Fisheries Newsletter

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In this issue

Editorial

Three articles in this issue are related to sharks. Not surprising as the critical status of many coastal and oceanic shark populations definitely calls for attention... and action.

First, Shelton Harley (p. 4) reports about a recent SPC study showing that some tuna longline boats operating in the equatorial Pacific Ocean were specifically targeting sharks by adding shark lines to their fishing gear. The results of the study helped reinforce the call for a ban of this technique, which was partly adopted at the December meeting of the Western and Central Pacific Fisheries Commission.

Second, Éric Clua and Serge Planes (p. 19) summarise the discussions of a five-day workshop dedicated to find ways "to reinforce the partnership between sharks and humans". According to the authors, if the workshop conclusions had to be summarised in only one statement, it would be "A sole priority: Take action".

Third, Shelley Clarke (p. 49) uses four common suppositions about the relationship between shark fishing and the shark trade to explore several ways that shark catch and trade data could be used in combination to better conserve shark populations. She concludes by observing that while humankind's constantly increasing appetite for sharks poses a great threat to their populations, "it also represents a powerful opportunity to strengthen fisheries management by using trade statistics as a new tool for conservation".

Aymeric Desurmont
Fisheries Information Specialist (aymericd@spc.int)

Hammerheads are among the shark species that most need protection (image: Alan C. Egan, http://alancegan.com).

Secretariat of the Pacific Community

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

What do tuna look for in the deep sea?

SPC and the French Institute of Research for Development (IRD) joined forces to try to answer this question during the scientific cruise of the Nectalis 3. The cruise received support from the French Agency for Marine Protected Areas (AAMP).

The main objective of the cruise was to sample micronekton, the 2–20 cm-long fish, squids, crustaceans and gelatinous organisms that constitute part of the diet of tuna. Food availability is an important driver of the spatial distribution and quantity of tuna. Tuna move from one area to another in search of food to maintain their high energetic needs. Understanding where the tuna prey food is located will help understand the movements of tuna and the ups and downs observed in tuna catches from the fisheries.

A team of six scientists from SPC and IRD joined the IRD research vessel *Alis* for three weeks in November–December 2014 to explore the southwestern part of New Caledonia's exclusive economic zone (EEZ), where albacore tuna is the main tuna species exploited by New Caledonia commercial fishermen.

The physical data collected (e.g. temperature, currents) show that the northern part of the cruise took place in warm waters influenced by the equatorial warm pool and the southern part of the cruise was conducted in cooler waters characteristic of the return current of the East Australian Current. Several eddies were crossed along the track. Phytoplankton measurements show that the surface waters had low levels of phytoplankton while the maximum amount of phytoplankton was found at a depth of 100 m. Detailed analyses of collected physical data, nutrients, phytoplankton, zooplankton and micronekton still need to be conducted, but overall, it will allow us to understand how the physical and biological oceanography are connected, and the temperature and nutrient conditions needed for phytoplankton to multiply and allow the development of a food web constituting zooplankton, micronekton and tuna.

Micronekton was sampled using a large net towed in midwater depths between 16 m and 590 m, catching organisms that were frozen and that SPC taxonomist will identify in the coming months. Along the cruise track, the research team also used several acoustic sounders to record the signal sent by micronekton. The acoustics will give information on the spatial distribution of micronekton in the EEZ and within the water column. Preliminary results show that quantities of micronekton were higher in the southern part of New Caledonia's EEZ, and vertical profiles demonstrate the known daily vertical migration of micronekton from the surface at night, down to depths of over 400 m during the day.

Content of a micronekton net showing deep dark myctophid fish, transparent fish larvae, small squids with luminescent organs, and small shrimps, a delicacy for tuna (image: Elodie Vourey, SPC).

These data will allow us to identify areas of high and low micronekton productivity and biodiversity. The location of these areas will be further analysed to determine if they match the areas of high and low tuna catch per unit of effort. This information will be crucial for fisheries managers, both for identification of areas of interest for conservation and for tuna management.

