two FADs deployed during the JICA course in 2007 had accumulated several large schools of skipjack tuna, frigate mackerel and yellowfin tuna. These schools were successfully fished during a FAD fishing methods workshop in July 2008, conducted by the Fiji Department of Fisheries with assistance from SPC's Nearshore Fisheries Development and Training Section.

The other subsurface FAD was not submerged when it was initially deployed. Although the deployment depth matched the scope of rope needed for the

FAD to be submerged at 20 m depth, the rope's stretching capacity was miscalculated, resulting in the FAD being stretched to the surface. During FAD preparation at the workshop, a forklift was used to stretch the rope for this FAD. The other FADs were manually stretched by workshop participants. The force exerted on the mooring ropes by the buoyant section was around 240 kg, so the ropes should have been stretched to this limit instead of being stretched greater than this by the forklift.

This subsurface FAD is suspected to have totally submerged after attempts by the Fiji Department of Fisheries technicians to sink it to around 20 m; instead of settling at 20 m or so the FAD likely sank to the bottom. The added weights must have been more than the upward pressure on the floats could withstand.

Following on from the deployment of these two subsurface FADs in Fiji, JICA will be deploying another two in Tonga, while completing the third component of the JICA Community-Based Fisheries Diversification in Small Island States Course for Pacific Islands Fisheries Officers. The decision to carry out this subsurface FAD deployment in Tonga was the result of an action plan proposed by the Tongan participant on the course, which was acknowledged by JICA as a constructive FAD development programme for the country.

Noumea subsurface FAD

Two subsurface FADs were constructed in Noumea by SPC's Nearshore Fisheries Development and Training Section (NFDTS) in August. The intention was to have these FADs deployed at strategic locations so that they could be periodically monitored by the Section's officers to ascertain their fish aggregating capabilities, longevity, fishing response, catch rate, and any other impacts that may be beneficial or otherwise to small-scale fishermen.

One of the subsurface FADs was deployed off Dumbea passage on 18 September, while the second one will be deployed off Passe Saint-Vincent at Tenia once sea conditions improve and NFDTS officers are back from duty travel.

Pre-construction calculations

The structure of the two Noumea subsurface FADs was based on the design that was used in Nauru in early 2007, where pressure floats, stainless steel wire, chain, and grapnel anchor were used. This design focused on being:

- easy to construct,
- easy to transport and deploy,
- durable with minimal resistance to the weather and sea forces, and
- not as expensive to produce as other subsurface FAD designs.

An Excel table listed all of the FAD components in the sequence the FAD was rigged, and the formulas used to calculate:

- Number of 30G-2 oval pressure floats required to support the middle mooring and a minimum of 10 m of chain off the bottom.
- Total weight of the anchor and connecting shackle.

Figure 1: Subsurface FAD deployed in 2007 off of Suva, Fiji.

- Total weight of the mooring section, including the middle mooring.
- Number of 30G-2 floats required to lift the anchor and total mooring completely off the bottom.
- Actual length of chain lifted off the bottom (in metres).
- Actual length of chain remaining on the bottom (in metres).
- Holding weight remaining on the bottom.

With this information, the weight of the full anchor system could be determined so that it would not be necessary to use an overly heavy anchor for the job but at the same time be sufficient to securely anchor the FAD in position (Fig. 2).

Emphasis was placed on using the chain as the principal anchor weight with a grapnel anchor at the end to prevent the chain from sliding along the bottom. With hindsight, the grapnel anchor that was used in this project was too bulky but this could be improved on in future FAD work to make transportation of the full FAD rig to the deployment site less cumbersome.

Dumbea FAD buoyancy section

The buoyancy section consisted of four 30G-2 oval pressure floats buffered by a halved piece of Polytech M700 purse-seine float between each 30G-2 float; three pieces were used in the mooring (Fig. 3). These were connected together with a 20-mm three-strand Polypropylene rope rove through a 22 mm clear flexible tube then through the 40-mm centre holes of the floats. An eye loop was spliced at the top end of the flotation system with a Turks head directly below the splice to prevent the floats from riding up on the splice. The end leading to the anchor mooring was spliced directly on to a #4 Nylite rope connector. This was shackled to a 16-mm stainless steel swivel with a 16-mm stainless steel shackle.

