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Editorial

In the Pacific Island region, it is estimated that: 1) coastal fisheries resources provide the primary or secondary source of income for up to 50 per cent of households and 50–90 per cent of the animal-sourced protein consumed; 2) most coastal fish and invertebrate resources – at least all those accessible to coastal communities – are over-exploited or exploited to their limits; and 3) the population of many Pacific Island countries is growing rapidly and consequently the need for proteins is also growing.

There are a few alternative sources of protein: a bigger share of the offshore catch (primarily tuna) by industrial fleets could be reserved for local populations, and production from agriculture and livestock could probably be further developed, at least in high islands. But if coastal fisheries keep declining, these sources will not fill the gap, and they will not make up for the loss of income that coastal fisheries provide to communities.

A workshop dedicated to tackling these issues was convened in Noumea in early March this year. It attracted the participation of more than a 100 people: representatives from fisheries and environment departments in 22 SPC member countries, coastal communities, regional organisations and non-governmental organisations. After four days of intense discussions, the participants developed a strategy summarised in the document 'A new song for coastal fisheries – pathways to change' that we reproduce here (p. 37). It is a vibrant call for an enhanced focus on coastal fisheries management in the Pacific region, fully involving communities in the process.

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Gillnet fishing in Kiribati (Image: Quentin Hanich)

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

Remarkable growth of seaweed farming in Bougainville

*The number of people farming cottonii seaweed (*Kappaphycus alvarezii*) in the Autonomous Region of Bougainville, Papua New Guinea and its small offshore islands increased remarkably from 800 in 2014 to 4,552 in 2015 after training for coastal communities sparked great interest in seaweed farming. Eleven new nurseries and seaweed planting sites have since been established around Bougainville to support the large number of farmers entering this new industry.*

These 4,552 farmers are now planting seaweed that they will send to Bougainville Seaweed Ltd (BSL), who exports the dried seaweed to China. In addition to buying the seaweed produced by the farmers, BSL supports them with seed stock nurseries that are now established in the Nissan, Selau, Atoll, Tinputz and Buka Districts of Bougainville.

This significant increase in the number of farmers is attributable to post-training scale-up and expansion efforts being coordinated by BSL, district officers of Bougainville, the Papua New Guinea National Fisheries Authority, and the Secretariat of the Pacific Community (SPC). The National Fisheries Authority has also provided a great deal of ropes and other equipment to BSL and the farmers.

Conducted by SPC, the training 'Practical skills for aquaculture of cottonii seaweed' was held in Buka from 6 to 9 October 2014. Sixty-nine participants – farmers from over 20 islands, district officers, National Fisheries Authority officials and BSL staff – completed the training. Topics included seaweed nurseries, farming methods and practices, seaweed processing and disaster mitigation measures. The training sessions were led by Mr Kevin Labis, a trainer with extensive

Kevin Labis, the lead trainer, shows how to select seaweed seed and tie it to lines. (Image: Avinash Singh)

Training on site selection and planting of seaweed using the off-bottom method (Image: Elenio Yap)

commercial seaweed farming experience who had been contracted from the Philippines to conduct the training with SPC. The district officers and BSL extension staff have since utilised the skills gained from the training and taken seaweed farming out to the communities that were interested.

The training was the result of a multi-partner collaboration with one of the Pacific's leading development partners, the European Union, through its Increasing Agricultural Commodity Trade (IACT) Project. The IACT Project is implemented by SPC's Land Resources Division and the Fisheries Aquaculture and Marine Ecosystems Division. SPC officials collaborated with the National Fisheries Authority in Papua New Guinea and the Bougainville government officials to conduct the training.

BSL's exports to China have brought in much needed economic returns to this autonomous region in Papua New Guinea, and confirm the existence of high demand for good quality seaweed in international markets. The first quarter of 2015 alone saw 40 tonnes exported out of Bougainville.

National Fisheries Authority Fisheries Officer Mr Kevin Anana said, 'The training was very timely as there has not been any training conducted since the introduction of seaweed farming on Carteret Island (the main production area, north of Buka). The training was fantastic and very helpful.'

The hands-on practical training was intended to help participants improve their own production and pass the knowledge on to their communities so that more people can engage in seaweed farming.

Mr Raymond Moworu of Bougainville Seaweed Ltd said that there was huge scope for growth of the seaweed industry and that hurdles to reduce high transportation costs must be addressed to take the industry further.

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Hands-on training in sandfish and microalgae hatchery techniques

The simulator tanks where sandfish broodstock is kept – Kiribati (Image Beero Tioti)

To support livelihoods of communities and assist in the replenishment of sea cucumber stocks in the region, the Secretariat of the Pacific Community (SPC), with funding assistance from the Australian Centre for International Agriculture Research (ACIAR)/ DFAT Australia, has conducted two workshops on sea cucumber (sandfish) breeding and live microalgae culture techniques. The participants were fisheries officers and people working in the private sector in Pacific Island countries that have a sea cucumber restocking and farming programme.

The first workshop was conducted in Kiribati with the Ministry of Fisheries and Marine Resources Development in January 2015 as part of an ACIAR project on community-based aquaculture, which, for Kiribati, focuses on the culture of sandfish (*Holothuria scabra*). A total of 14 staff from the Tanaea hatchery, including fisheries assistant trainees, were trained in all aspects of hatchery techniques for breeding sea cucumber and microalgae culture. The second workshop, conducted from 27 April to 23 May 2015 in Fiji at the government's fisheries station in Galoa, was attended by 12 participants from Fiji, Vanuatu, Solomon Islands and Cook Islands.

The participants were taught about various spawning induction methods and culture techniques for rearing sandfish larvae in tanks. They also learned how to culture microalgae – a staple food for most marine organisms, including sandfish, pearl oysters and shrimps – in an artificial environment, a hatchery, and how to follow feeding protocols using microalgae and Spirulina, an artificial dried alga, to ensure high survival of larvae produced.

During the four-week course, the participants set up a simulator habitat tank for growing sea cucumber in an artificial environment. Resembling the natural habitat, being covered with the nutrient-rich seagrass that is often inhabited by sea cucumbers, the simulator is used for growing and conditioning adult sea cucumber for the breeding programme. It can also be used for nursing and growing juvenile sea cucumber produced in the hatchery.

Another part of the Fiji course involved obtaining eggs from a female sandfish and fertilising them with male sperm in a beaker. Despite the small number of eggs fertilised, the *in-vitro* fertilisation technique proved that female eggs can be fertilised by artificial means (stripping gonads) and then reach pentactula stage (early settled juveniles). This technique could be improved and used to enhance stocks of sea cucumbers that are currently under threat from overfishing. One of the participants who was impressed with the outcome of the technique said, 'During times of harvest when a lot of sea cucumber are being gutted, one could actually collect all gonadal matter and fertilise

it *in-vitro,* producing sea cucumbers which otherwise would not have existed.'

Replenishing natural sea cucumber stocks, which are almost all under the threat of overfishing, will require efficient and well-monitored management measures. Mastering the artificial reproduction of sea cucumbers by using the hatchery techniques taught during this training will come as an additional tool to assist with the rebuilding of natural stocks.

The training sessions were conducted by Masahiro Ito, who has over 30 years of marine hatchery experience in the region. He was assisted by the SPC aquaculture team and the Galoa aquaculture staff of the Fiji Ministry of Fisheries and Forests. The training programme was a success, with most countries now being able to carry out their breeding and restocking programmes to enhance current depleted stocks that will, it is hoped, improve livelihoods of local communities.

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Masahiro Ito (right) explains how to induce sandfish specimens to spawn. (Image: Beero Tioti)

After 12,000 stomachs, we gain some insights on the impact of fishing on the ecosystem

Since 2000, countries of the Pacific region have invested in monitoring their pelagic ecosystem by having observers collect predator stomachs during tagging campaigns and having the stomach contents analysed by the Secretariat of the Pacific Community (SPC). The monitoring provides an opportunity to model the ecosystem dynamics of the warm pool ecosystem in the western equatorial Pacific. Such models provide a baseline of the ecosystem structure that can be used to evaluate:

1. *the effects of climate variability and change on ecosystem function, which provides indicators for timing the implementation of adaptations that maintain fisheries sustainability and industry profitability; and*
2. *the effects of different fisheries harvest regimes on ecosystem structure and function, which provides information for the development of management measures.*

This paper focuses on the second point: the effects of different harvest regimes on ecosystem structure and function.

Building the warm pool ecosystem model

Over 12,000 predator stomachs have been collected and analysed since the monitoring began. Results of these analyses have been incorporated into a trophic model that describes the warm pool ecosystem (Fig. 1) and allows forecasting the dynamic responses of the ecosystem to simulated changes in fishing effort through time (Ecopath with Ecosim, www.ecopath.org).

The modelled simplified ecosystem was composed of 44 groups: fisheries discards (1 group), detritus (1), phytoplankton (2), zooplankton (2), forage/prey groups (epipelagic, mesopelagic, bathypelagic, migrating or not, fish, mollusc, crustaceans) (11), bycatch species

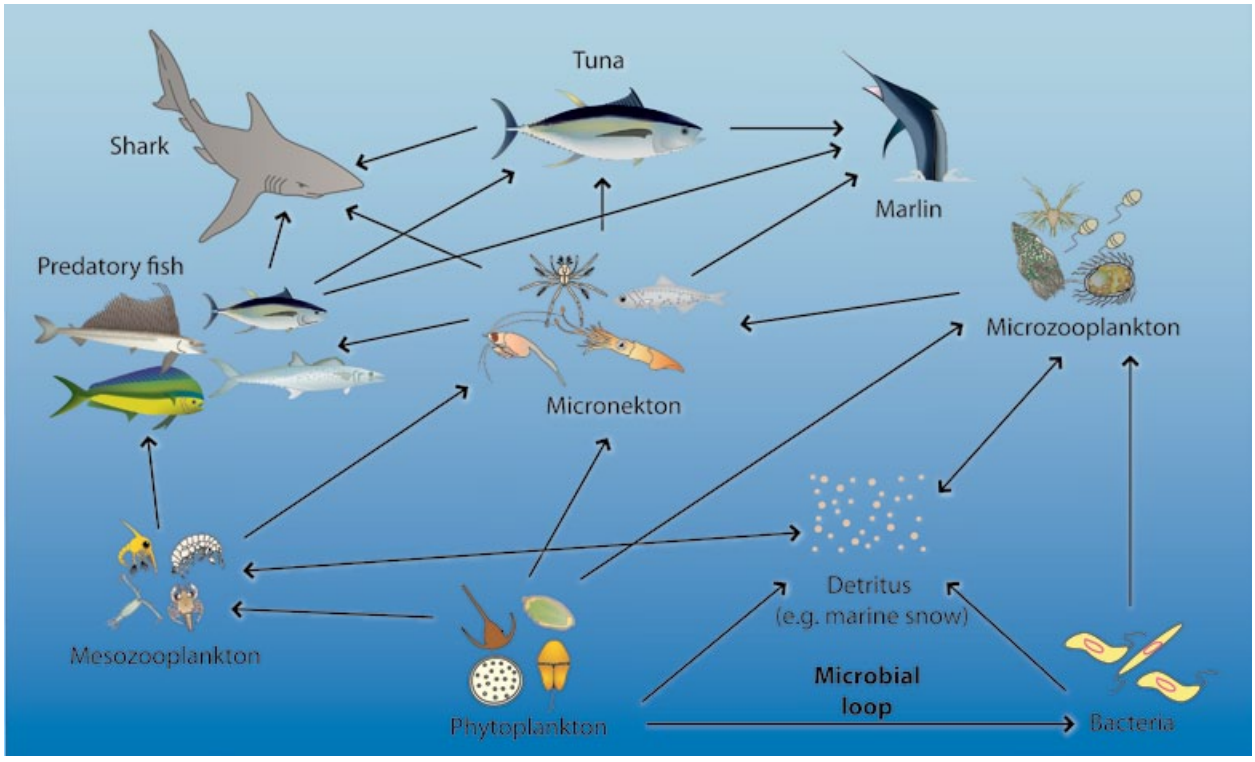

Figure 1. Simplified view of the generalised food web supporting tuna and other large pelagic fish in the warm pool. Note that, at the bottom of the food web, both phytoplankton (microscopic plants) and 'marine snow' (phytoplankton and zooplankton remains decomposed by bacteria, also known as detritus) contribute trophic inputs.

(rainbow runner, pomfret, opah, lancetfish, escolar and oilfish, small tunas, dolphinfish, wahoo) (8), tuna (albacore, skipjack, yellowfin, bigeye of different size classes) (8), sharks (oceanic white-tip, silky, blue, mako and other sharks) (5), billfish (swordfish of two size classes, striped marlin, blue marlin and other billfishes) (5) and turtle (1).

Four fisheries (longline, pole-and-line, purse-seine unassociated schools, purse seine associated schools) were included in the model.

Nine scenarios of fishing effort were explored. They comprised measures designed to reduce/increase the catch of the bycatch community and measures designed to reduce/increase the harvest of tuna by (a) altering the amount of longline fishing and purse-seine fishing, both unassociated (free schools) and associated with fish aggregating devices (FADs), and (b) by simulating the implementation of bycatch mitigation measures. Results were projected for 2026 and 2046.

How does the warm pool ecosystem work and what are its key dynamics?

The majority (74%) of the ecosystem's biomass is in phytoplankton and zooplankton (trophic levels TL 1 and 2), whereas the industrial fish catch (tuna and bycatch) are in TL 4 and 5 at the top of the food web, representing less than 8% of the total biomass of the pelagic ecosystem (Fig.2).

The most important keystone group in the warm pool ecosystem model is small yellowfin tuna, due to its high production and consumption values and its diverse diet. The next most important keystone groups are the prey organisms, which have high production values as predators, but are also important prey for a range of larger fish such as tuna and marlin.

Potential impacts of fishing strategies on the whole ecosystem

The modelled ecosystem was resistant to considerable disturbance from fishing. We suggest that this is related to the considerable diversity of predators in the food web that consume a wide range of prey. Maintaining the diversity contributes importantly to the sustainability of the system.

The structure of the ecosystem was most sensitive to changes in the biomass of prey groups (e.g. small pelagic fish, such as anchovy) because these mid-trophic level species are important prey for tuna, as well as being predators for lower trophic levels, such as zooplankton. Hence, variations in prey availability and quality in relation to changes in the climatic conditions will affect the whole ecosystem and the fisheries.

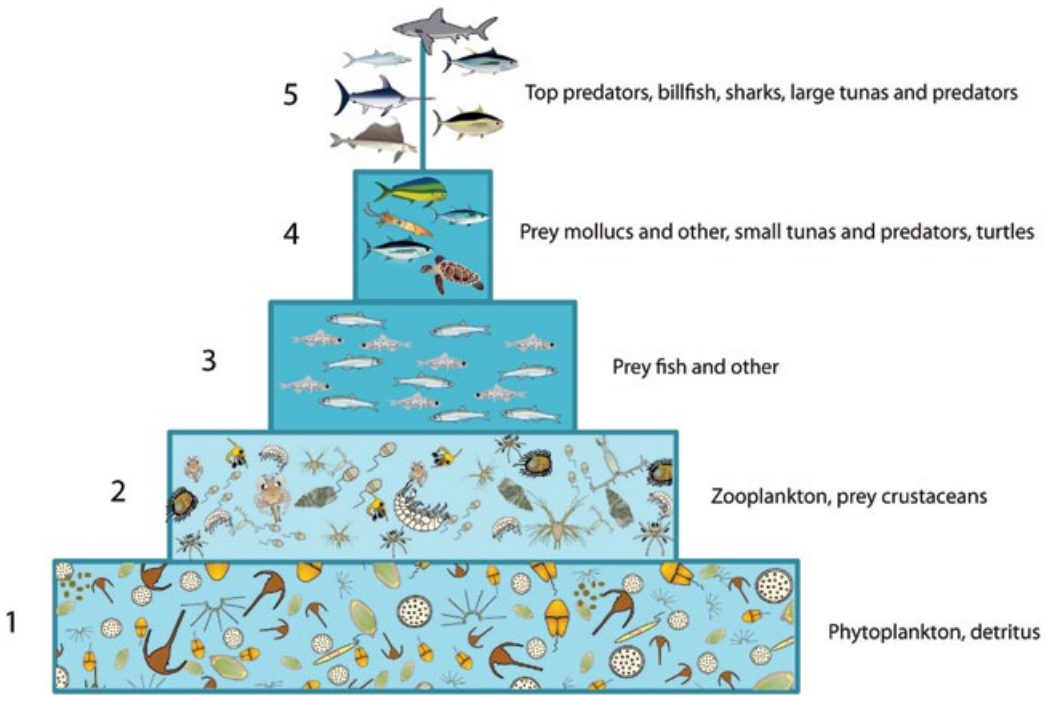

Figure 2. The warm pool ecosystem model is characterised by a large number of trophic links between groups and a diverse pool of prey on which a wide diversity of predators is feeding.

The simulations showed that groups comprising long-lived, bycatch species with low productivity, such as sharks, opah and billfish, are most likely to be affected by changes in purse-seine and longline fishing effort.

Increases in purse-seine fishing on FADs results in greater mortality of sharks and decreases in the biomass of some species and size classes of tuna. This scenario had the most negative impact on the ecosystem. Conversely, reductions in purse-seine fishing on FADs increases the numbers of sharks, although such benefits are not as pronounced when purse-seine fishing effort on FADs is transferred to purse-seine fishing on free schools of tuna.

Increases in longline fishing result in greater mortality of sharks, opah and some billfish species. The negative impact on opah and billfish is also observed when longline fishing effort is unchanged but shark mortality is decreased by the implementation of shark mitigation measures.

The simulations to date suggest that some species of the ecosystem will benefit from variations in fishing effort and others will lose; managers will have to define which groups of species are expected to benefit.

It is also apparent that no single indicator is able to provide a good representation of the responses of the ecosystem to changes in harvest. This reflects the complexity of the ecosystem. The use of a variety of indicators is likely to be required to detect the full range of impacts from alterations to harvest strategies.

As with tuna stock assessment models, use of the best available data is critical. Continued and expanded monitoring of catch and discards for bycatch species by observers (at sea or electronic) is critical for further model development and improvement. Similarly, expanding fisheries monitoring programmes to include prey species through predator stomach collection as a routine observer duty is necessary to spatially disaggregate the model.