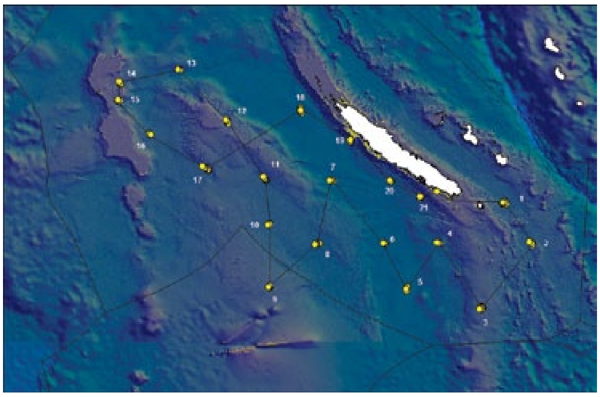
For more information:

Nectalis 3 daily logbook: www.spc.int/oceanfish/en/ofpsection/ema/biological-research/nectalis/419-nectalis-3-journal-logbook

Results of previous Nectalis 1 and 2 cruises:

Hunt B.P.V., Allain V., Menkes C., Lorrain A., Graham B., Rodier M., Pagano M. and Carlotti F. 2014. A coupled stable isotope-size spectrum approach to understanding pelagic food-web dynamics: A case study from the southwest sub-tropical Pacific. Deep Sea Research Part II Topical Studies in Oceanography. doi:10.1016/j.dsr2.2014.10.023

Menkes C.E., Allain V., Rodier M., Gallois F., Lebourges-Dhaussy A., Hunt B.P.V., Smeti H., Pagano M., Josse E., Daroux A., Lehodey P., Senina I., Kestenare E., Lorrain A. and Nicol S.J. 2014. Seasonal oceanography from physics to micronekton in the south-west Pacific. Deep Sea Research Part II Topical Studies in Oceanography. doi:10.1016/j.dsr2.2014.10.026



Cruise track and location of sampling stations (yellow dots).

Contacts:

Valérie Allain
Fisheries Research Scientist, SPC
valeriea@spc.int

Christophe Menkes
Oceanographer, LOCEAN, IRD
christophe.menkes@ird.fr

Elodie Vourey
Laboratory assistant, SPC
elodiev@spc.int

Crew preparing the micronekton net for trawling (image: Florian de Boissieu, IRD).

The best way to protect heavily depleted shark populations? Stop trying to catch them!

The silky shark is one of two heavily depleted pelagic sharks in the western and central Pacific (image: Alan C. Egan).

It was previously thought that the two heavily depleted pelagic sharks in the western and central Pacific — the silky and the oceanic whitetip — were victims of unintended bycatch. A startling new study by SPC, however, shows that sharks are actually being specifically targeted by some tuna longline boats operating in the equatorial Pacific Ocean.

Dr Shelton Harley, Principal Fisheries Scientist in SPC's Oceanic Fisheries Programme, said:

> The results of this work were quite unexpected and pretty exciting. We knew that almost all the longline catch of these species was caught by boats targeting tuna but, when we analysed the data collected by independent Pacific Island fisheries observers, we discovered that a lot of the sharks were being caught on special lines with wire traces and shark bait attached to the floats on the longlines. In fact, these lines took up to half of all silky and oceanic whitetip sharks captured on the observed longline trips.

These findings were heralded as great news by the Pacific Islands Forum Fisheries Agency (FFA). "Both of these species are in a bad way and if it was accidental bycatch then it might be a difficult problem to solve, but here we see that the main problem is these appropriately named 'shark lines' (see Fig. 1). FFA members proposed that these shark lines be banned in 2013, but some fishing countries argued that the technique was important for non-shark species," said FFA Deputy Director-General, Wez Norris.

The recent study found, however, that no less than 12 of the top 15 species caught on these special lines were sharks (Fig. 2); mahi mahi (2nd), great barracuda (7th) and wahoo (12th) were also caught on these lines. In addition to silky shark (1st) and oceanic whitetip shark (3rd), the list included several other shark species that have been recognised by international organisations as being of concern, such as tiger sharks and two species of hammerhead sharks.

Based on these findings and the confirmation that shark-targeted fishing is occurring in the western and central Pacific where the highly depleted silky and oceanic whitetip sharks are found, FFA members again called for banning this fishing technique at the Western and