The total flotation buoyancy was calculated to be 90.5 kg, which should lift the chain 21.3 m off the sea floor. It is expected that the three halved pieces of M700 purse-seine floats will eventually be squeezed out to become a liability to the flotation section, thus reducing the buoyancy to 80 kg, and eventually dropping the chain to be lifted off the bottom from 21 m to 15 m.

Middle mooring

The middle mooring section for the subsurface FAD was constructed with 360 m x 5 mm x 7 x 7 (6x1) stainless steel wire.

The top end of the middle mooring was connected to the stainless steel swivel on the flotation section using a Flemish eye and three bulldog wire grips to clamp the dead end of the wire to the working end (Fig. 4).

Figure 2 (top). Grapnel anchor for mooring the FAD.

Figure 3 (bottom). Flotation section for the subsurface FAD.

The anchor end of the middle mooring was connected in the same way to a 22-mm forged swivel, which was then shackled to the 12-mm galvanized chain with a 12-mm galvanized bow shackle (Fig. 5). All the shackles and bulldog grips in the system were seized with wire to prevent the pins and nuts from unwinding and these were all wrapped in rubber tube to further strengthen the locking properties.

Anchor system

The anchor system consisted of 30 m x 12 mm galvanized chain and a grapnel anchor weighing 67 kg (58 kg in seawater). The initial weight of the anchor and chain remaining on the bottom immediately after deployment should have been around 84 kg. However, after the M700 floats were squeezed out, the FAD should have submerged an additional 6 m and more chain would have settled on the bottom, bringing the holding weight to around 103 kg.

Deployment of the Dumbea subsurface FAD

The Dumbea subsurface FAD was deployed in 390 m depth. The flotation section was first released at the deployment position, then the middle mooring wire was paid out as the vessel drifted downwind. At one stage there was a slight tangle in the wire as it was paid out. This occurred because of a lack of vigilance to ensure that the top wire loop flipped over and out and not slide under several coils while paying out. However, this problem was quickly rectified and the deployment finished without further disruptions.

An aggregator was tied on to the wire rope immediately beneath the flotation section to enhance and speed up the fish aggregating process. This aggre-

Figure 4 (top). Connection to flotation to the stainless wire in the middle mooring.

Figure 5 (middle). Connection of the middle mooring to the anchor chain.

Figure 6 (bottom). Tying on the aggregators while paying out the middle mooring wire.

gator was constructed from multiple 2-m lengths of plastic binding straps rove through the strands ofa 10-m green Polypropylene rop (Fig. 6).

A 2-mm twine was calibrated every 10 m and coiled onto a plastic bottle for checking the settling depth of the subsurface FAD. The twine was paid out as the vessel drifted downwind while releasing the middle mooring wire. After the anchor was deployed and the flotation section had submerged to its settling depth, this was measured by retrieving the twine and reading off the calibration.

After all the wire was paid out, the vessel was pushed ahead, away from the flotation section, so that the wire was at an angle to the boat. The anchor was then deployed after checking the depth again and ensuring that the wire angle was sufficient to prevent the anchor from being dropped on top of it and fouling the mooring.

When the anchor was finally deployed, the FAD settled at 60 m below the surface. This was deeper than initially intended but was still an effective depth for aggregating pelagic fish. Some of the subsurface FADs in Okinawa were at 100 m. There were two possible reasons why this subsurface FAD settled deeper than initially planned: the anchor settled at a deeper depth on the bottom slope, and the effects of the current on the FAD gave it a scope that settled the FAD deeper at its extreme stretch. After plotting the deployment position on the chart it was evident that the anchor had settled deeper than intended.

Subsurface FAD to be deployed at Tenia

Except for two minor changes, the Tenia subsurface FAD was constructed with the same procedures and components used for the Dumbea subsurface FAD. The changes included:

- A longer middle mooring section of 510 m to meet the depth at the deployment site of 540 m. The subsurface will FAD initially settle at around 10 m below the surface, and then sinking further to 17 m below the surface when the M700 floats get squeezed out.
- Instead of rigging a Flemish eye at both ends of the middle mooring wire, and then securing this with three bulldog grips, the ends were grommet spliced then secured with three bulldog grips (Figs. 7).

The rest of the subsurface FAD construction remained the same as for the Dumbea subsurface FAD. The shackle pins and bulldog grip nuts were secured with wire then wrapped in rubber tube as additional security.

Figures 7 (left and right). Middle mooring wire; grommet spliced then secured with bulldog grips, seizing wire and bound with a rubber strap.