Further reading

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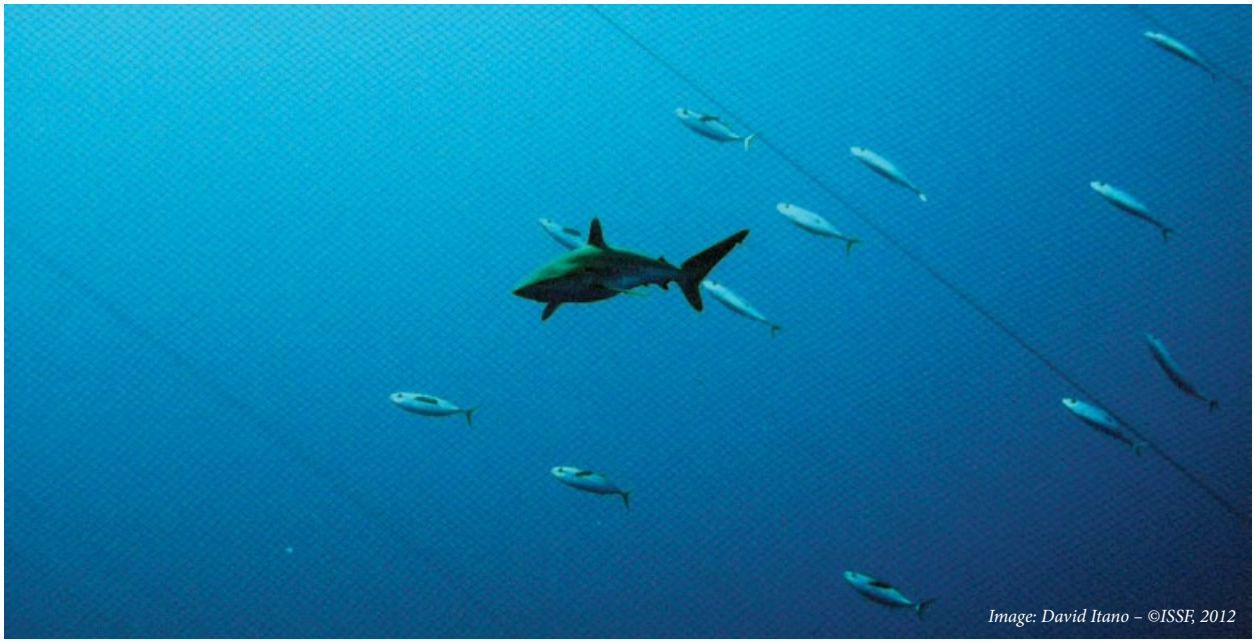

Image: David Itano – ©ISSF, 2012

Pacific Islands flame angelfish probably all belong to the same stock

The flame angelfish, Centropyge loricula *(Günther 1874), is one of the most popular reef fish in the marine aquarium trade. It is sourced exclusively from the Pacific region.*

A flame angelfish, Centropyge loricula *(Image: Colette Wabnitz)*

Key to their appeal is their vibrant colouration and distinctive markings. Flame angelfish are characterised by a bold orange to red body with up to seven broad black bars running vertically down each side. The edges of the anal and dorsal fins are black with a blue margin. There are slight differences in the colouration and markings of this species in different locations (Pyle 2003). Flame angelfish in Marshall Islands are more red than orange, with thicker black bars; those in Kiritimati Island are red/orange and have thinner black bars; those in Tahiti are blood red in colour with a smaller number of black markings on the body, while in the Marquesas they are more orange in colour and completely lack the vertical black bars. Recent work by Schultz et al. (2007), based on mitochondrial DNA analysis of 116 individual fish from throughout the region, shows that, while there is a strong geographic component to the distribution of colour morphs in *C. loricula*, there is no evidence of corresponding genetic partitioning.

Centropyge loricula can be found at depths between 10 and 60 m on the reefs of a number of Pacific Island countries and territories at varying abundance levels. Flame angelfish are secretive and tend to stay close to shelter. They can be found associated with a variety of habitats, from coralline algae-encrusted rugose pavement, to thick Halimeda (green calcareous macroalgae) beds, to areas covered in 100% live coral. They feed predominantly on algae. Currently, these fish are primarily collected from Marshall Islands and Kiritimati Island in the Central Pacific. Other important exporters are Vanuatu, Cook Islands and, until recently, Kosrae in Federated States of Micronesia.

Despite its popularity in the marine aquarium trade, relatively little is known about the basic life history parameters of this species (e.g. length-weight relationships, age-size relationships). Contrary to other angelfish species, information on the embryonic and larval development of *Centropyge* species is plentiful. Studies by Baensch (2002, 2006) and Rhody (2006), for example, have revealed that egg and larval characteristics are very similar among species and that many egg and early larval traits are similar across angelfish genera (see also Hioki and Suzuki 1987). Flame angelfish eggs are free drifting, with larvae measuring on average just over 1 mm when they hatch (Rhody 2006), which is known to occur 14 to 16 hours after fertilisation at 27°C (Baensch 2002). The angelfish pelagic larvae stage is complex and can last upwards of 6 weeks (Thresher 1985), settling and metamorphosing after 110 days (Baensch 2006).

To contribute to our understanding of the life history of *C. loricula* and to the management of the species as an important resource for the aquarium trade, SPC obtained morphometric data, fin clips and otoliths from a total of 234 individuals[1]. The fish were collected across a gradient of fishing pressure from sites in Marshall Islands,

[1] Fin clips were also taken from an additional five fish in New Caledonia.

Vanuatu, Kiritimati, Kosrae, Cook Islands, Pohnpei (no active fishery), and Nauru (no active fishery). All samples were obtained and shipped by SPC and/or obtained with the support and collaboration of relevant local authorities and aquarium trade operators, following all necessary permit and quarantine requirements.

Preliminary results from genetic analyses, conducted by colleagues at the Institut de Recherche pour le Développement with whom SPC is collaborating for this part of the project, appear to corroborate the findings of Schultz et al. (2007), namely, that flame angelfish populations are not genetically partitioned in the region.

Morphometric measurements reveal that the size of flame angelfish on a given reef, on average, ranges between 26 mm and 89 mm total length, with most individuals falling within the 35 mm to 75 mm size bracket. The greatest spread in fish sizes was obtained from Kiritimati. Within this regional sample, no significant difference was found in the length-weight relationship of fish, whether they were obtained from operators,[2] reef sites from an island with an active fishery, or sites from an island without an active fishery.

Centropyge loricula is a relatively small fish with small to very small otoliths. Otoliths, also commonly known as earstones or fish ear bones, are hard, calcium carbonate structures (crystals) found directly behind the brain of bony fish. Their function has been compared to that of our inner ear; they assist fish with balance, orientation and sound detection. As a fish grows, new material is added to the exposed surface of the otolith over time, but existing material cannot be removed. Thin sections of an otolith under a microscope show bands of opaque and translucent material, much like the growth rings in a tree trunk. It is typically assumed that these rings form on a yearly basis. Counting the number of dark/translucent bands on an otolith will yield a fish's age. However, the smaller the otolith and the closer to the equator the fish is collected (Longhurst and Pauly 1987), the more difficult it is to see the bands and determine with accuracy the age of the fish. Initial results on 20 fish between 47 mm and 75 mm in length show that, although faint, there are bands of opaque and translucent material, yielding age estimates ranging between 2 and 6 years.

Final results and their analysis are expected at the end of the southern hemisphere's summer. These will be disseminated to project partners throughout the region and it is hoped they will inform the development of management considerations for this species where it significantly contributes to the marine aquarium trade.

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[2] These fish were often obtained just prior to export, meaning they had not been fed for up to three days to ensure they do not soil the bags in which they are shipped during transport. This optimises their health.

Commercial marine aquarium surveys in Samoa

In April 2015, in response to an industry operator expressing an interest in establishing himself in Samoa, the Secretariat of the Pacific Community (SPC), in collaboration with an external consultant and the Fisheries Division of the Samoa Ministry of Agriculture and Fisheries, undertook commercial surveys of targeted marine aquarium fish around the island of Upolu.[1]

Following up on preliminary work conducted in 2008 (Yeeting and Samuelu Ah Leong 2008), the overall aim of the surveys was to determine if a sustainable and viable aquarium marine fishery could be set up in Samoa. Specific goals of this survey were fourfold:

1. to determine if flame angelfish (*Centropyge loricula*) (Fig. 1) could be found in commercial quantities;
2. to verify that red hawkfish (*Neocirrhites armatus*) (Fig. 2) were present in commercial quantities and that the habitat in which they were found would allow a sustainable and viable collection;
3. to make note of other fish species of interest, available in sufficient numbers to support sustainable and viable collection; and
4. to record clam and coral colours that would make for potential interesting broodstock were mariculture activities to be developed.

The majority of surveys were conducted over eight days by three or four individuals, SCUBA diving on the outer reef slope at depths between 10 m and 40 m at locations all around the island of Upolu (Fig. 3). A few surveys were also conducted in shallower waters (5 m and less), diving and/or snorkelling.

Over the course of the surveys, we did not record a single flame angelfish. Similarly, while *Pocillopora* heads, the typical habitat for red hawks, were abundant at over 50% of the sites surveyed, we recorded only a total of two red hawks. Interestingly, and of note, is that both fish were the completely red morph and had no black stripe, while red hawks in Fiji and French Polynesia present a distinct black bar on the upper body, just below the dorsal fin and typically extending above the eye.

In general, we found leopard wrasse (*Macropharyngodon meleagris*) to be the single most consistently spotted and abundant fish around Upolu. A few areas had collectible quantities of angelfish species other than flames, such as threespot angelfish (*Apolemichthys trimaculatus*), lemonpeel (*Centropyge flavissimus*), Herald's angelfish (*Centropyge heraldi* with a black dorsal), regal angelfish (*Pygoplites diacanthus*), as well as Scott's wrasse, (*Cirrhilabrus scottorum*) and Walsh's wrasse (*Cirrhilabrus walshi*). However, such areas were generally small in size.

Figure 1. Centropyge loricula, *the flame angelfish, is considered to be one of the most colourful and attractive of the angelfish species commonly found in the marine aquarium trade. (Image: Andreas März)*

Figure 2. A red hawkfish, Neocirrhites armatus, *perched in a* Pocillopora *coral head. This is the typical colour morph, displaying the black band at the top of the body. The two fish spotted in Upolu lacked this distinctive bar. (Image: Brian Gratwicke)*

[1] The surveys were made possible in part by industry

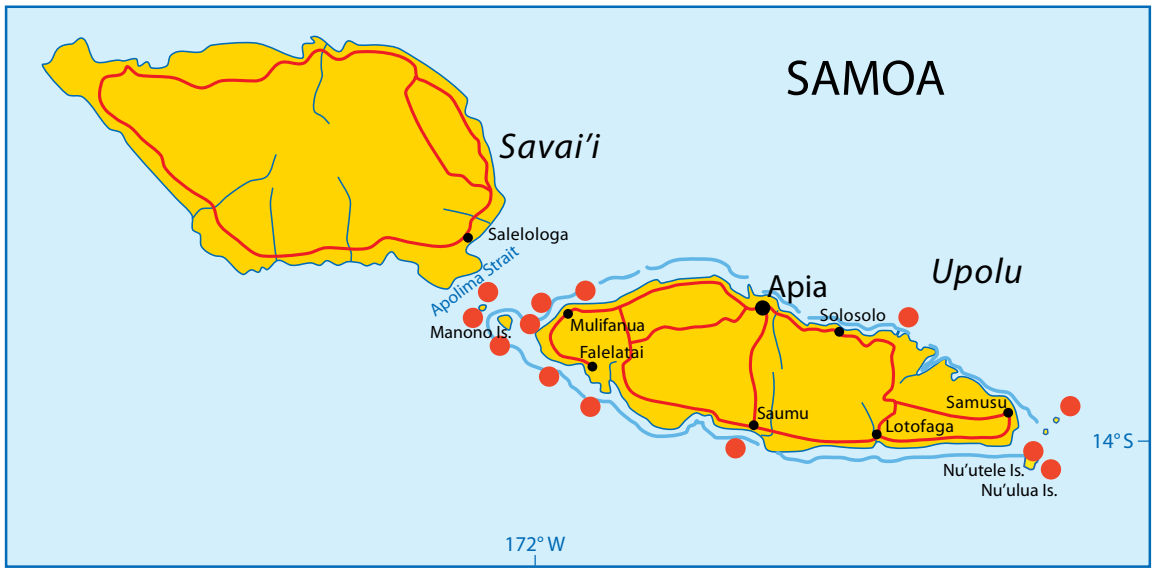

Figure 3. Upolu Island, Samoa. Red circles represent dive locations.

The islands off the extreme east (Fanuatapu, Manua, Nu'ulua) and west (Apolima) of Upolu had good numbers of interesting fish, such as a few species belonging to the *Cirrhilabrus* genus and blackfin *C. heraldi*. However, these islands would not support the regular sustainable and viable collection of fish, given that suitable habitat around these islands is limited, and that weather and ocean conditions limit visiting opportunities. Other species of interest included whitecheek tang (*Acanthurus nigricans*) and mimic tang (*Acanthurus pyroferus*), with only a few individuals recorded in a size suitable for the aquarium trade.

The presence of flame angelfish (and red hawk) in abundances that would allow their sustainable long-term collection was critical to the development of an economically viable industry in Samoa. The findings of the survey do not support the assertion that a sustainable and/or viable industry can be developed on the island.

Clams

We came across only a few attractive clams per dive, primarily in shades of green and blue. The main species on the reef are *Tridacna squamosa*, *T. maxima* and *T. noae*.

Corals

Overall coral diversity around Samoa is low, and of the species present, few were found to be of particular interest to the aquarium industry, in terms of variety and/or colour.

The main observation was that a significant and widespread bleaching event affecting the majority of coral species, but particularly *Acropora,* was under way around Upolu. Compounding the destructive impact of the bleaching, there was also an ongoing extensive crown-of-thorns outbreak. Of particular note is the reef at the island of Nu'ula in the southeast (Fig. 4). It hosts significantly greater diversity than other locations, both in terms of corals and fish; it benefits from cooler temperatures and is subjected to stronger currents; and, at the time of the surveys, only a few individual corals appeared bleached. Unfortunately, the adjacent island of Nu'utele was observed to be suffering from a mass bleaching/mortality (Fig. 5) event and crown-of-thorns outbreak.

In response to these observations, the Department of Environment, the Fisheries Division and Conservation International, with financial support provided by the German Agency for International Cooperation, GIZ, jointly sent out a response team to monitor the extent of the damage and control the crown-of-thorns outbreak through the use of biosalt injections. Crown-of-thorns were also removed physically with the support of community members from 33 selected village reefs and lagoons.[2]

[2] See the article on page 24 of this newsletter.

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Figure 4. Reef at Nu'ula island, where water temperatures were up to 2 degrees cooler than at other sites around Upolu Island at comparable depths. While Acropora species were still found to be dominant on the reef, diversity was generally much greater than at other locations and fish life more abundant. (Image: Colette Wabnitz)

Figure 5. Mass bleaching event observed at Nu'utele Island. The image on the left shows Acropora colonies in the process of bleaching (in about 7 m of water or less), while the image on the right shows dead colonies (from about 7 m to deeper water), with structures intact covered in algae and essentially devoid of fish life. (Images: Colette Wabnitz)

A review of coastal fisheries in Fiji

In late 2014, a review of coastal fisheries in Fiji was carried out by three senior fisheries specialists with substantial work experience in Fiji and overseas. A summary of the report of that review[1] is given here. The results of the study were reviewed and endorsed by a workshop of senior Fisheries Department staff on 19 November 2014 and further discussed during a workshop of senior Fisheries Department staff on 18–19 March 2015.

The March 2019 workshop that discussed coastal fisheries management in Fiji: the Minister for Fisheries, senior staff of the Fisheries Department, and the authors of the review of coastal fisheries in Fiji (Image: Bob Gillett)

This study reviews the status and management of coastal fisheries in Fiji, with the objective of providing suggestions to enhance the Fisheries Department's performance to a level similar to their accomplishments in offshore fisheries. Information on Fiji's key coastal fisheries resources was reviewed, including estimates of production, current status, financial and other benefits, and the likely challenges to be faced in the future. The structure and role of the Fisheries Department in coastal fisheries management was examined. Links with NGOs and other agencies who are also active in this area, and the degree to which their activities link with those of the Department, were discussed. Based on this review, the study draws out the major governance issues associated with the management of coastal fisheries that need to be addressed to enhance the performance of the Fisheries Department in coastal fisheries.

The main points of the review are:

Limited information on coastal fisheries

Fiji has a wide range of coastal fishery resources, including finfish, invertebrates and plants. Estimating coastal fisheries production and the status of these resources, at a level that is useful for informing or monitoring management effectiveness, is a complex, expensive and challenging process. The statistical system that is used to provide coastal fisheries data in Fiji is no longer functional, primarily due to the prioritisation of scarce government resources. This has resulted in a shortfall of fisheries information, such that the success (or otherwise) of management is hard to determine. This also contributes to the inadequate recognition of the economic and social value of coastal fisheries.

Fully exploited with limited potential for expansion

The limited information available suggests that the finfish and invertebrates in many areas of Fiji, in common with many other reef fisheries in the Pacific, are overexploited. It is therefore unlikely that coastal fisheries production can increase markedly, creating a potential clash with those that favour the development of infrastructure for fisheries to stimulate economic growth. The key challenge is to maintain and, where possible, increase, the large existing benefits from coastal fisheries.

[1] Gillett, R., Lewis A. and Cartwright I. 2014. Coastal fisheries in Fiji: Resources, issues, and enhancement of the role of the Fisheries Department. 60 pages. The full report is available at www.gillettprestonassociates.com

Importance of coastal fisheries

There is no doubt that coastal fisheries production brings extensive benefits to Fijian communities, including employment and nourishment. The direct contribution of coastal commercial and subsistence fishing to the GDP of Fiji is about FJD 73 million, almost eight times greater than that from offshore fishing) with around 27,000 tonnes of fish produced. Export data are questionable but suggest that coastal fishery exports in 2007 and 2008 were FJD 25 million and FJD 46 million respectively. There is also a range of benefits that is difficult to quantify; they include social and recreational values.

Future challenges to coastal fisheries

While there are considerable challenges facing coastal fisheries today, the future is likely to add more pressure, which will provide additional threats. Current trends of over-exploitation and habitat degradation provide some insight into what the future holds unless action is taken. Increases in population and urbanisation are likely to lead to the following situations, which, in turn, have the potential to dramatically reduce the substantial benefits from coastal fisheries.

- ✓ Coastal fisheries accessible to urban residents will probably decline through over-exploitation and habitat destruction.
- ✓ Expanding urban populations fishing intensively will increase levels of overfishing close to those populations.
- ✓ A growing proportion of the urban population will not be able to catch sufficient fish to provide for household consumption.
- ✓ The above points will contribute to more expensive fish and the incentive for members of poorer households to go fishing and exacerbate the problem.