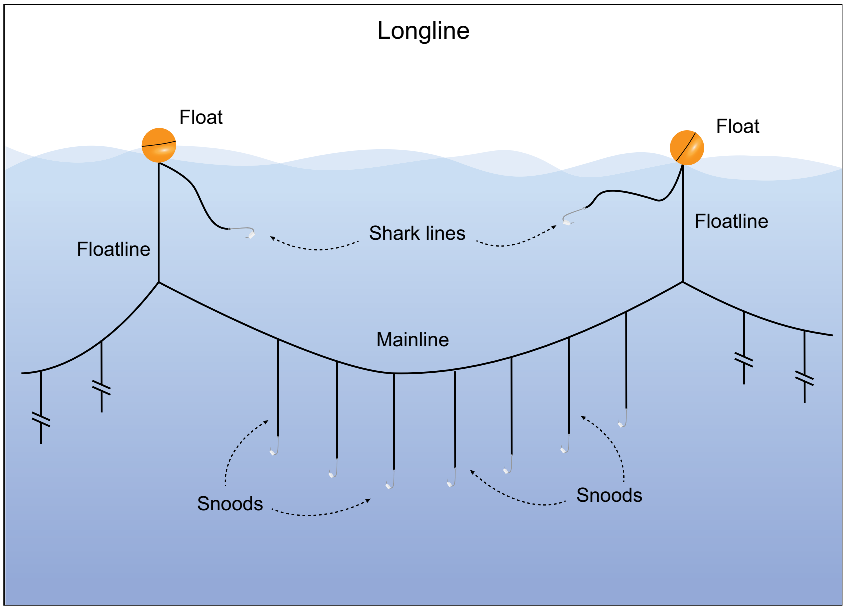


Figure 1. How shark lines are added to tuna longlines.

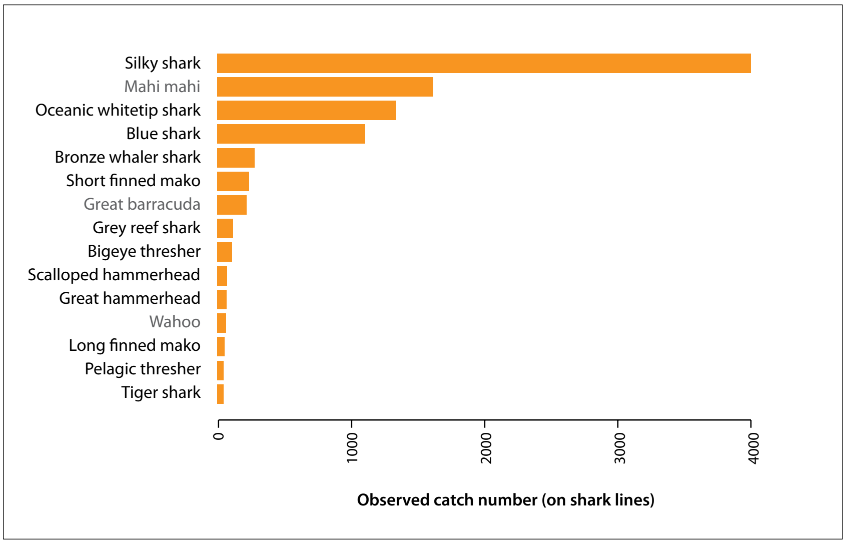


Figure 2. The 15 main species caught on shark lines during the observed fishing trips.

Central Pacific Fisheries Commission meeting held in Apia, Samoa, in December 2014. In one of the few agreements made at the meeting, it was agreed that vessels either not use lines directly attached to floats or not use wire leaders.[1] Further, the Commission agreed that any country that has shark-targeted fisheries must provide a plan to the Commission that explicitly demonstrates how the fisheries aim to avoid or reduce catch and maximise the number of live releases of silky and oceanic whitetip sharks caught incidentally. The effectiveness of this measure will be reviewed in two years.

For more information:

Shelton Harley
Principal Fisheries Scientist, SPC
sheltonh@spc.int

[1] https://www.wcpfc.int/system/files/CMM%202014-05%20Conservation%20and%20Management%20Measure%20for%20Sharks.pdf

Predicting the distribution of deepwater snappers in the western and central Pacific Ocean

Deepwater snappers are a significant resource for many Pacific Island countries and territories (PICTs) where they have supported important domestic and export markets for decades. Rapid expansion in deepwater snapper fisheries occurred during the 1970s but was soon followed by declines only two decades later, mainly due to lower catch rates, unreliable access to export markets, and a shift towards tuna longlining, which was more profitable at the time.

Recently, there has been interest in re-developing deepwater snapper fisheries in the Pacific in recognition of the limited potential for further commercial development of shallow reef and lagoon fisheries in the region, and the perception that there are unexploited populations in more distant locations. However, policy-makers are approaching such expansion with caution because there is limited information on the extent of deepwater snapper habitat and the potential sustainable yields.