Focus of the Fisheries Department

Around 280 staff work in the Fisheries Department, 57 of whom are dedicated to offshore fisheries. Staff responsible for coastal fisheries management are spread across the most of the six technical divisions and four geographical areas of Fiji. While the department is deeply involved in coastal fisheries management, the focus and nature of this work is not directed to achieve specific management outcomes. The department focuses significantly more attention on offshore fisheries than coastal fisheries, the former having a dedicated management division, which has ensured adequate attention to key priorities.

Management vs. development

Appropriately, the early focus of the Fisheries Department was on increasing production of coastal fisheries and surveys of new resources. Over time, there has been a growing recognition among stakeholders and the Fisheries Department that the over-exploitation of coastal resources is the major threat to fisheries in Fiji. Despite this, there continues to be emphasis on increasing production through direct assistance and subsidies to the fishing industry to encourage more fishing to meet demand. Ironically, in the long term and without adequate management in place, this assistance is likely to result in less rather than more fisheries production.

NGOs and FLMMA

More than 20 NGOs and other agencies are significantly involved in coastal fisheries, with a focus on conserving fisheries resources. They include the Fiji Locally-Managed Marine Area Network (FLMMA), which has been recognised as very effective. The network encourages coordination among agencies that work with communities to better manage traditional fishing grounds, using a well-established and documented process. These NGO activities, while not well coordinated nor necessarily aligned with government priorities, have gradually assumed a number of government-type functions. While there is a strong case for the Fisheries Department to take on some of the FLMMA/NGO roles, there is also a need for NGOs and donors to accept and assist such a transition. The recent establishment of conservation officers within the i-Taukei Affairs Board does not appear well coordinated with the Fisheries Department.

Improving governance

This report suggests a number challenges that need to be addressed by the Fisheries Department if it is to be more effective in management and ensure that the benefits of coastal fisheries are not further eroded. Currently, the department addresses the major issues by default rather than design, and a new approach is needed.

[1] FJD1.00 = USD 0.49 (May 2015)

Dealing with over-exploitation

Few department staff appear dedicated to dealing with over-fishing, mostly due to a continuing focus on development and increasing production. Distractions such as reef ranching and alternative activities such as continuing experimental aquaculture are unlikely to be effective in addressing over-exploitation.

Declining capacity

Key elements of Fiji's coastal fisheries management services have degenerated over the years. They include: fisheries statistics, enforcement of coastal fisheries regulations, effective management tools, formulation/implementation and updating of management plans, and consultation with stakeholders.

Addressing the management / development balance

Currently there is no lack of high-level directives that focus on urgent actions to improve the management of coastal fisheries. There is, however, no national policy or plan that lays out a clear pathway to implement these high-level directives at different levels or re-focus the work of the department.

Improving resource knowledge

To address gaps, it will first be necessary to determine the additional information required for achieving management objectives and reconciling those needs with the current programme of marine resource inventories. Updating the existing resource profiles with more recent information might serve as a catalyst for such prioritisation.

Consolidating services

One reason for the strength of offshore fisheries management is the fact that it is managed by a dedicated division within the department. Given that coastal fisheries produce far more food and jobs, as well as a greater contribution to GDP, it seems logical to create a division for coastal fisheries. Such a division would focus, consolidate and coordinate the supply of fisheries management services to that sector. It would also provide the impetus for achieving adequate funding and staff. An appropriate level of decentralisation of the new division to the provinces will need to be determined.

Improving communication

Stakeholders have reported that there is very limited interaction between departmental staff, NGOs and coastal fishers/communities. There are many ideas for improvement of the current arrangements and increased communication would have multiple benefits.

Other actions

Fisheries legislation has not kept pace with the changing requirements of coastal fisheries, particularly community-based approaches for fisheries management. A review, update and revitalisation of regulations and their enforcement would be an important action to underpin improved coastal fisheries management.

Fiji is not unique in its challenges regarding coastal fisheries; advantage should be taken of the many good examples of successful re-orientation to coastal fisheries management that took place in other countries facing similar challenges.

Fundamental change required

Simply creating a new division in the Fisheries Department will be insufficient to meet current and future challenges. Two fundamental changes must also occur:

- ✓ Acceptance by senior government leaders that: (i) landings from coastal fisheries are approaching their limits in all but the most isolated areas, and (ii) urgent management action is required to safeguard existing production. Where stocks are heavily depleted, reduced fishing may well increase production.
- ✓ Fisheries staff must be committed to the suggested new, more focused, approach to coastal fisheries management. This will not be easy, given the decades of efforts to increase and subsidise production through development initiatives.

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Educational Managed Marine Areas (EMMAs) in French Polynesia

What is an educational managed marine area?

An educational managed marine area (EMMA) is a coastal area that is managed in a participatory manner by a school or group of school children.

When a school sets up an EMMA, it is making an ongoing, long-term commitment. The children interact with government authorities, scientists and users to manage their EMMA. They can suggest rules for their EMMA, such as minimum shellfish sizes or mooring bans in certain areas. If the rules are adopted, they are not legally binding, but users generally comply because they are proposed by children in settlements where everybody knows each other. Also, EMMAs are located in relatively small, well-defined areas measuring 4 to 45 hectares.

This participatory management approach involving school children in a civic action is designed to allow them to study and manage their marine environment.

A concept is born

The EMMA concept was first launched in 2013 in the Marquesas Islands of French Polynesia by Vaitahu Primary School on Tahuata Island; the Marquesan cultural and environmental federation, Motu Haka; the Marine Protected Areas Agency, with support from the Government of French Polynesia; the Marquesan municipal council alliance (CODIM); and the Government of France. It was initiated after the massive 2012 oceanography campaign in the island group: *Pakaihi i te moana* (Respect the ocean). The campaign included a school awareness component on the Marquesas' rich marine biodiversity. Inspired by the campaign, the children said that they wished to take charge of their own marine protected area in the bay opposite their school.

The Government of French Polynesia and its partners then sought ways of organising this type of approach and offering it to all schools in the country, and even the region, that were willing to adopt it. They set up criteria for a quality label to reward schools that wished to involve their students in developing a marine study and management project.

A pilot programme dubbed *Pukatai* – coral in Marquesan – was launched in the Marquesas in 2014 to test the label criteria methodology after the government and its partners won a 2013 French Coral Reef Initiative (IFRECOR) tender awarded to innovative marine protected area initiatives.

The educational managed marine area concept was presented at three international workshops: the 2013 International Marine Protected Areas Congress, the Sydney

Children in front of their EMMA at Vaitahu, Tahuata, Marquesas Islands (Image: Pascal Erhel)

Children learning to carry out an environmental assessment in the Hanaiapa EMMA, Hiva Oa, Marquesas Islands (Images: Créocéan)

2014 World Parks Congress, and the 2014 Fiji UNESCO Pacific Workshop. It was a great success, particularly with regard to its deployment and sister projects in the Pacific region.

A philosophy

The EMMA label is in the process of gaining legal protection to ensure that its philosophy is upheld. Linked to the school curriculum, the EMMA philosophy is based on the teaching objectives: knowing, experiencing and talking about the sea – in French and Polynesian languages. Three pillars support the philosophy:

1) *A knowledge pillar: Knowing the sea*

   The EMMA project must assist students in improving their knowledge of their marine environment and maritime culture.

2) *A practical pillar: Experiencing the sea*

   The objective is to teach the children in practical ways to become knowledge bearers and marine professionals (fishers, scientists and craftspeople, etc.); and

3) *A management pillar: Talking about the sea*

   Activities involving knowledge transfer and sharing with seafarers will lead the students to select specific activities to manage their EMMAs.

Pukatai pilot network of six educational managed marine areas soon to be extended to other French Polynesian islands

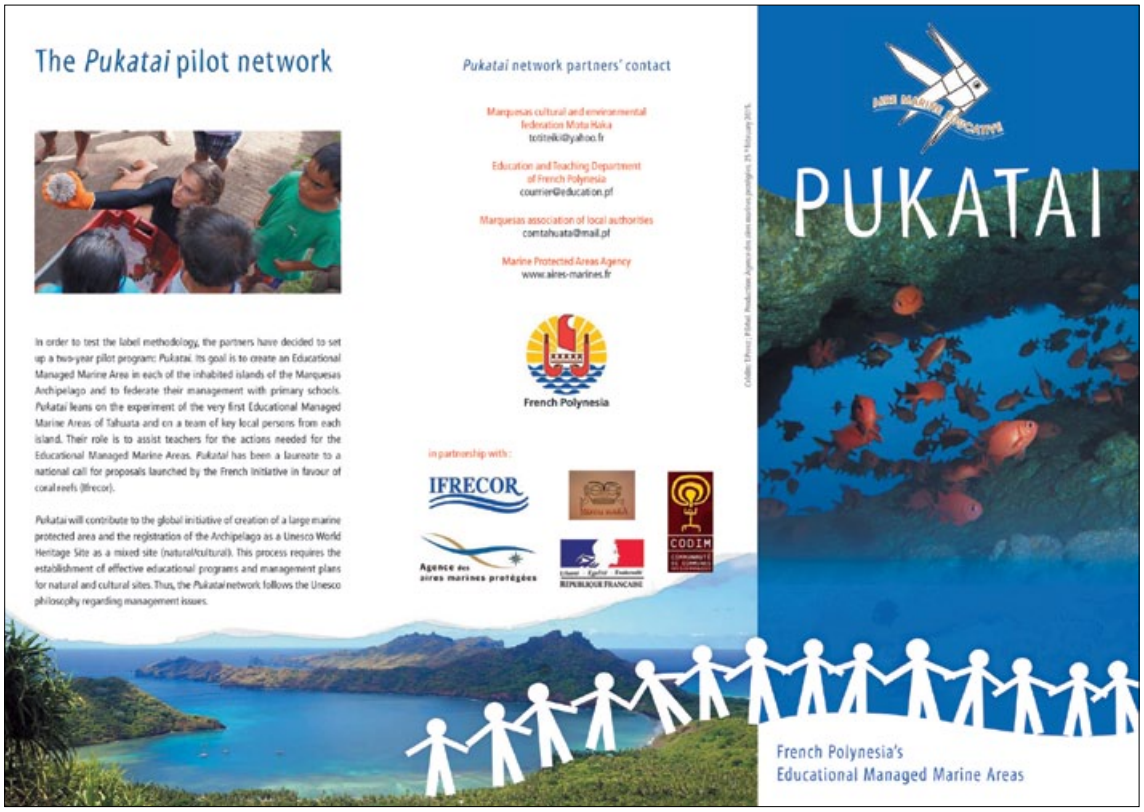
The 12 Marquesas Islands, six of which are inhabited, are located in northern French Polynesia. The *Pukatai* pilot network is designed to create six educational managed marine areas, i.e. one for each inhabited island, and to encourage their joint management.

Pukatai is based on a participatory approach involving civil society and is a one of the public policies developed by the Government of French Polynesia and the Marquesan Municipal Council Alliance. It is important to note that an application is pending to include the Marquesas Islands on the UNESCO World Heritage list and that process requires appropriate educational programmes and management plans for natural and cultural sites. The EMMA network, therefore, follows the management philosophy of UNESCO-supported properties.

Today, 120 children aged 6 to 12 years on six Marquesan islands are involved with their schools in setting up their EMMAs in Vaitahu, Hanaui, Hakahetau, Hanaiapa, Anaho and Hane bays. Other schools in French Polynesia also wish to set up EMMAs early in the 2015–2016 academic year on Tahiti (Mahina and Punaauia) and in the Tuamotu and Austral Islands. Further afield, though still in Polynesia, schools on Rapa Nui also wish to join the network.

Recent events in the Marquesan EMMAs in French Polynesia

Ua Pou Island EMMA project submitted: In March 2015, the children involved in the Ua Pou Island EMMA submitted their project to the municipal council. This involved zoning and other activities.



Flyers were published in English and French to promote French Polynesia's EMMA concept.

Arago visits organised: *Arago*, a French naval public-service patrol boat, is working with the six Marquesan EMMAs. In late April, it conducted a tour that allowed its crew to interact with the 120 school children involved in the six Marquesan EMMAs. When the Arago made port calls, the students were allowed on board for a few hours to visit and learn more about the ship, observe a few seafaring trades, conduct theoretical and practical marine environment activities, and go out to view their EMMA from the sea.

Environmental status of the southern Marquesan educational marine managed areas. The EMMA philosophy involves starting a new family of marine protected areas which require in-depth knowledge of the marine environment. An initial environmental assessment was, therefore, conducted[1] for all six EMMAs. The environmental status of the habitats and species was determined and, more importantly, a methodology developed for teaching the children scientific observation techniques for the marine environment. They took part in transects and other scientific work in the coastal area.

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[1] Carried out by Créocéan consultancy firm

The World Wide Fund for Nature launches a new shark conservation initiative

It is widely accepted that, on a global scale, sharks and rays are facing some significant threats to their populations. In 2014, a study led by the Shark Specialist Group of the International Union for Conservation of Nature (IUCN)[1] assessed over a thousand elasmobranch species, concluding that nearly a quarter of all species are threatened with extinction and that almost half of all species are classed as 'data deficient'. The study identified overfishing and habitat loss as the two major threats facing sharks and rays, and these are compounded by an absence of information on populations of sharks and rays within each Pacific nation's territorial waters. The Pacific region is not immune to these problems. A lack of capacity within fisheries and environment ministries, coupled with the geographic isolation of some fishing communities, means that most nations are unable to put resources towards collecting and analysing data on sharks in order to make informed decisions on their management. This has knock-on implications for designing effective conservation policies suitable for an individual country's needs.

The World Wide Fund for Nature (WWF) recognises these limitations, and is developing a rapid assessment tool-kit that can be used to collect and analyse data on sharks and rays from a wide variety of sources. On 8 April this year, Brad Moore from the Secretariat of the Pacific Community (SPC) attended the inaugural workshop to assist with the design of this project, and to ensure it complements existing SPC initiatives. The workshop was facilitated by WWF, and attended by shark and fishery experts from the Forum Fisheries Agency (FFA), the Secretariat of the Pacific Regional Environment Programme, the IUCN Shark Specialist Group, James Cook University, the Australian Institute of Marine Science, the Commonwealth Scientific and Industrial Research Organisation, and the University of the South Pacific. Expertise ranged from shark ecology to coastal fisheries to policy development. The three-day workshop also explored different areas where shark and ray data can be acquired and analysed.

The rapid assessment tool-kit is one part of WWF's broader Pacific Shark Heritage Programme, which aims to reinforce the cultural significance that sharks and rays play in the heritage of the South Pacific. WWF understands the importance of sharks to the region, and it is not just about shark fisheries. Coastal species of sharks play a vital role in keeping the oceans healthy. Recent scientific research from Canada[2] indicates that a loss of sharks from reefs could have a knock-on effect on other fish such as snappers and groupers, fish that many coastal communities use on a daily basis for food.

Sharks and rays are also a major draw for many tourists bound for the South Pacific. Almost every dive operator will tell you that when it comes to getting dive tourists excited, it is sharks and large mantas that do the trick. From small reef sharks to larger predators, every sighting is another endorsement for the region as a mecca for divers. And with each tourist come the tourist dollars, helping support local businesses and economies. In Fiji, the world-renowned Beqa lagoon shark dive draws people from around the world to see large bull sharks and other species swimming on healthy reefs, with money going direct to local communities. There are also a number of unique shark-focused projects throughout the region, allowing volunteers to contribute to the understanding of these animals.

The primary objective of the rapid assessment tool-kit is to provide the governments of Pacific Island states with some rudimentary data on sharks and rays within their territorial waters, so that they can make informed policy decisions about sustainable management of these creatures. Each country in the Pacific is unique, with different requirements and there is no silver bullet to put a stop to the unsustainable harvesting of sharks and rays overnight. But once the project is under way, one of the immediate benefits will be alleviating the burden on over-stretched ministries and fisheries managers, with a longer-term goal of increasing the capacity of the region's institutions to provide informed conservation advice.

The inception phase of the project sought advice from some of the world's leading researchers in the fields of shark ecology, genetics, data poor fisheries, eco-tourism and policy development to design innovative data sampling strategies that will provide sufficient information for a country to undertake a shark assessment report. This is a set of guidelines recommended by the FAO to help countries understand the current issues facing sharks and rays within their jurisdiction. The next phase for the project is to explore how the relevant ministries can use the tool-kit to develop their conservation

[1] Dulvy, N.K. et al. 2014. Extinction risk and conservation of the world's sharks and rays. eLife 2014;3:e00590

[2] Ruppert J.L.W., Travers M.J., Smith L.L., Fortin M.-J., Meekan M.G. 2013. Caught in the middle: combined impacts of shark removal and coral loss on the fish communities of coral reefs. PLoS ONE 8(9); e74648. Doi;10,1371/journal.pone.0074648

Even small reef sharks, such as these whitetip reef sharks, are what many tourist divers hope to see when they visit Pacific islands. (Image: Sam Cahir)

strategies. Developing the shark assessment report is the first step to drafting national plans of action for sharks. If the reports are produced on a regular basis, they can be used to determine how effective existing policies are at reducing shark mortality, and they can then be refined or re-drafted.

The rapid assessment tool-kit is also aiming to avoid re-inventing the wheel or duplicating existing work in other organisations. SPC is already working on producing an excellent market-based survey for use in coastal fisheries, and the WWF project should be able to provide information on sharks and rays to complement that work. Similarly, FFA is assisting countries to develop sustainable fisheries policies, and the WWF project should be able to provide more information towards this initiative.

Collaboration will be the key to the success of this project, whether that is with regional academic institutions, CROP agencies or government ministries. It is not WWF's goal to try to impose set shark conservation strategies upon countries, but to effectively reduce the mortality of threatened shark and ray species. It is only with sustainable populations of sharks and rays that a country will be able to develop long-term strategies for fisheries or shark-based eco-tourism, which will form the foundation for economic growth and food security for Pacific Island communities.

WWF has offices throughout the Pacific, and is currently seeking to work with countries that are keen to develop long-term, sustainable policies for sharks and rays, and with countries that want to evaluate and refine their existing shark conservation policies.

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Using body language to measure your fish

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Marine animals – clams, crabs, fish, sea cucumbers, shrimps and turtles – all have to reach a certain size, different for each species, before they can spawn. It is important to leave them in the sea until they have reached that size and have therefore spawned at least once before catching them. Otherwise, there will be fewer parents for the next generation and eventually no more will be left. We also know that in fish species that grow to a large size, such as some groupers, parrotfish and trevallies, the biggest fish are the main producers of eggs and so they, too, should be protected.