Across the western and central Pacific Ocean (WCPO), over 20 PICTs have: 1) active deepwater snapper fisheries, 2) participated in deepwater snapper fisheries historically, or 3) expressed some interest in developing this capacity. It is plausible that many of these nations are exploiting the same stocks, given the wide distribution of most target species, and the potential for substantial connectivity among deepwater snapper populations across large geographical areas. Collaboration among PICTs, based on a consensual mapping of deepwater snapper habitats, could provide the basis for better management of deepwater snapper resources in the region.

There are no resources available, however, to conduct the comprehensive surveys needed to create detailed maps of deepwater snapper habitat throughout the Pacific. In the absence of detailed maps, the distribution of deepwater snapper habitat can only be estimated from available data. This report describes a modelling approach that combines available fisheries and oceanographic data to predict the distribution of deepwater snappers in the WCPO.

Methods

Scientists in the Oceanic Fisheries Programme at SPC used state-of-the-art computer modelling techniques and existing fisheries and oceanographic data to identify which oceanographic factors are most influential in determining the distribution of deepwater snappers. These factors were then used to predict the potential distribution of deepwater snappers across the WCPO.

Fisheries data

There are at least 20 species of deepwater snappers in the Pacific Ocean. The most common species captured by deepwater fisheries are listed in Table 1. Information on where these species are present was collated from previous SPC research surveys and from New Caledonia and Tonga fisheries data. The less common species of deepwater snapper were not considered, including Tang's snapper (*Lipocheilus carnolabrum*), saddle-back snapper (*Paracaesio kusakarii*), cocoa snapper (*P. stonei*), yellowtail blue snapper (*P. xanthura*), Vanuatu snapper (*P. gonzalesi*), and Randall's snapper (*Randallichthys filamentosus*), because these species are only a minor component of the catch and there was insufficient location information available. The species were grouped by genus (i.e. *Etelis*, *Pristipomoides* and *Aphareus*) for all data because often the particular species was not recorded. Although the habitat preference of species within each of these groups may vary, previous research shows a similar depth preference among species within each group.

Table 1. List of deepwater snapper species commonly captured in the Pacific Ocean.

Species name	Common name
Etelis carbunculus	Ruby snapper
Etelis coruscans	Flame snapper
Etelis marshi	Pygmy ruby snapper
Etelis radiosus	Scarlet snapper
Pristipomoides multidens	Goldbanded jobfish
Pristipomoides zonatus	Oblique-banded snapper
Pristipomoides filamentosus	Crimson jobfish
Pristipomoides flavipinnis	Golden eye jobfish
Pristipomoides argyrogrammicus	Ornate jobfish
Pristipomoides sieboldii	Lavender jobfish
Pristipomoides auricilla	Goldflag jobfish
Pristipomoides typus	Sharptooth jobfish
Pristipomoides squamimaxillaris	Scalemouth jobfish
Aphareus rutilans	Rusty jobfish

Physical and oceanographic data

The distribution of deepwater snappers was considered to be most influenced by depth, slope and temperature. Global bathymetric data, available at a spatial resolution of 0.016° (~1.85 km^2), was used to determine the depth (m) and slope (%) of the ocean floor. Global temperature-at-depth data, available at a spatial resolution of 0.25° (~15 km^2), was used to determine the average temperature at 0–50 m and 50–100 m.

Distribution modelling

Species distribution models were used to predict the distribution of deepwater snappers. First, a subset of fisheries and oceanographic data was selected from New Caledonia and Tonga, where the most reliable fisheries data were available. These data were used in models to evaluate which oceanographic factors were most important in determining the distribution of deepwater snappers. The models used the depth, slope, and temperature information at each location where deepwater snappers were captured to evaluate how influential each variable was in predicting where deepwater snappers were captured.

Second, the full set of fisheries and oceanographic data was used in species distribution models to predict the distribution of deepwater snappers across the WCPO. Maps of predicted deepwater snapper habitat were generated for the three species groups: *Etelis*, *Pristipomoides* and *Aphareus*. The area and proportion of predicted habitat for each species group was then calculated for the exclusive economic zones (EEZs) of 32 countries, territories or island groups.

Results

Oceanographic factors

Depth was the best predictor of presence for all deepwater snapper species, while slope and temperature-at-depth were much poorer predictors (Fig. 1).

Habitat distribution across the WCPO

Maps of predicted distribution of deepwater snapper habitat across the WCPO are shown in Figure 2. There were strong regional patterns in the predicted distribution of suitable habitat for deepwater snappers, with large areas of suitable habitat predicted in some EEZs, and more limited habitat predicted in others.