Fisheries officers put up notices and posters showing the minimum and maximum sizes for capture in markets and other public places. But these are often a long way from the fisher on the beach or in a boat, and by the time the catch reaches the market – if it goes to the market at all – the animals, other than turtles, are probably all dead.

Most fishers across the Pacific sell their catch at a market or take it home and, with populations getting bigger, it is ever more important to follow the rules on the size of capture to avoid depleting the fisheries. Stiff penalties are sometimes handed out to those who break the rules. The problem is, how to remember all those smallest and largest sizes and apply them when you are far from the market? Here are some suggestions, with diagrams to illustrate them.

Use your fingers

Middle fingers are usually 80–90 mm long. In some places, 80 mm is the smallest allowable length of a pony-fish and the head of a lobster, and the smallest allowable width of a trochus shell and coconut crab carapace.

Use your hands

Measure the length of your hand. Most adult hands are 180–200 mm long. In some areas, the smallest allowable capture length for many reef fish and for giant clams is, coincidentally, 180–200 mm. To be sure those you have caught are legal, throw back any that are not a little longer than your hand.

You can also use the length of your hand palm plus the first joint of your middle finger. It is usually around 130–140 mm, which is the minimum size recommended for mud crab carapace width in several countries.

For those large-growing fish, some have smallest capture lengths of 300–400 mm, which is a little more than 1½–2 hands. The longest size for such fish may be 400–600 mm, which is 2–3 hands long, if your hand is 200 mm long.

Use your feet

Measure your foot from the back of your ankle. It is probably 250-mm long or more. This represents, in some places, the shortest length for some species of emperors, snappers and squirrelfish that it is legal to catch.

Use your arms and legs

Hawksbill turtles, where they are allowed to be caught, may have a smallest length for capture of 700 mm, roughly the length of your arm from the top of the shoulder. For a green turtle it is 850 mm, the average length of the inner side of your leg.

Use your boat

A few notches in the gunwale of a canoe can become a handy ruler for the main kinds of fish you are targeting. A little paint or permanent marker pen can do a similar job on an aluminium boat.

Use your head

When in doubt, compare a less common species with one of the common ones for which smallest and largest sizes are provided, rather than assuming there is no legal size range because it is not shown in a poster in the market.

Use your eyes

Remembering and applying all those lengths is still a chore and ignorance of the law is no excuse. One way to help remember which sizes belong to which fish is to make a simple drawing on A4- or letter-sized paper of a person's body and write beside it which marine animals have minimum (and maximum) lengths that correspond to the different parts of the body.

Use your mouth

A nice way to help remember the rules is to write a rhyme/song for each body part-fish type combination on the drawing. A trivial English example might be: A trochus must be longer than a finger, so we don't catch a fine from the fisheries inspector. A song (and dance?) could be composed – in your own language – to include all the common rules. Why not have a competition to find the best song?

Finally, in deciding on what approximation to use in all these memory aids, the smallest size recommended or prescribed by scientists need not be followed exactly by fisheries officers, as long as the approximation is conservative. In other words, it can be longer but not shorter than the length of first spawning. In any case, this length is not precise to the millimetre but has a range within and among fish populations. Thus, to keep the number of different sizes to a minimum for ease of remembering, fish with smallest given capture sizes of 180 and 200 mm could be combined as 200 mm and so on.

All this information can fit on a single A4- or letter-sized page. Detailed lengths could be added on the reverse side of the page. Many copies can be made cheaply with a photocopier for wide distribution. In fact, the illustration featured below can also be printed, photocopied and widely distributed. If these sheets can be laminated, they will be durable enough to be tacked to a wall or stored in a boat.

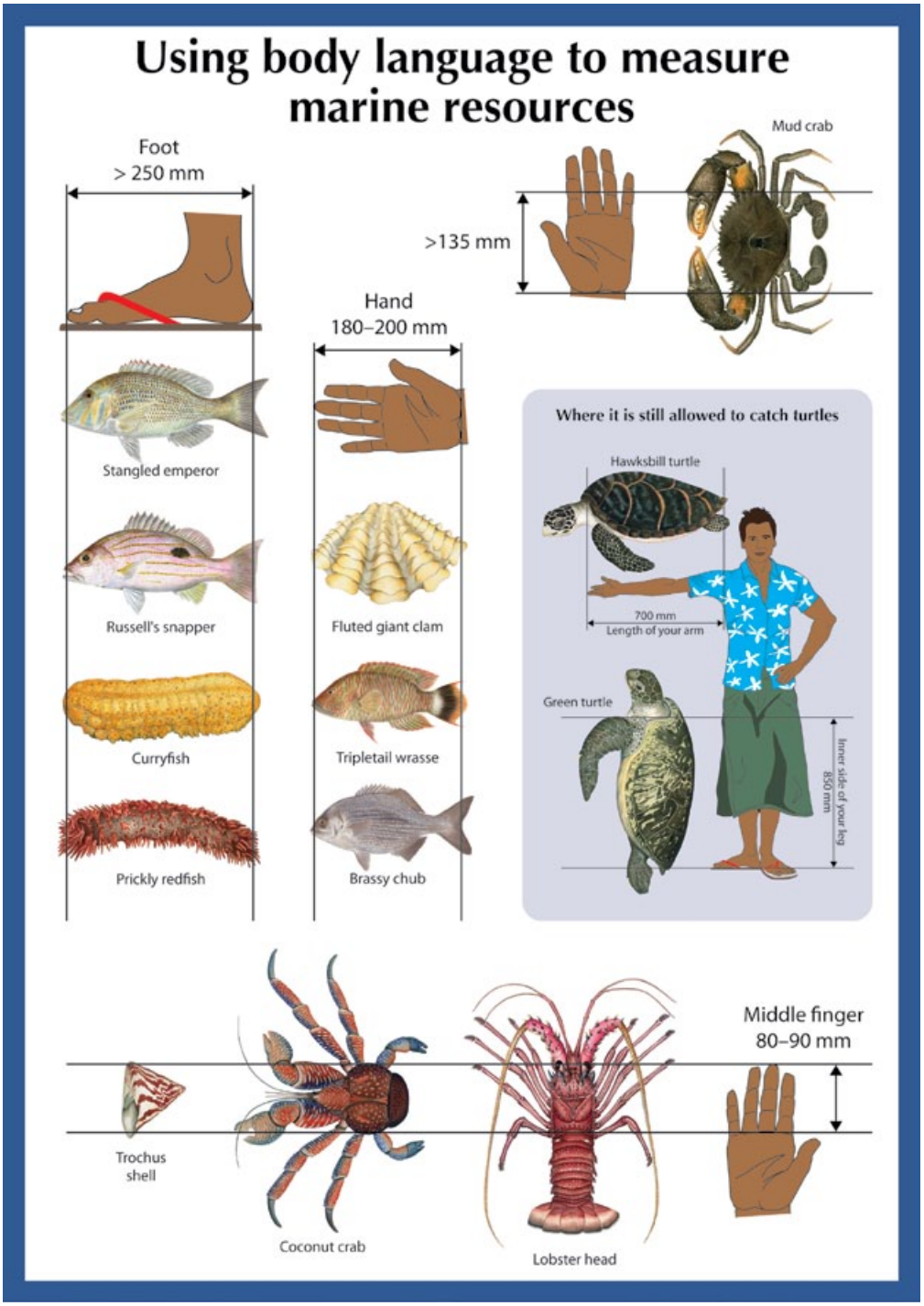

Illustration: Boris Colas, SPC

Samoa's crown-of-thorns clean-up campaign

Source: Adapted from a media release issued by the Samoa Ministry of Agriculture and Fisheries, 27 April 2015.

With technical and funding assistance from the Secretariat of the Pacific Community and the German Government, the Samoa Fisheries Division of the Ministry of Agriculture and Fisheries joined forces with village fisheries management committees to implement a crown-of-thorns – or *alamea* as it is named locally – clean-up campaign.

The clean-up was carried out as one of the major activities of the SPC/GIZ Coping with Climate Change in the Pacific Island Region (CCCPIR) Programme. The programme addresses and focuses on five important development sectors in the Pacific Island region, namely: land use (agriculture, forestry and land-use planning), fisheries, education, energy and tourism. The SPC/GIZ CCCPIR project supports Pacific Island countries' efforts to increase their resilience and capacity to adapt to the effects of climate change.

Alamea is a large, nocturnal, corallivore starfish, a carnivorous predator that preys on reef coral polyps. Scientific studies have revealed that each *alamea* can consume up to six square metres of living coral reef per year. *Alamea* consumes the microscopic animals that make food for the corals. As a consequence, the coral dies and turns whitish (bleaches) in a week. The *alamea* has been reported responsible for massive coral bleaching in popular coral reef systems, such as the Great Barrier Reef in Australia.

The Samoa campaign began on Upolu, in the Falelatai District. From 23–27 March, the seven villages of Sama'ilaualo, Falevai, Matanofo, Matautu, Siufaga, Pata and Samatau were covered. From 7–14 April they worked in Falealili District, covering the eleven villages of Matatufu, Sapo'e, Salani, Salesatele, Sapunaoa, Satalo, Malaemalu, Tafatafa, Matavai, Matautu and Saleilua.

The campaign then moved to the island of Savaii. From 19–24 April, the six villages of Asau, Auala, Vaisala, Fagasa, Sataua and Papa in the Asau District were covered. From 4–8 May, the campaign covered the subvillages of Siufaga, Malae, Sapini, Luua and Salimu in the village of Faga.

So far, the campaign has removed over 5,000 juvenile, sub-adult and adult *alamea*, indicating a crown-of-thorns outbreak was taking place in the lagoons and reefs of Samoa. Removal of *alamea* from the reefs minimises the impacts of natural stressors on the marine environment and important habitats.

The campaign also strengthened the partnership with local communities participating in the community-based fisheries management programme. The programme is encouraging the management of fisheries and the marine environment by village communities as resource owners and users, with the Samoa Fisheries Division and partners providing technical and supporting services. Members of the village fisheries management committees from all villages and districts were also on site to spearhead the campaign in their respective villages.

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April 2015 crown-of-thorns collection campaign at Itu-Asau District: Fisheries staff with Vaisala Village Fisheries Management and Advisory Committee representatives...

... and part of their catch

(Images: Etuati Ropeti)

Nearshore fish aggregating devices for food security in Solomon Islands[1]

Background

Coastal fisheries are central to the lives of rural Solomon Island villagers, supplying daily food and serving as one of the few sources of income. Yet, it is predicted that coastal fisheries in Solomon Islands, as in many countries in the Pacific region, will not be able to provide enough fish to meet peoples' needs by 2030. Given that there will be localised differences across the country, this assessment implies that some communities will face hardship from declining reef fish supply over the next few decades. Proposed strategies to prevent this scenario include improving the management of coastal fisheries and diversifying the sources of fish by enhancing access to other fish, either through aquaculture or the use of fish aggregating devices.

Fish aggregating devices, known as FADs or 'rafters', are fishing devices that concentrate pelagic fish (e.g. tuna) in one location to make them easier to catch. Nearshore FADs (sometime referred to as inshore FADs) are anchored to the sea floor, close to the coast, to allow fishers from coastal communities to access them, including by paddle canoe.

Solomon Islands was among the first countries in the Pacific region to adopt offshore FADs in the industrial fishing sector, yet nearshore FADs remain a relatively new intervention for most coastal communities. To enable a strong case to be made by Solomon Island communities or by provincial and national governments for recurrent budgets to support long-term nearshore FAD programmes, we need to better understand nearshore FAD effectiveness from both a catch-efficiency and a social perspective.

A strategic priority of the Solomon Islands Ministry of Fisheries and Marine Resources (MFMR) is to improve the health of inshore fisheries and marine resources to support the nation's rural communities. The Mekem Strong Solomon Island Fisheries programme funded by New Zealand is part of this effort. It has provided funding to WorldFish to work in partnership with MFMR to develop a Solomon Island National Inshore FAD programme (2010–2013). Through a larger collaboration of MFMR, the Secretariat of the Pacific Community, the University of Queensland and WorldFish, 21 nearshore FADs, using four different FAD designs, were deployed at various locations across Solomon Islands in order to assess the designs and evaluate the FADs' contribution to food security. For this purpose, fish catch rates (at FAD and non-FAD fishing areas) and socio-economic data were collected in locations where FADs were deployed. This programme brief draws on data collected from four of the FAD locations, where FADs were in the water long enough (i.e. three months) to allow adequate data collection.

Towing the FAD raft out to sea, Langalanga, Solomon Islands (Image: G. Orirana, WorldFish)

[1] This paper was originally published as:
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Attributes of a sustainable national FAD programme in Solomon Islands

This research has provided evidence that nearshore FADs can increase access to fish by coastal fishers and can play a role in future food security for coastal Solomon Island communities. Key attributes of a sustainable national nearshore FAD programme for Solomon Islands identified through this research are outlined below.

Consider site-specific FAD designs to improve longevity

The length of time that FADs last in the water is one of the greatest risks to the viability of a long-term national FAD programme. Twenty-one FADs (testing three designs) were deployed between March 2011 and October 2012 at 13 locations across Solomon Islands. Longevity ranged from 6 days to 3.5 years (six of the 21 FADs were still in the water as of June 2014). Three main factors were found to influence longevity: vandalism, rough seas and technical design. Understanding the reasons for loss has provided us with a number of lessons for future nearshore FAD programmes.

Three important characteristics have been used to recommend nearshore FAD designs for Solomon Islands: ability to deal with rough seas; low cost; and accounting for high canoe traffic. (Table 1 and Figure 1).

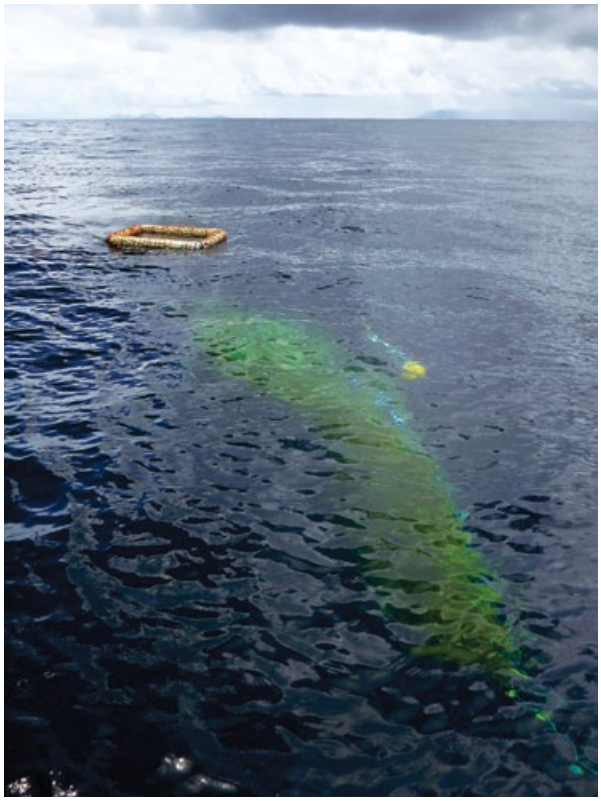
Subsurface FADs are becoming increasingly popular in the Pacific region, due to the reduced opportunity for sabotage and less wear and tear from wave action. To date, only two nearshore subsurface FADs have been deployed in Solomon Islands, and their efficacy and degree of fisher acceptance remain under research. Early results suggest that subsurface FADs require a surface buoy (as a visual marker for fishers) and surface attractants (e.g. coconut leaves) to increase fish aggregation potential.

Subsurface FADs are more difficult to deploy than surface FADs as the anchor system is heavier and more difficult to handle, and accurate deployment locations are required (to ensure that the floatation device remains at 20 m under the water surface). Care must be taken to ensure accurate rope length calculations (accounting for rope stretch) are carried out and sufficient anchor weight is used to counterbalance the floatation device so that it remains stationary on the sea floor.

Use local fishers knowledge to optimise FAD location

Establishing criteria for the distance to deploy nearshore FADs from shore and appropriate distances between FADs is difficult, as information from Solomon Islands and the wider Pacific is sparse and largely dependent on

Surface FAD (Image: Simon Albert)



Subsurface FAD (Image: Joelle Albert)

Table 1. Recommended nearshore FAD designs for the three selected characteristics (rough seas/strong current, low cost and high local canoe traffic).

		Characteristics		
		Rough sea/strong current	**Low cost**	**High canoe traffic**
FAD design	**Poly*/nylon rope**	4 pressure and 13 purse seine floats with 18–20 mm combined poly/nylon rope. Combined anchor (2 x ½ cement drum/ engine block with grapnel) with 2 x 2-eye pressure float above anchor. Use Samson rope connectors for additional strength and plastic strapping for longer lasting attractants.		
	Bush materials		Bamboo (or other floating timber) for floatation, 2 pressure floats (one at 20 m depth) and 18–20 mm poly rope. Use engine block or cement drum anchor,** Use old shredded rope for attractants	Bamboo (or other floating timber) for floatation, 1 old/used pressure float (for surface float), 1 pressure float (at 20 m depth) and combined poly/nylon rope. Engine block or drum anchor.* Use old shredded rope for attractants
	Subsurface	18–20 mm poly rope with 5 pressure floats and combination (4 x ½ cement drum/engine block with grapnel) anchor. 1 old/used pressure float (for surface float). Use Samson rope connectors for additional strength and plastic strapping for longer lasting attractants.	18–20 mm poly rope with 4 pressure floats and 4 x ½ cement drum/engine block anchor.* Use an old/used pressure float (for surface float). Use old shredded rope for attractants.	Poly rope with 4 pressure floats and cement drum/engine block anchor. Use an old/used pressure float (for surface float). Use old shredded rope for attractants or plastic strapping for longer lasting attractants.

* Poly = polypropylene
** On sloping sites, anchor design should include a grapnel along with a cement drum/engine anchor.
Note: Nearshore FAD designs are constantly evolving and further advice should be sought from SPC.

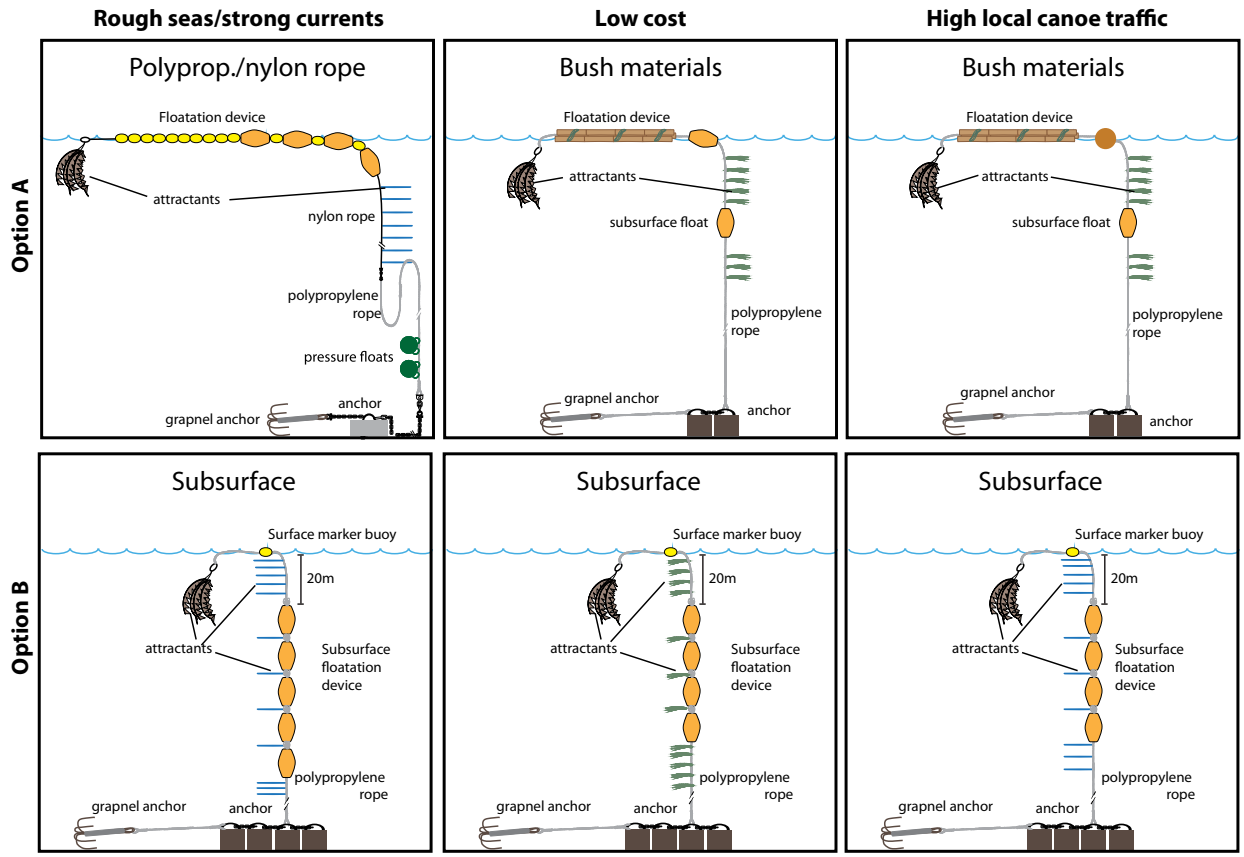


Figure 1. Visual representation of recommended nearshore FAD designs for Solomon Islands, dependent on three key site characteristics

the characteristics of the local environment. Experience from the industrial fisheries sector indicates that anchoring a series of FADs within a given area is most likely to aggregate and maintain schools of pelagic fish. However, there is a risk that if too many FADs are deployed close to one another, FADs or fishing gear can become tangled and nearby FADs may interact, attracting fish from one another, rather than from the open ocean. In Solomon Islands, most local fishers indicated that they were not willing to paddle more than two kilometres to fish at a FAD. However, FADs also need to be at least one kilometre away from seaward reefs to attract pelagic fish and reduce aggregation of reef-associated fish. Using the best information available, as a general rule, nearshore FADs should be deployed in water depths of 200–500 m and more than one kilometre from the coast more (or seaward reef). The recommended minimum distance between nearshore FAD sites is five kilometres. Recent observations by SPC indicate that, at a particular FAD site, a cluster of three FADs separated by ~500 m is optimum. Ultimately, the selection of the FAD deployment site should be undertaken with local village fishers who have an in-depth knowledge of existing pelagic fisheries. This should ensure that FADs are placed in an optimal site to aggregate pelagic fish and are well-utilised by local fishers using boats available in the village.

Community awareness can promote effective use of FADs and negate losses

Vandalism is by far the most common reason for loss of FADs. Participatory planning (provider and community) and community awareness programmes prior to FAD deployment (both within the immediate community and the surrounding communities) about the purpose and responsibilities related to a nearshore FAD can promote the effective use of FADs and reduce the risk of early losses. Awareness and sharing lessons among communities can facilitate informed discussions on the positive and negative social effects communities might encounter, and help with making plans to mitigate these before FADs are deployed.

Focus FAD deployments on food 'insecure' communities that have a high dependence on fish and limited access to diverse or productive fishing areas

In contrast to other studies that have shown higher catch rates at nearshore FADs compared to open water fishing in some Pacific Islands nations, catch and effort monitoring in Solomon Islands did not consistently show significantly higher catch rates at the FADs areas compared to the non-FAD fishing areas (in terms of either weight or number of fish caught). The average weight-based FAD catch rates ranged from 1.0 to 2.9 kg fisher^{-1} hr^{-1} at the four study villages and was similar to the average non-FAD catch rate, which ranged from 0.9 to 2.2 kg fisher^{-1} hr^{-1}. These results suggest that, in general, fishing at the nearshore FADs was not more efficient than fishing at existing fishing grounds, but there were important differences from village to village.

FADs were utilised by 35% to 75% of local fishers. In villages with lower non-FAD catch rates and reef fish diversity there was a greater proportion of FAD fishers. Conversely, a lower proportion of FAD fishers was observed in villages with higher non-FAD catch rates and greater diversity of reef fishes. This suggests that villages with limited access to diverse or productive fishing areas are more likely to use FADs to better effect.

Village-based fisher training can improve catch rates and FAD longevity

Troll-line fishing was the most commonly recorded mechanism for fishing at nearshore FADs, despite there being no evidence of higher weight-based troll-line catch rates compared to non-FAD fishing grounds. The aggregating nature of FADs is such that larger fish are located at deeper depths; fishers may underutilise FADs because of limitations in fishing gear and techniques that target larger fish. Lack of knowledge about appropriate methods to catch fish at a FAD can lead to catch rates that are less than their potential, fishers not using the FAD, or early loss of the FAD due to vandalism by frustrated fishers.

In recognition of this, SPC has developed FAD fishing and sea safety training modules (Preston et al. 1998). Boat and sea safety training are important when fishers travel some distance away from the shore. Village-based training of fishers, using a slightly modified version of the SPC modules and taking into account gear and boats available to rural fishers, was undertaken in a small number of the villages where FADs were deployed in this study. The training sessions were well received by fishers and in some cases resulted in higher (gear specific) FAD catch rates. The training also promoted the transfer of knowledge among fishers, and improved their knowledge of the behaviour of fish around FADs. These outcomes highlight the importance of village-based training of fishers, sharing knowledge among villages and drawing on lessons learned by fishers.

Implement nearshore FADs as part of broader development planning

Household and fisher interviews reveal that nearshore FADs can have both positive and negative impacts on village life. The perceived benefits of nearshore FADs were relatively uniform across villages where interviews were undertaken. They were a source of income (through the sale of fish) and improved nutrition (through an increase in fish consumption); and, at the community level, they

The use of local materials may allow communities to deploy and maintain their own FADs. (Image: Grace Orirana).

provided fish for fundraising and feasts (e.g. funerals, weddings, church and community events) and were a source of income for community-related expenses (e.g. church and schools).

There were some negative elements identified in relation to the presence of FADs. At the family level, FADs were said to create arguments between husband and wife (mostly attributed to the husband spending more time fishing and less time assisting with household activities, such as gardening). In one village, the resulting neglect of gardens led to a period of hardship when the FAD was lost in rough seas; there was no food from the garden and no fish from the FAD. At the community level, the most commonly mentioned negative aspect of FADs was a reduction in fishers' attendance at church and other community activities.

Fishing at nearshore FADs, while using existing skills and being consistent with daily village life, has some characteristics consistent with the introduction of a new livelihood option to the community. A reduction in the time male fishers spend attending to other household and community activities may have both short-term and long-term consequences for households and communities. A national FAD programme could benefit from being embedded in the wider development planning by communities and national agencies in order to recognise and respond to benefits and trade-offs, including those that disproportionately affect some members of society, such as women gardeners.

Monitoring can build an information base to allow informed policy making

A general acceptance that FADs are effective in increasing access to fish for a coastal community has resulted in investments to date being dominated by practical issues about FAD design and deployment, rather than quantifying realised benefits and their distribution amongst communities. The results discussed here suggest that benefits can be variable and depend on a range of socio-ecological conditions. If nearshore FADs are to become more widespread, a robust analysis of their contribution to gender equitable development outcomes is required.

The study reported here has provided important lessons for site selection, FAD design and mechanisms for improving FAD longevity, as well as highlighting social dimensions around FAD deployments in Solomon Islands. The study has also shown that nearshore FADs are used by rural fishers, albeit to varying degrees, and it highlights the potential role that FADs can play in rural communities by providing fishers with access to a 'new' or hitherto under-utilised source of fish. Continued monitoring and assessment of nearshore FAD deployments will provide an ongoing mechanism for the government to assess the contribution of nearshore FADs to food security, livelihoods and income generation for rural communities and to inform future policy.

A national nearshore FAD monitoring programme should include at a minimum, information on FAD

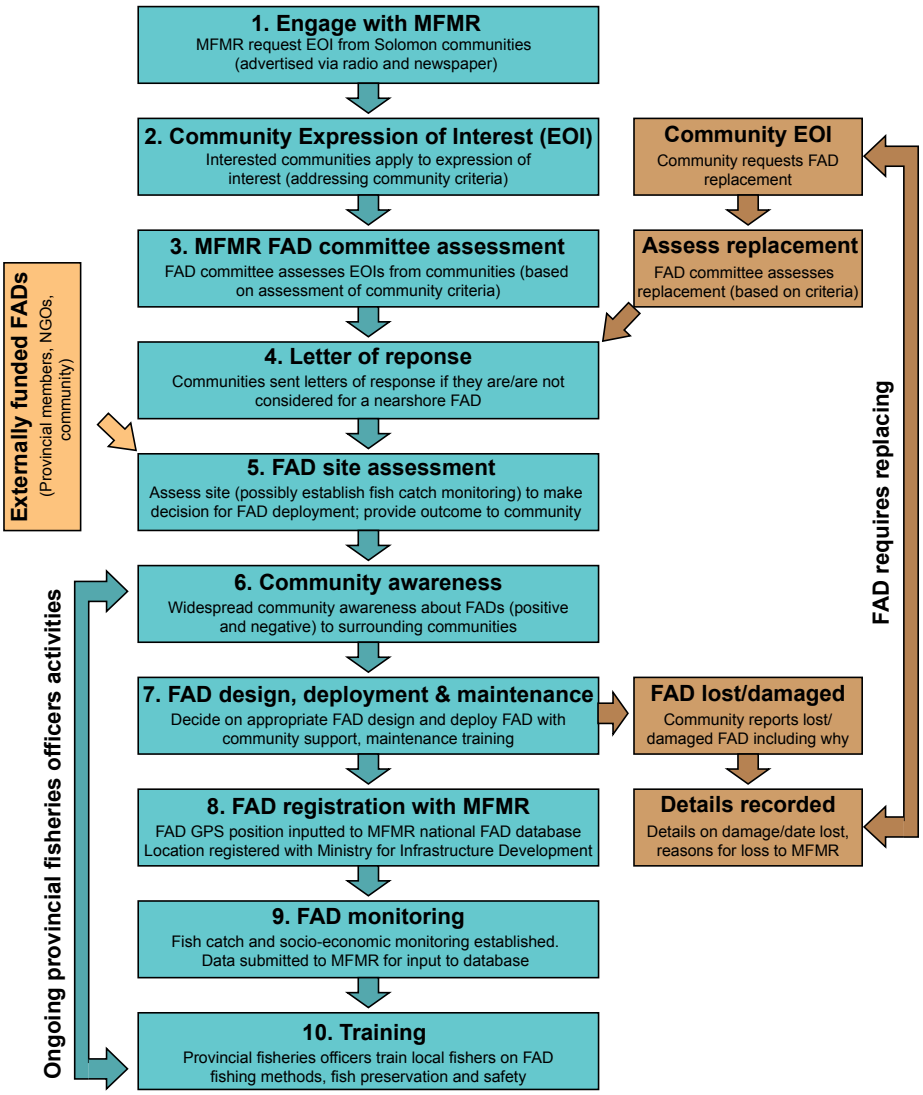


Figure 2. Ten-step process for implementation of nearshore FADs in Solomon Islands

deployment location, longevity and reasons for losses. More detailed recording and analysis of fisher use and fish catches, as well as the social, ecological and economic dimensions of the impact of nearshore FADs, could be included. Monitoring fish catches prior to the deployment of a nearshore FAD, or at least assessing indicators of the productivity and diversity of existing fisheries, can provide an initial indication of likely FAD use, assist with site selection and contribute to a better understanding of the potential impacts of FADs (the shift of fishing effort from reef species to more resilient oceanic species).

Source recurring funds to maintain a national FAD programme

Nearshore FADs have a finite lifetime and all FADs, regardless of vandalism, will eventually break free. Recurrent and readily available funds should be in place at national level to deploy, redeploy and provide ongoing support to communities (i.e. training, technical advice, site surveys, FAD maintenance). Nearshore FADs that are routinely maintained (e.g. floatation system checked, excess growth from the FAD ropes removed) are more likely to remain in the water for a longer period of time. Building community ownership and the capacity to maintain and redeploy their own FADs (particularly designs that use local materials) can increase FAD longevity and reduce the burden on limited government resources.

A common national approach for nearshore FADs

Developing a coordinated national approach for implementing a long-term nearshore FAD programme for Solomon Islands is proposed. A ten-step process to guide those who commonly implement nearshore FADs (government, NGOs and provincial and national political representatives) is outlined in Figure 2.

Contributions

The contents of this programme brief draw on the experiences of WorldFish, the Ministry of Fisheries and Marine Resources, the Secretariat of the Pacific Community and the University of Queensland in the deployment and monitoring of nearshore FADs in Solomon Islands and elsewhere in the Pacific region.

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Clear water sharks – muddy coastal habitats

New research shows that coastal mangroves and mudflats can be vital to reef shark populations

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Reef sharks live on coral reefs. This is where they are seen and photographed, and reefs are usually where fishermen catch them. The normal reef shark we see in the Pacific is a sleek grey animal against a background of clear blue water and corals. However, in some places, large numbers of reef sharks can be found in muddy coastal waters, mangroves and seagrass beds (Fig. 1), but it is only recently that research has documented what they are using these habitats for.

For artisanal fishers in many Pacific Island countries and territories (PICTs), reef sharks such as the grey reef shark, the blacktip reef shark and the whitetip reef shark, may be important sources of supplementary income (Armagan and Foale 2006). In some places (e.g. Fiji, Palau and French Polynesia) sharks are important to eco-tourism and provide a sustainable, long-term source of income (Clua et al. 2011; Brunnschweiler and Barnett 2013; Vianna et al. 2012). Sharks and rays can also be very important to the traditions and culture of Pacific peoples [Chin 2005], featuring in the dances, songs, myths and customs that contribute to cultural identity. Unfortunately, however, reef sharks in the Pacific are under increasing pressure and there are many stories about shark declines that are supported by scientific studies (Nadon et al. 2012; Heupel et al. 2009; Robbins et al. 2006). The impacts of coastal and artisanal fishing are increasingly being recognised (Clua and Planes 2015) and threaten the social, ecological and economic values and services that sharks and rays provide.

The main pressure facing reef sharks in the Pacific is fishing. However, sharks and rays can also be affected by habitat loss, as important feeding and breeding grounds are disturbed by pollution and/or coastal development. Destruction of these habitats disrupts breeding cycles

Figure. 1. Blacktip reef sharks are sometimes seen aggregating in murky waters in coastal habitats such as mangroves, seagrass beds and coastal mudflats. These sharks were photographed in Cockle Bay, North Queenlsand. (Image: Amos Mapelston, JCU)

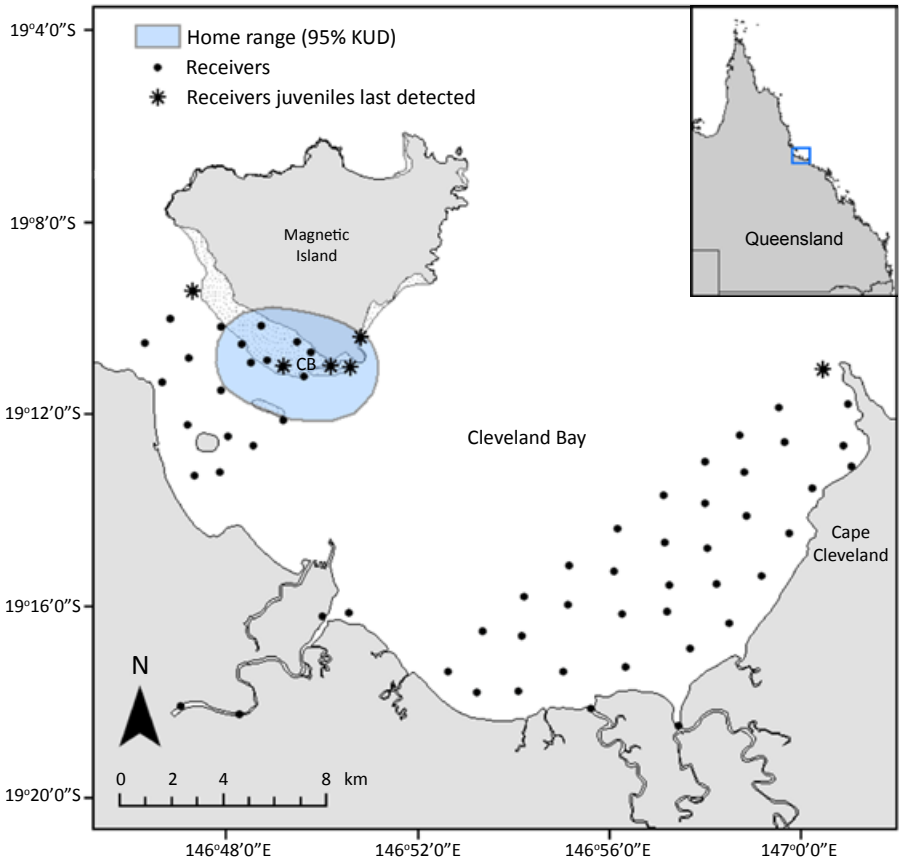

Figure 2. Map of Cleveland Bay including the nominal home range of juvenile blacktip reef sharks (A. Chin unpubl. data), the location of Vemco VR2W receivers in the eastern and western sides of the bay, and the locations of receivers where juveniles were last detected. CB = Cockle Bay.

and can reduce the number of pups entering the population. It has long been known that sharks such as bull sharks, sandbar sharks, bonnethead sharks, nurse sharks and the Atlantic lemon shark, use coastal habitats as nursery areas (Knipp et al. 2010). These coastal habitats include mangroves, mudflats, estuaries and seagrass beds, where the water may be very muddy; very different from the clear water environments of Pacific coral reefs. However, recent research on the Great Barrier Reef suggests that these muddy habitats may be crucial to reef shark survival in the Pacific as well.

Researchers from James Cook University in Queensland, Australia, have completed a three year tagging and tracking study of coastal blacktip reef sharks (*Carcharhinus melanopterus*) in Cleveland Bay, a muddy coastal bay on the Great Barrier Reef coast. Sharks were tagged with plastic fin tags and 27 blacktip reef sharks were also tagged with acoustic tags that reported their movements for up to 2½ years. As sharks swam throughout the area, their movements were recorded on Vemco VR2W receivers that were deployed throughout the bay and at other reefs and islands. The research team also worked with commercial net fishermen along the coast to record shark catches and to tag sharks. The data from these efforts have revealed some unexpected results.

Catch data from along the coast showed that some reef sharks, such as grey reef sharks (*Carcharhinus amblyrhynchos*), whitetip reef sharks (*Triaenodon obesus*) and blacktip reef sharks, are being caught by net fishermen in inshore habitats. While the catches are small compared to those of other shark species, the data show that these reef sharks do occur around inshore reefs and shallow shorelines, where water clarity can be less than 1 m visibility (Chin et al. 2012). Of the reef sharks captured along the coast, the blacktip reef shark was the reef shark caught most often in these muddy coastal habitats (Chin et al. 2012).

Focusing on these sharks uncovered yet more surprises. Catch sampling, tagging and tracking across Cleveland Bay showed that, although the sharks had access to the whole Cleveland Bay area (Fig. 2), they mainly lived in a very small area (<2 km^2) in Cockle Bay – a small bay on a coastal island (Chin et al. 2013b). While there were coral reefs nearby, the blacktip reef sharks spent most of their time on the sand and mud shorelines and in

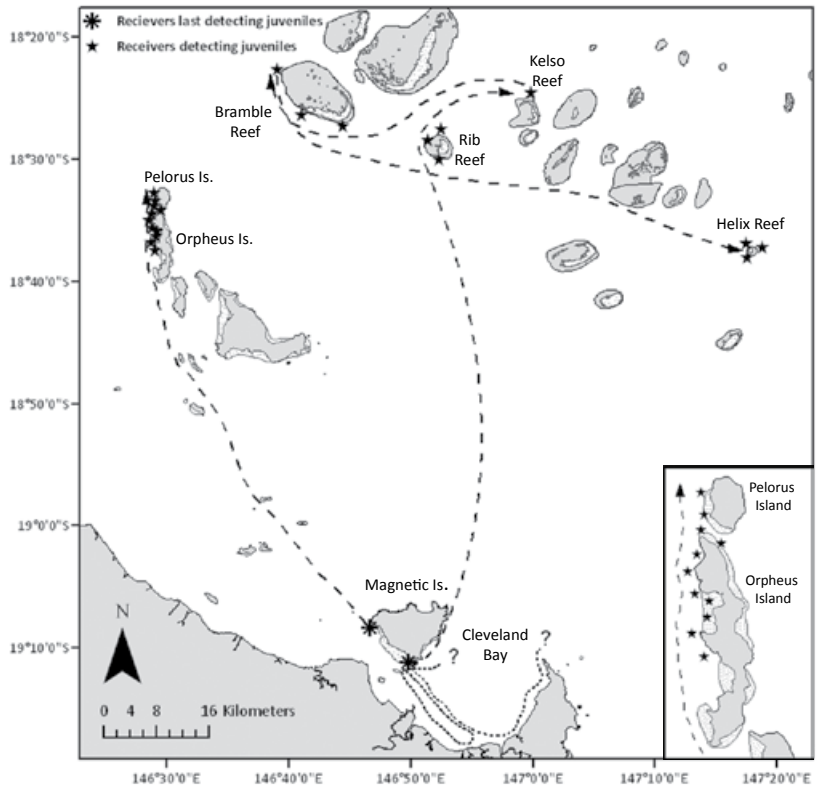

Figure 3. Movements of juvenile blacktip reef sharks that left Cleveland Bay and moved to mid-shelf coral reefs and Orpheus Island. Movements of two juveniles across Cleveland Bay followed by their departure to unknown locations are also shown. Inset map shows detail for Orpheus and Pelorus Islands.

seagrass beds. Juveniles were seen congregating in the mangroves. Surprisingly, the sharks did not use the reefs in other parts of the island, and they left Cockle Bay only on rare occasions.

The other surprise was the population structure. The normal patterns seen in coastal sharks are that adult females enter shallow coastal habitats to reproduce and, once the pups are born, the females depart, leaving the young sharks to mature in these coastal nurseries. The young can then forage without competition or predation from adult sharks, allowing them to survive and reach maturity faster. However, this new research turned this pattern upside down. In these coastal habitats, the resident population is comprised of neonates (new born sharks), juveniles, and adult females – and sharks of all three sizes shared the same small area over several years. These animals stayed in Cockle Bay all year round, even during a Category 5 cyclone that made other coastal sharks leave the bay for deeper water (Udyawer et al. 2013). In contrast, sub-adult/maturing sharks (animals between ~95 cm and 1.2 m) were never seen, and adult males were rarely present – only appearing during the breeding season and leaving shortly after (Chin et al. 2013b).

The second surprise came from an unexpected source. Researchers working on sharks and fish in other locations detected two of the juvenile sharks from Cockle Bay near other islands and at offshore coral reefs over 80 km from Cockle Bay (Fig. 3) (Chin et al. 2013a). Closer analysis of the neonates and juveniles uncovered another pattern. When the juveniles reached about 95 cm, they were detected leaving the Cockle and Cleveland Bay and never returned. These did not seem to be random movements as, once the animals broke away from their normal patterns, they very quickly left the bay.

The detection of juveniles at other locations indicated that these young sharks can cover over 80 km in two or three days. Another juvenile blacktip reef shark tagged at a different location along the coast was also caught three times at different places, providing additional data showing how young sharks can swim long distances away from their natal habitats (Chin et al. 2013a). While the pattern of fishes migrating from inshore coastal nurseries to offshore coral reefs has been shown for fish, these studies show that this process also occurs in reef sharks.

What does this mean for shark management?

These research projects highlight again how important it is to protect and manage the coastal habitats of mangroves, seagrass beds, and shallow mud and sand flats. They also demonstrate that to effectively protect reef sharks, managers may need to understand if and where breeding females are aggregating. In Pacific countries with large islands that have coastal mangroves, seagrass beds, and mud and sand flats, managing agencies and communities should recognise that these places may be vital to reef sharks, and actions to protect or rebuild reef shark populations may need to consider protecting these coastal habitats. If these breeding and nursery habitats are lost, reef shark populations in distant locations may be severely affected and cause loss of fishing and tourism income. Action is also needed to make sure that fishing is sustainable. Overfishing one coastal area could reduce the flow of young sharks replenishing another distant island or reef, which, in turn, could reduce the number of adult sharks returning to coastal areas in future years. The high concentration of sharks in very small coastal areas could also make it very easy to deplete these resources if fishing is not managed properly. Protecting the Pacific's reef sharks will need multiple approaches that include managing fishing impacts on reefs and in coastal habitats, and in protecting the key habitats that support reproduction and eventual restocking of shark populations.

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Image: Aymeric Desurmont

A new song for coastal fisheries – pathways to change:

The Noumea strategy

Developed by the Future of Coastal/Inshore Fisheries Management Workshop 3–6 March 2015, Noumea, New Caledonia, with financial support from the Australian Government and the Australian Centre for International Agricultural Research (ACIAR)

Facilitated by the Secretariat of the Pacific Community

Endorsed by the ninth SPC Heads of Fisheries Meeting, March 2015, Noumea, New Caledonia

Introduction

A new song for coastal fisheries – pathways to change: The Noumea strategy was developed by participants at a regional workshop on the future of coastal/inshore fisheries management that was held in March 2015. The workshop brought together representatives from fisheries and environment departments in 22 SPC member countries; coastal communities; four agencies of the Council of Regional Organisations in the Pacific; and non-governmental organisations. Resource people came from regional partner academic institutions and consultancy firms. The Secretariat of the Pacific Community provided the technical support , and financial assistance was provided by the Australian Government and an events funding grant from the Australian Centre for International Agricultural Research.

The strategy was endorsed by the ninth SPC Heads of Fisheries Meeting, held in Noumea, New Caledonia in March 2015.

The populations of many Pacific island countries and territories (PICTs) are growing but coastal fisheries resources, which provide the primary or secondary source of income for up to 50 per cent of households and 50–90 per cent of the animal-sourced protein consumed, are declining. Simply put, more of the same will not do, a new innovative approach is needed.

The 'new song':

- ✓ is the innovative approach to dealing with declines in coastal fisheries resources and related ecosystems. It enhances and builds on the strengths of the now expired *Pacific Islands Regional Coastal Fisheries Management Policy and Strategic Actions* (Apia Policy), which was forged to harness the benefits of coastal fisheries in response to the Pacific Island leaders' recognition of the importance of coastal fisheries through the Vava'u Declaration in 2007.
- ✓ calls for an enhanced focus on coastal fisheries management and related development activities in the Pacific region. Its 'Pathways to change framework' on page 50 outlines actions that national governments and all other stakeholders will need to commit to in order to provide substantial support for this community-driven approach.
- ✓ is designed to provide direction and encourage coordination, cooperation and an effective use of regional and other support services in the development of coastal fisheries management. At the regional level, it brings together initiatives and stakeholders with a shared vision of coastal fisheries management and a strong, coordinated approach. At the national and sub-national level, it seeks political recognition of the value of coastal fisheries to food security and rural development.

Coastal communities and their environment collectively represent a complex system, facing a range of challenges beyond fisheries. To be successful, implementing the 'new song' initiative will require a coordinated approach – communities and fisheries agencies working together with stakeholders from a range of other sectors, including health, environment and agriculture. Climate change will affect all these sectors.

The Pacific Community, through the Secretariat, will be responsible for building momentum for the 'new song' at the regional level and will implement an effective monitoring, evaluation, and learning framework to identify and address critical issues in a timely manner.

SPC will assess progress, support and facilitate implementation, taking into account the dynamic nature of coastal communities and ecosystems. It will provide an opportunity for the region to report to leaders on coastal fisheries, including under the FFA/SPC 'Future of Pacific Island Fisheries' initiative.

SPC will promote endorsement of the 'new song' through relevant regional forums in a sequenced and logical fashion.

1. Context

Inshore fisheries provide the primary or secondary source of income for up to fifty per cent of households in the Pacific region. Amongst rural populations, 50–90% of the animal-sourced protein consumed comes from fish. At the national level, coastal fisheries carry significant cultural and economic value. They are estimated to contribute 49% of the total fisheries contribution to GDP, demonstrating that they are central to the Pacific way of life.

The populations of many Pacific island countries and territories (PICTs) are growing but coastal fisheries resources are declining. This is causing the gap between the amount of fish required for food security and sustainable harvests from coastal fisheries to widen. Within 15 years, it has been estimated that an additional 115,000 tonnes of fish will be needed across the region for good nutrition. PICTs face many challenges in dealing with their changing physical and social environments but unless the food gap is minimised and filled (Figure 1) there will be significant negative impacts on the traditions, health and wellbeing of Pacific Island communities. Strategies to minimise and fill the gap currently lack definition.

Pacific Island leaders have recognised the importance of coastal fisheries. The Vava'u Declaration in 2007 calls for effective management of coastal fisheries to support food security and sustainable livelihoods. The Apia Policy was then forged to help harness the benefits of coastal fisheries. Similar themes are embodied in the Joint Forum Fisheries Agency/Secretariat of the Pacific Community (SPC) report *The Future of Pacific Island Fisheries;* the International Union of Conservation of Nature's call for action; the strategic plan of SPC's Fisheries, Aquaculture and Marine Ecosystems Division (FAME); the outcomes from the Third International Conference on Small Island Developing States; the Melanesian Spearhead Group's *Roadmap for inshore fisheries management and sustainable development 2014–2023*; the Pacific Islands Forum Secretariat's *Framework for a Pacific Oceanscape;* and the 2014 Palau Declaration: *The Ocean: Life and Future.*

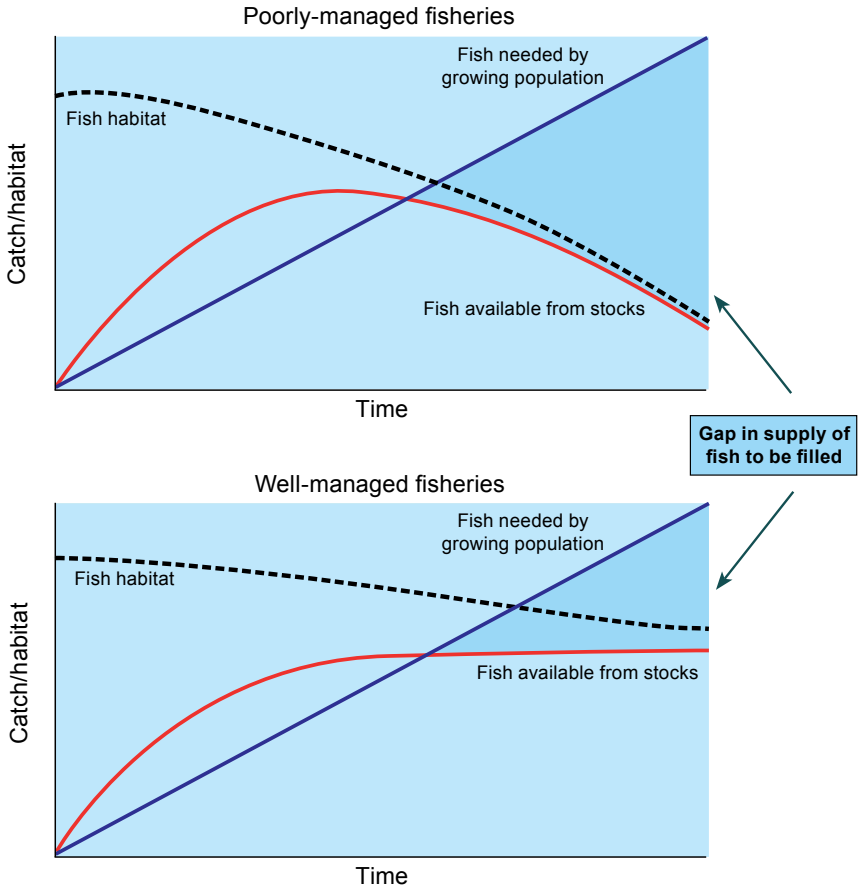

Figure 1. A stylised representation of the developing fish supply gap in the Pacific Region (Source: based on Bell et al. 2011[1])

[1] Bell et al. (2011). Implications of climate change for contributions by fisheries and aquaculture to Pacific Island economies and communities. In, J.D. Bell, J.E. Johnson, and A.J. Hobday, eds. Vulnerability of tropical Pacific fisheries and aquaculture to climate change, pp 733–801. Noumea, New Caledonia, Secretariat of the Pacific Community.

These documents collectively call on PICTs to implement integrated coastal resource management arrangements, drawing on the strengths and traditions of community, district, provincial and national levels of government to achieve sustainable island life.

Coastal fisheries are complex and interdependent social and ecological systems that are influenced by many factors, such as national governance, trade and land-based activities. Their management, therefore, faces many challenges in balancing development aspirations and sustainability, and in adapting to change outside the influence of coastal communities. There is increasing exposure within the region to the various approaches to coastal fisheries management and considerable literature on the subject to inform new initiatives. As coastal fisheries management continues to evolve, community-based ecosystem approaches to fisheries management (CEAFM) will play a central role in securing the benefits that flow from coastal resources.[2]

The importance of taking an ecosystem approach, which considers a wide range of impacts on coastal ecosystems in addition to fishing, is clear and is being increasingly incorporated into management approaches. There are, however, significant challenges associated with evaluating the successes and failures of isolated CEAFM initiatives and in scaling up coastal fisheries management to a national level. Although many instances of local success can be found, these alone will not be sufficient to meet future national and regional food security demands. It is estimated that upwards of 90 per cent of coastal communities do not have viable coastal fisheries management in place and large areas are not under effective management.

2. A new approach

The convening of a dedicated CEAFM workshop attracting broad-based participation is an indication of the increased profile of CEAFM. The workshop was clear that a new and innovative approach to dealing with declines in coastal fisheries resources and related ecosystems is needed. Simply put, more of the same will not do and a 'new song' for coastal fisheries is needed.

At the regional level, what is needed most is to bring together disconnected initiatives and stakeholders into a strong, coordinated approach with a shared vision of coastal fisheries management. At the national and sub-national level, what is needed is political recognition of the value of coastal fisheries to food security and rural development and a related commitment to resource the sector. With appropriate national and regional support, coastal fisheries management incorporating community-based ecosystem approaches will be scaled up to meet domestic development aspirations.

The Melanesian Spearhead Group's roadmap and associated national plans provide useful guidance on what such an approach should consider. The proposed approach in this booklet is complementary to, and does not duplicate, the MSG roadmap.

The following key needs were highlighted during discussions of a 'pathway of change' towards sustainable coastal fisheries based on CEAFM.

Understanding the facts

There is now a strong body of work on the projected food gap in the Pacific Island region – what works and does not work in CEAFM and the consequences of inaction. The value of coastal fisheries to communities is frequently understated; in reality they are often far greater than offshore tuna fisheries. The limited application of management in areas where population growth and fishing/habitat pressure is increasing is apparent. These facts speak for themselves, but they should be more widely publicised and must form the basis of a planned strategy to halt the decline in our coastal fisheries. Further analytical work on inshore fisheries will better define problems and help to focus inputs where they will have the best effect.

Advocacy and political will

Improvements to coastal fisheries will require significant commitment in terms of resources and support at all levels – local, national and regional. The issue of fisheries decline and the dire consequences arising need to be elevated to the highest political levels and beyond the fisheries sector. This is essential if hard decisions are to be made and real change occurs on a meaningful scale. Champions for the cause of sustainable coastal fisheries will be needed at all levels.

Scaling up

Small pockets of effective coastal fisheries management will not be adequate to address the problem. Ways must be found of building on successes and expanding them to meaningful proportions of the coastal environment. The process of scaling up will commence with widespread appreciation and understanding of the process

[2] There are many terms used by countries that encompass community-based fisheries management (see below) and these could be used interchangeably in the context of this document, provided they encompass an ecosystem approach that will sustain livelihoods and ensure resilient communities. CEAFM = community-based ecosystem approach to fisheries management: CBNRM = community-based natural resource management, CBFM = community-based fisheries management, CEAFM = community-based resource management, CBAM = community-based adaptive management, LMMA = locally-managed marine areas

and benefits of CEAFM in the short term. This must be followed by increased support from all stakeholders, including non-governmental organisations, regional organisations and governments in areas such as legislation and staffing.

Balancing offshore and inshore fisheries

Historically, the focus of fisheries agencies has been on development and commercial fisheries – tuna in particular. Now, however, with the ongoing livelihoods and food security benefits of good coastal fisheries management being clear, it is time for governments to ensure an appropriate level of resources to secure the considerable benefits that flow from the sustainable management of coastal fisheries. Ad-hoc funding from donors and NGOs is valuable for short-term, project-based initiatives, but is no substitute for the allocation of long-term funding support for coastal fisheries management from government budgets.

Empowering communities

Coastal fisheries management is not only about managing fish; it is about supporting people at the community level. It is vital that these communities are empowered, motivated, and adequately resourced if CEAFM is to be successful. Traditional and local management will often be effective in their own right, but governments have a role, both in CEAFM and in those instances where different forms of coastal management are required.

Women and youth

Women and youth are integral to successful coastal fisheries management. In the fisheries sector, their role is often overlooked or diminished. Gender relations have a significant effect on the course of development and so the voice of women and youth must be heard and acted upon effectively in all future CEAFM strategies. In addition to playing a greater role in decision-making, women and youth must have more equitable access to the benefits flowing from coastal fisheries.

Closing the gap

Fish plays a central role in the diets of Pacific Islanders. In addition to improving CEAFM, minimising and filling the gap to meet increases in the demand for fish from growing populations will require using alternative sources of fish for food. This includes the catch and bycatch of industrial tuna fisheries, small scale tuna fishing around FADs, aquaculture, and small pelagic species. The existence of these sources of seafood does not remove the need for taking hard decisions on improving coastal fisheries management. Inclusion of alternative sources of protein and other foods (as diets diversify) will require complementary strategies from communities and other sectors (e.g. health, agriculture, education). Providing for future food security without an increased risk of diet-related non-communicable diseases is a key consideration.

Working together

The range of stakeholders and their current and potential interactions is huge, with a vast array of complex interactions. Key players include communities, government and government agencies, churches, faith-based organisations, regional agencies, private sector stakeholders, research institutes, networks, NGOs and the media. If any new approach is to be successful, these stakeholders must sing in harmony from the same songbook, or risk being ineffective. Communities must have direct and effective contact and support from all relevant participants, including government – noting also the need for regional and sub-regional coordination of support services.

A holistic approach

While unsustainable fishing is a key factor in the decline of coastal resources, the need to deal with other impacts on coastal ecosystems is evident. Mining, logging, development associated with urbanisation, tourism and the growth of cities, climate change and natural disasters – all these affect the coastal marine environment and must be managed as effectively as possible. The same applies to catches of protected and endangered species and other activities that affect ecosystems.

Using the right methods

One size will not fit all in developing a new approach; there are clear local, sub-regional and regional differences in the circumstances of coastal fisheries. While community-based management remains central to achieving our goals for coastal fisheries, other tools and mechanisms will be required, including control of exports and regulatory approaches as defined in statutes. In some instances, CEAFM will not be appropriate to improved management. For example, CEAFM is difficult to implement in urban areas or places with contested marine tenure. Where CEAFM is not appropriate, government will have a more critical role. Developing and resourcing relevant and effective monitoring, control and surveillance mechanisms will be central to this challenge. Approaches must also be simple, realistic and implementable.

Maintaining livelihoods

The need for cash in coastal communities is increasing. If income is reduced from management measures in the short term, this may cause hardship and a reluctance to adopt CEAFM. While providing alternative sources

of income for coastal communities will therefore need to be considered, in no circumstances should it be 'traded off' as a prerequisite to taking effective fisheries management decisions, which will secure longer-term incomes and underpin the future sustainability of coastal communities.

3. The barriers

The workshop identified 11 key barriers that must be overcome if effective coastal fisheries management is to be implemented on a useful scale in the region:

- ✓ geographical isolation, the extent of coastlines and the diversity of coastal communities;
- ✓ lack of political profile, will and support in advancing CEAFM, including services delivered at the sub-national level;
- ✓ inadequate focus on coastal fisheries management by fisheries agencies compared to the offshore tuna sector, with limited capacity and resources being applied to coastal fisheries management;
- ✓ outdated management policy, legislation and planning, with little or no monitoring of effectiveness or sustainability;
- ✓ lack of relevant data, analysis and knowledge to inform management at all levels;
- ✓ inadequate empowerment of local communities and links with sub-national government;
- ✓ poor stakeholder collaboration/connection at the national and regional levels;
- ✓ inadequate compliance with fisheries rules and variable/inadequate sanctions;
- ✓ lack of integration of CEAFM into national economic policy and strategies;
- ✓ failure to adequately recognise the crucial role women play in the management and sustainable use of inshore fisheries resources; and
- ✓ limited alternative livelihoods and lack of available commercial funding mechanisms to support small-scale community livelihoods.

Image: Quentin Hanich

4. A vision for coastal fisheries

The workshop agreed to the following vision:

> *Sustainable well-managed inshore fisheries, underpinned by community-based approaches that provide food security, and long-term economic, social and ecological benefits to our communities*

To give effect to this broad vision, eight outcome statements were developed and agreed on at the workshop, along with a number of intermediate outcomes, activities and responsibilities, as outlined in the 'pathway to change' framework below.

The suggested approach seeks to be non-prescriptive. It is designed to provide direction and encourage coordination, cooperation and an effective use of regional and other support services in the development of coastal fisheries management. It is of necessity broad in nature and it is expected that, if endorsed by leaders, more detailed pathways to change will be developed and/or implemented at sub-regional and/or national levels.

The minutes of the workshop may be found at http://www.spc.int/FAME/en/meetings/229-regional-workshop-on-the-future-of-coastalinshore-fisheries-management

5. Outcomes from the coastal/inshore fisheries management workshop

Overarching outcomes

✓ *Improved wellbeing of coastal communities*

✓ *Productive and healthy ecosystems and fish stocks*

Key outcome areas

The workshop participants noted that, in order to reach these long-term overarching outcomes, progress is needed in the eight medium-term outcome areas below.

1. Informed, empowered coastal communities with clearly defined user rights
2. Adequate and relevant information to inform management and policy
3. Recognition of, and strong political commitment and support for, coastal fisheries management on a national and sub-national scale
4. Re-focused fisheries agencies that are transparent, accountable and adequately resourced, supporting coastal fisheries management and sustainable development underpinned by CEAFM
5. Strong and up-to-date management policy, legislation and planning
6. Effective collaboration and coordination among stakeholders and key sectors of influence
7. More equitable access to benefits and decision making within communities, including women, youth and marginalised groups
8. Diverse livelihoods reducing pressure on fisheries resources, enhancing community incomes and contributing to improved fisheries management

The workshop participants expanded each of the medium-term outcome areas into shorter-term outcomes that will need to be tackled over the next five years.

6. Roles of governments, SPC and other stakeholders

The 'new song' initiative calls for an enhanced focus on coastal fisheries management and related development activities in the Pacific region. To effectively implement the actions suggested in the Pathways to Change Framework shown in Section 9, national governments and all other stakeholders will need to commit to substantial support for a community-driven approach. The different forms of support necessary from governments and all other stakeholders to achieve the vision, while outlined in the framework, will be addressed in follow-up work.

The Secretariat of the Pacific Community will be responsible for building momentum for this new direction at the regional level and for supporting, facilitating and preparing regular assessments of progress with the 'new song' initiative.

Previous involvement and the broad participation and support of NGOs, communities and community-based networks in the elaboration of the song is an indication of their future engagement and commitment.

In summary, coastal communities and their environment collectively represent a complex system, facing a range of challenges beyond fisheries. The workshop noted that, in order to be successful, implementing the initiatives in this document will require a coordinated approach. This approach will include communities and fisheries agencies working together with stakeholders from a range of other sectors, including health, environment and agriculture. Climate change will affect all these sectors.


Image: Quentin Hanich

7. Monitoring and evaluation

If the 'new song' is to be effective, it is vital to monitor progress and identify and address critical issues in a timely manner and take account of the dynamic nature of coastal communities and ecosystems. The framework below makes preliminary suggestions as to possible performance indicators.

Monitoring the 'new song' will provide an opportunity for the region to report to Pacific leaders on coastal fisheries, including under the FFA/SPC future of Pacific Island fisheries initiative.

The implementation of an effective monitoring and evaluation framework will be a key task for SPC's Fisheries, Aquaculture and Marine Ecosystems (FAME) Division as implementation of the 'new song' progresses.

SPC will advance endorsement of the 'new song' through relevant regional forums in a sequenced and logical fashion.

8. Next steps

Pacific Island countries and territories heads of fisheries have endorsed this Noumea strategy – this 'new song' – and the broader outcomes of the workshop. In May, it will be presented at the Forum Fisheries Committee meeting and, in July, it goes to the FFC ministerial meeting for higher endorsement and will constitute the major input by SPC to the joint FFA/SPC future of fisheries exercise. As part of this exercise, the 'new song' will also be presented to all CROP (Council of Regional Organisations in the Pacific) agencies. Subsequently, it will be presented at SPC's Committee of Representatives of Governments and Administrations CRGA meeting scheduled for November 2015 in Niue.

With its strong focus on the community level, the 'new song' should help guide effective engagement in the sector for many years to come. It will, however, remain a dynamic document managed by SPC's FAME Division. The design and addition of a relevant monitoring and evaluation (M & E) framework, drawing on the suggestions presented here, will be a priority task.

The 'new song', together with the M & E framework (when drafted), should be shared with all relevant stakeholders in the inshore fisheries sector. They all have a role in promoting the 'new song' and in securing the future of sustainable coastal fisheries.

9. Pathways to change framework

OUTCOME # 1: Informed, empowered coastal communities with clearly defined user rights

Intermediate outcomes	Key players	Indicators
Informed and empowered communities – robust awareness and communication programmes	Community leaders, fisheries authorities, stakeholders, NGOs, women, churches, faith-based groups, youth, fishers, ministries of education, other government departments, CEAFM networks.	Awareness surveys # of communities practising CBNRM Compliance rates
Coastal fisheries management and marine ecosystems included in school curricula	Ministries of education, heads of fisheries, regional organisations (SPC, SPREP)	Curricula # of schools using curricula
Legal and regulatory frameworks recognising community empowerment	Heads of state, government ministers, attorneys general, fisheries agencies, traditional leaders and communities, SPC and SPREP, NGOs, government departments	# of national and sub-national laws updated and supporting community-based management # of national and sub-national policies and strategies guiding coastal fisheries management # of community-based management or action plans being implemented
Community management programmes	Traditional leaders / council / community fisheries agencies, networks, private sector, NGOs	Community management plans legally recognised # of traditional management practices supported
Strong partnerships at all levels	Traditional leaders / council / community, fisheries agencies, networks, private sector, NGOs, provincial government/equivalent	# of joint partnership programmes # of MOUs Evidence of active and strong partnerships

OUTCOME # 2: Adequate and relevant information to inform management and policy

Intermediate outcomes	Key players	Indicators
Government and community managers have good quality information to inform decisions	Fishers, managers (village chiefs, local fisheries administrators), networks, scientists, skilled data collectors	# of active databases, disaggregated by social factors # of fishers/communities providing high quality data # of trained data collectors, including in social and economic methods # of appropriate surveys and assessments completed Evidence that data is being used to inform decisions
Science is translated into simple and informative material to guide community management	Community members and fisheries staff with resource management people, academics, networks, capacity providers (SPC, FFA, MPI, NGOs), scientists	Management plans guided by data # of resources available to the community # of fisheries programmes integrated into school curricula # of evidence-based decisions Curricula
Communities have a greater understanding of status, biology and habitats of key species (in addition to existing local ecological knowledge)	Communities (traditional knowledge), managers, networks, government, research institutes, extension staff	# of extension staff Data easily accessible # of communities receiving feedback # of relevant publications being produced Incorporation of coastal fisheries management in school curricula # of schools with above curricula

OUTCOME #3: Recognition of, and strong political commitment and support for, coastal fisheries management at a national and sub-national scale

Intermediate outcomes	Key players	Indicators
Informed and supportive politicians at the national and sub-national levels	Permanent secretaries, directors (primary) community leaders/voters, faith-based organisations, NGOs	Change in budget allocation # of policies, statements, MOUs # of workshops and training for members of parliament
Raised public support of coastal fisheries through engaging awareness campaigns with consistent and community-relevant messaging and creative information-sharing tactics (e.g. use of celebrities, role models, etc.)	Communication organisations, fisheries working groups, media, spokespersons (celebrities, etc.)	# of media materials and activities produced related to coast # of people reached by media campaigns relating to coastal fisheries
Coastal fisheries management is a permanent agenda item at regional meetings (e.g. MSG, SPC, Secretariat of the Pacific Regional Environment Programme, FFA)	Heads of fisheries, CROP agencies, Fisheries Technical Advisory Committee	# of agenda items relating to coastal fisheries # of decisions taken at regional meetings

OUTCOME #4: Re-focused fisheries agencies that are transparent, accountable, and adequately resourced, supporting coastal fisheries management and sustainable development, underpinned by CEAFM

Intermediate outcomes	Key players	Indicators
Coastal fisheries management is adequately resourced	Ministers, heads of fisheries, SPC, planning departments, donors, ministries of finance	$ assigned to coastal fisheries management # of people assigned to coastal fisheries management # of staff with appropriate skills (social, gender, economic, ecological)
Documented coastal fisheries management activities, which are regularly reviewed	Heads of fisheries and other relevant agencies, SPC, planning departments, donors, communities, NGOs	# of documented activities Outcomes of review
Coastal fisheries management activities are integrated and coordinated with other relevant stakeholders	Heads of fisheries and other relevant agencies SPC, donors, communities, NGOs	# of plans demonstrating integrated and coordinated partnerships
Reviewed and integrated coastal fisheries management activities	Fisheries agencies, ministers, NGOs	# of reviews
Coastal fisheries staff conducting effective CEAFM activities	Donors, regional training organisations (e.g. SPC), fisheries agencies	# of trainees Training including appropriate range of topic areas (including social, ecological, economic)
Raised community awareness of coastal fisheries	Media, fisheries agencies, regional organisations, communities	# of published materials

OUTCOME # 5: Strong and up-to-date management policy, legislation and planning

Intermediate outcomes	Key players	Indicators
Coastal fisheries policy guiding management	All resource owners/users along with agencies in charge of natural resources (fisheries, environment, etc.), SPC	# of polices guiding coastal management # of countries with up-to-date policy
Updated legislation that allows policy to be implemented and empowers communities	Attorneys general, fisheries and other national agencies, regional organisations, SPC, parliaments	# of pieces of legislation guiding coastal management # of countries with sufficient legislation for effective management Compliance rates
Effective policy implementation through plans, monitoring and evaluation	Policy makers, fisheries agencies	# of updated plans # of references to regional inshore fisheries strategy
Illegal, unsustainable and unregulated fishing is minimised	Law enforcement services, community authorised officers, customs	# of prosecutions # of infringements recorded

OUTCOME # 6: Effective collaboration and coordination among stakeholders and key sectors of influence

Intermediate outcomes	Key players	Indicators
Coastal fisheries management is included in broader development processes	Ministries of strategic planning and finance, development NGOs, donors, communities	# of development programmes that include CEAFM activities
National forums are coordinating and providing cross-sector advice relevant to coastal fisheries management	Governments, NGOs, churches, faith-based organisations, private sector	# of forums Frequency of meetings # of meaningful decisions relevant to coastal fisheries
Church groups are integrated into coastal fisheries management activities	Churches, communities, faith-based organisations	Evidence of religious leaders advocating for good fisheries management
Private sector, finance providers and land-based organisations are involved in CEAFM	Cooperatives, financial institutions, donors, wholesalers, fishermen's associations, land,-based organisations (e.g. forestry, agriculture), finance providers	Active participation of private sector on advisory committees # of instances of private sector providing investment in support of sustainable fisheries services # of private sector investors # of communities provided with financial support # of land-based experts participating in dialogues
Regional and national coordination of policy	Regional organisations, donors, national governments	Regional commitments embedded in national policies and plans
Increased spread and quality of CEAFM among communities	Sub-national governments, communities, NGOs, CEAFM networks	Collaboration and learning among communities and practitioners Country-specific indicators of spread

OUTCOME # 7: More equitable access to benefits and decision making within communities, including women, youth and marginalised groups

Intermediate outcomes	Key players	Indicators
Equitable access to the resource and benefits from coastal fisheries within communities	Communities, champions for change, gender researchers	# of gender-differentiated studies # of community action plans in which access to benefits for women, youth and marginalised groups are improved Indicators of wellbeing are gender-differentiated and socially disaggregated Engagement of women and youth in fisheries activities
Greater inclusivity of decision-making while acknowledging cultural norms and traditional values	All demographic and social groups within a community, including village leaders	# of women, youth, others involved in decision making forums New stakeholder groupings are developed in decision-making forums
Decision-making processes are transparent and the roles of government and traditional authorities are clear	Communities, leaders	# of community members aware of decisions and decision-making processes
Plans take account of equity issues, especially those involving gender and youth	Communities, leaders, women and youth	# of plans that explicitly address equity issues

OUTCOME # 8: Diverse livelihoods reducing pressure on fisheries resources, enhancing community incomes, and contributing to improved fisheries management

Intermediate outcomes	Key players	Indicators
Diverse livelihoods, contribute to coastal fisheries management	Communities, private sector, fisheries agencies	Healthy stocks Diversity of livelihoods Proportion of income from coastal fisheries
Enhance value of wild-caught fisheries	Fishers, private sector	Total household income
Aquaculture, tourism and inshore FADs cost effectively contribute to sustainable livelihoods	National departments, private sector, communities, SPC and NGOs	Household income Status of fish stocks

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Collective action and lime juice fight crown-of-thorns starfish outbreaks in Vanuatu

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Introduction

Among the broad range of large-scale disturbances that affect Indo-Pacific coral reefs, the coral-eating starfish *Acanthaster planci* (crown-of-thorns starfish, COTS hereafter) is a major cause of coral reef destruction; its impact is quantitatively comparable to a cyclone. While *A. planci* generally occurs at very low densities (typically < 1 individual ha^{-1}), populations can dramatically increase during certain periods, reaching extremely high values (e.g. 538 ind. ha^{-1}; Kayal et al. 2011). These outbreaks represent one of the most significant biotic disturbances on coral reefs, causing massive and widespread coral mortality. Over a third of Indo-Pacific reefs were recently affected by severe COTS outbreaks, leading to growing concern that they are becoming more frequent and more prevalent (e.g. Brodie et al. 2005). While there is historical evidence that coral reefs can recover from COTS outbreaks, they drive even more pressure on already weakened systems (Bellwood et al. 2004; Bruno and Selig 2007; De'ath et al. 2012). The cascading effects from coral loss can severely harm the entire coral community, which raises serious concerns in areas where coastal resources (fish, invertebrates) form the basis of traditional, subsistence fishing.

Crown-of-thorns, an overlooked issue in Vanuatu

In Vanuatu, as in most Pacific countries where local people depend on coral reefs for their livelihood, COTS constitute a potential threat to food security and the lifestyle of coastal communities. While the presence of crown-of-thorns starfish has frequently been observed on the fringing reefs of many islands during the last decades, quantitative data are very scarce (Naviti and Aston 2000; Friedman et al. 2008). Large populations of

Acanthaster planci, *the crown-of-thorns starfish (Image: Pascal Dumas)*

A. planci were reported at some of the 35 sites surveyed by Done and Navin in 1989–1990. COTS outbreaks were documented in 2004 in the island of Espiritu Santo, while the reefs of Efate and the surrounding islands of Emao, Nguna, Pele, Moso and Lelepa have been successively hit since 2006. In 2008, quantitative surveys conducted by the Institute of Research for Development (IRD) reported peak densities locally, reaching up to 4,000 individuals ha^{-1} in Emao.

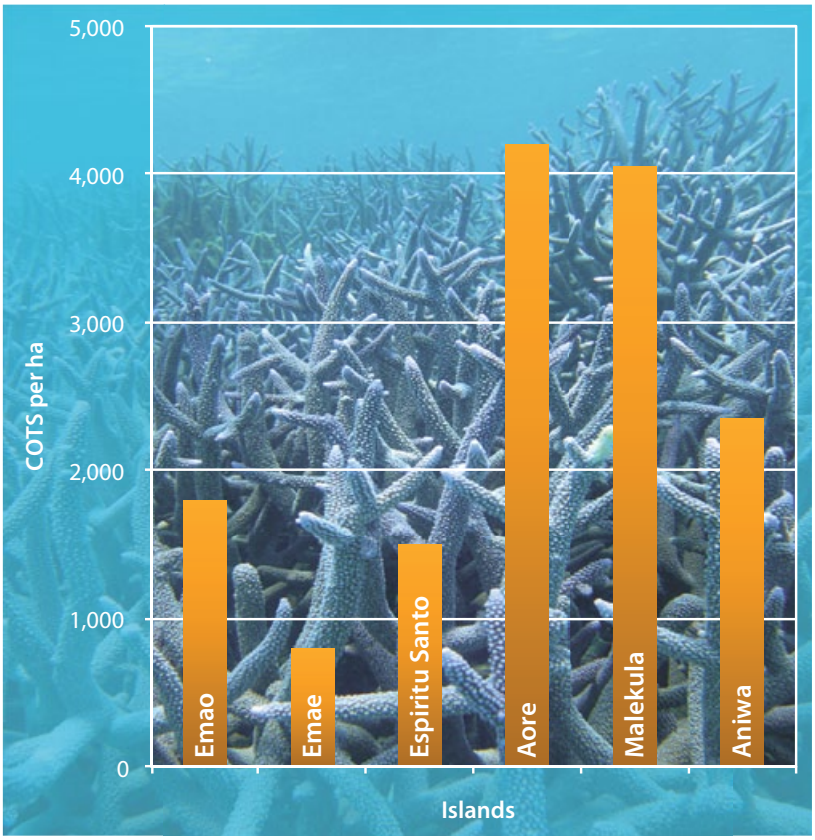

Figure 1. Peak densities of Acanthaster planci *in five islands of Vanuatu in 2014*

In 2013, alarming reports from coastal village communities, tourism professionals and NGOs raised new concerns about the geographical extension, intensity and social impacts of COTS in Vanuatu. Local scuba operators from Espiritu Santo and Efate reported increasing COTS aggregations in popular dive sites. Fishers from southern Espiritu Santo reported that, in some areas, women and children were afraid to go fishing on the reef because of very high COTS densities. In the Luganville area, there were cases of severe injury; the long, sharp spines of this species are slightly venomous and can inflict painful wounds that are slow to heal.

To address this issue, a series of COTS surveys was initiated in 2014 by the IRD and the Vanuatu Fisheries Department (VFD). COTS were investigated using standardised, quantitative underwater visual census methods across Vanuatu, supplemented by semi-quantitative observations provided by local observers. The results reveal that *A. planci* is widely distributed across the whole archipelago, with densities sometimes reaching extremely high values: up to several thousand individuals per hectare, which is similar or even higher than the highest densities usually reported from coral reefs (Dumas et al. 2015; Kaku et al. 2015; Dumas et al. 2014a, b). While the definition of an outbreak is still controversial, a COTS density of 15–300 ha^{-1} has been considered in various reports to constitute an outbreak population (e.g. Pratchett et al. 2014). The high densities observed during the 2014 surveys (with peaks of 800–4,200 individuals ha^{-1}) confirmed the occurrence of severe, localised COTS outbreaks in all of the six islands investigated (Fig. 1). Despite the lack of quantitative historical data, it is possible to assume multiple and/or recurrent infestations in these areas, with populations at various stages of growth: recent primary or secondary infestations (e.g. Emao in 2013, Malekula in 2014), infestations already installed or at the declining stage (e.g. Emae, Espiritu Santo, Efate since 2004–2006).

Addressing the COTS issue in Vanuatu

Despite growing concern from a variety of stakeholders, only recently has the crown-of-thorns starfish issue gained prominence at the national level. Local tourism operators have been struggling with COTS for many years, as untreated outbreaks can seriously affect the local tourism industry, especially in Vanuatu, which has many small marine-related business activities such as fishing, diving, snorkelling tours and glass-bottom boats. The result of COTS outbreaks is that a beautiful underwater landscape is lost, and for the tourism industry, this may have a devastating impact.

Currently, COTS outbreaks can only be reduced by direct human intervention. Since 2006, several scuba operators have been monitoring and removing COTS to help prevent further spawning. They do this at their own expense, whenever possible, during their tourist dive operations. Most of these efforts target only their usual dive operation areas, so benefits are often spatially restricted by lack of resources and the distance from dive operations.

Efforts have been made by the Fisheries Department, which led to awareness campaigns around the islands from 2003 to 2011, in collaboration with several local or international NGOs. They mostly targeted rural coastal communities, schools and tourism activities, but the campaigns were not implemented in a collaborative and coordinated manner. At the village level, basic information about COTS biology and ecology was clearly lacking (e.g. feeding behaviour, reproduction cycle, larval dispersal, growth, habitat, regeneration abilities), making it very difficult for the communities to understand the issues and efficiently manage COTS outbreaks.

Community-based management of COTS outbreaks in Vanuatu

While numerous approaches have been developed over the last decades, manual collection followed by disposal ashore is the most common technique used across the Pacific to regulate COTS outbreaks, at least on a small scale (Fraser et al. 2000). The starfish are usually collected manually by local snorkelers – using simple, everyday tools such as spears, sticks, hooks, spearguns and flour bags – and then buried or burnt ashore. The efficiency of these measures is very controversial, as i) their ecological efficiency is questionable for severe outbreaks and/or large affected areas; ii) they require significant manpower, long-term commitment and they entail a high risk of injury for the participants; and iii) timing is critical, in particular with respect to the spawning period of *A. planci*, which is not consistent across the country (Fig. 2).

In Vanuatu, the affected communities usually try to manage infestations by undertaking cleaning campaigns operated on the village scale, sometimes with the help of NGOs, local sponsors and funding agencies. Unfortunately, their efficiency appears very limited, given the lack of coordination and scientific/technical basic information, as well as long-term financial support.

In 2013, a pilot participatory project developed by IRD and the Fisheries Department in the heavily affected area of Luganville (southern Espiritu Santo) demonstrated that committed communities have the capacity to efficiently reduce COT densities on their reefs (Dumas et al. 2014c). More than 3.7 tonnes of COTS were removed from a narrow fringing reef by local snorkelers and volunteers from the Vanuatu Mobile Force during a nine-day community activity, using only very basic, locally-made collection tools. After this initial work and associated awareness, the local community took over, mainly on an individual basis (i.e. fishermen or snorkelers systematically removed the specimens of COTS that they found). Six months later, the density of COTS was divided by eight, back to 'normal' levels; women and children – who used to avoid the reef flat for fear of injury – were again seen fishing and swimming in the area. This was mostly achieved by teaching the local communities good ecological practices to remove the COTS from their reefs safely and efficiently, as well as providing direct logistical support to organise clean-ups.

The project did not implement a 'bounty programme', as has been done in some countries, e.g. Japan and Australia. Under this scheme, divers are paid a fee for every COTS they remove from a reef area, which creates an incentive

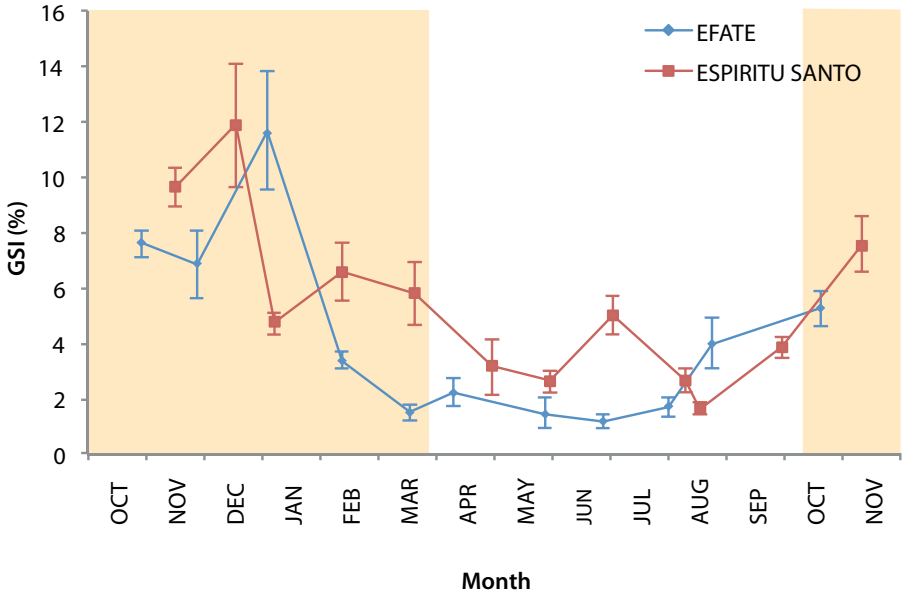

Figure 2. Spawning season (light yellow areas) of Acanthaster planci *in Vanuatu. Temporal evolution of gonado-somatic index (GSI) between October 2013 and November 2014 on Espiritu Santo and Efate.*

On this particular day, a team of more than 30 people, including members of the BanBan community and volunteers from the Vanuatu Mobile Force of Luganville, South Espiritu Santo, gathered to remove COTS from the area. (Image: Pascal Dumas)

for individuals to collect them. The main drawback is that the incentive for the collection of COTS becomes financial, and does not necessarily foster environmental concern among the local communities. Vanuatu people usually exhibit high commitment to the protection of their marine resources, so the emphasis was on environmental issues and long-term consequences of COTS outbreaks, and this motivated the participants. Despite very limited direct financial outcomes (food for all participants, closing ceremony with refreshments, and a daily fee of VUV 500 per person – ± USD 4.90 at that time), a high level of commitment was observed and the outputs were very satisfactory.

Acidic injections: a new 'cheap and natural' alternative?

Injection approaches – in which *A. planci* is injected with a variety of noxious solutions – are increasingly used as an alternative to manual methods, as they are more cost-effective than manual methods and fairly safe when handled correctly (see reviews in Rivera-Posada et al. 2012, Rivera-Posada and Pratchett 2012). However, there are drawbacks; most solutions injected over recent decades were not only noxious for COTS but for the coral community as well. For example, injections with copper sulphate were carried out in the Great Barrier Reef until it was judged too highly toxic for fish and many invertebrates (Yanong 2010).

Injections with sodium bisulphate are required at such high concentrations that they entail the risk of lowering oxygen levels in seawater (Roman and Gauzen 1993, Hoey and Chin 2004). Other chemical solutions may favour the growth of a particular type of bacterial pathogen (e.g. TCBS[1], Rivera-Posada et al. 2011), inducing disease and ultimately death in COTS, but with potential knock-on effects on the coral-associated community. Recently, single injections of 10 ml of TCBS protein ingredients (oxbile and oxgall) induced a strong immune response and death in *A. planci* with no evidence of negative effects on the coral community, so they are currently considered a promising alternative (Rivera-Posada et al. 2012, 2013). Nevertheless, the cost may be out of reach of many stakeholders; in Vanuatu, the cost of importing 250 g of oxbile or bile salts exceeds USD 900, freight cost included.

Against this backdrop, developing more cost-effective approaches is critical. In 2014, a new alternative, based on acidic injections of cheap, natural products was tested in Vanuatu by IRD and the Fisheries Department. Results from both aquaria and field experiments showed that fresh lime juice (extracted from local *Citrus arantifolia*)

[1] TCBS: thiosulfate-citrate-bile salts-sucrose agar.

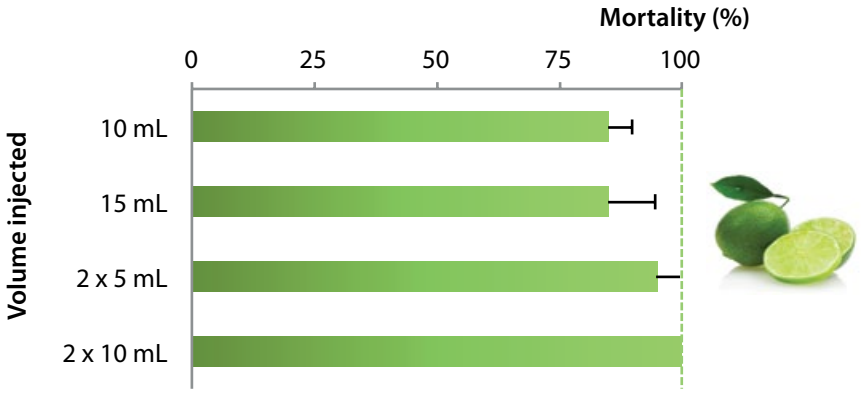

Figure 3. Effects of lime juice injections on Acanthaster planci. *Mean per cent mortality ± STE.*

and white spirit vinegar offer an option to control COTS outbreaks. They were found to induce high mortality, even with small volumes: 10-20 mL injected per starfish induced death in 89% and 97% of the injected specimens after an average of 34.3 hours, using lime juice, and 29.8 hours, using vinegar. Highest efficiency was reached with double shots of 10 mL each in two different areas of the body; 100% mortality occurred within 12–24 hours, which is similar or shorter than with other current injection methods (Fig. 3). With this new method, 10–20 L of lime juice or vinegar could kill up to a thousand COTS at a cost of less than USD 0.05 per specimen; and no permits or special handling procedures are required. Contagion to either conspecifics or a variety of other reef species was not observed. Based on these results, acidic injections of lime juice and vinegar offer great advantages when compared to current best practices and constitute a cheap and natural option for all countries affected by COTS, including Vanuatu.

Conclusion

The fact is that numerous coastal areas in Vanuatu are currently experiencing COTS outbreaks, the management of which is almost totally ineffective, leading to massive destruction of coral reefs and resources. While removal methods are only short-term responses to a complex phenomenon whose ultimate causes are not fully understood, their efficiency is increasingly recognised as a good protection for isolated or individual reefs (Bos et al. 2013). In the social and economic context of Vanuatu, the most promising approach in the long term is likely to be the use of cheap, low-tech removal techniques, relying on the strong commitment of the coastal communities through participatory, coordinated approaches. More effective control of COTS outbreaks will require that the lessons learnt at local (villages, communities) level be applied on a larger scale – a considerable challenge.

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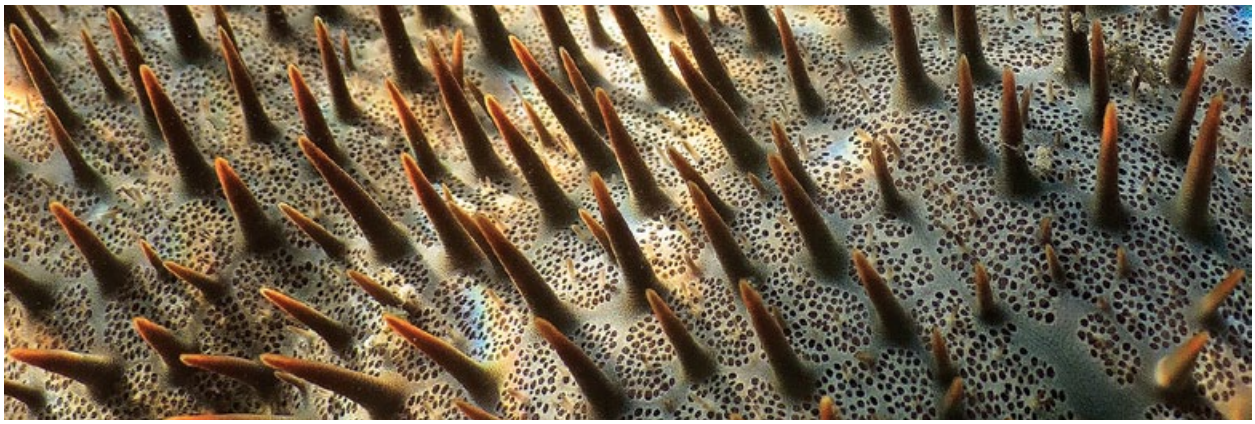

Wounds inflicted by COTS spines can be very painful. (Image: Pascal Dumas)

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