The highest proportion of suitable habitat was predicted in South Pacific EEZs, between approximately 15°S and 25°S (Table 2). Over 70% of cells within Tonga's EEZ and at least 30% within the EEZs surrounding Fiji, Wallis and Futuna, Vanuatu, New Caledonia, and Matthew and Hunter were predicted to contain suitable habitat for all three deepwater snapper species groups.

In contrast, less than 5% of 0.25° cells within the EEZs surrounding Australia, Howland and Baker, Jarvis, and Nauru were predicted to contain suitable habitat for all three species groups (Table 2). It is important to note that suitable habitat area was calculated using the total area of 0.25° cells within which suitable habitat was predicted, so it potentially overestimates the area of actual suitable habitat area (i.e. the area of suitable habitat in the cell may be much smaller).

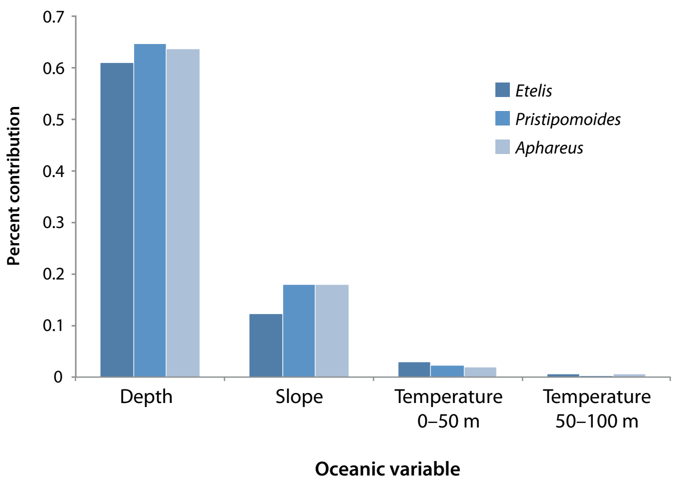


Figure 1. Relative contribution of oceanographic variables to model predictions of the presence of Etelis, Pristipomoides *and* Aphareus.

Table 2. Potential area ('000s km²) and proportion (prop) of suitable habitat of deepwater snapper species within the exclusive economic zones (EEZs) of 32 countries, territories and island groups from models at 0.25° spatial resolution. Note that potential area was calculated using the total area of 0.25° cells within which suitable habitat was identified and, therefore, provides an upper bound for actual habitat area. Estimates of unexploited biomass were available for the EEZs of 23 countries and territories (Dalzell and Preston 1992).

Country or territory	*Etelis*		*Pristipomoides*		*Aphareus*		Estimated unexploited biomass (t)
	area	prop	area	prop	area	prop	
American Samoa	18.5	0.04	23.1	0.06	30.8	0.07	-
Australia*	733.1	0.04	817	0.04	832.4	0.05	-
Cook Islands	85.5	0.04	139.4	0.07	244.9	0.12	413
East Timor	10.8	0.11	39.3	0.42	55.4	0.59	-
Federated States of Micronesia	90.1	0.03	301.9	0.10	410.4	0.14	1489
Fiji	714.6	0.50	828.6	0.58	914.1	0.64	4092
French Polynesia	429.7	0.08	571.4	0.11	662.3	0.12	3427
Guam	13.9	0.06	47.7	0.21	95.5	0.42	22
Howland and Baker	0.8	0.00	12.3	0.29	21.6	0.05	-
Indonesia*	224.1	0.03	834.7	0.11	1271.4	0.16	-
Jarvis	0	0.00	0	0.00	9.2	0.03	-
Kiribati (Gilbert Islands)#	44.7	0.04	91.6	0.09	97.8	0.09	731
Kiribati (Northern Islands)#	33.1	0.02	91.6	0.06	135.5	0.08	731
Kiribati (Phoenix Islands)#	23.1	0.03	57.8	0.08	64.7	0.09	731
Marshall Islands*	42.4	0.02	172.5	0.08	274.1	0.13	1108
Matthew and Hunter	90.1	0.38	84.7	0.35	67	0.28	-
Nauru	1.5	0.50	1.5	0.50	3.1	0.01	3
New Caledonia	517.5	0.41	504.4	0.40	471.3	0.37	1089
Niue	26.2	0.08	24.6	0.07	50.8	0.15	70
Northern Mariana Islands*	9.2	0.01	23.9	0.03	43.1	0.05	236
Palau	10	0.02	32.3	0.05	50.1	0.08	162
Palmyra	4.6	0.02	35.4	0.12	44.7	0.15	-
Papua New Guinea	363.5	0.13	736.2	0.25	944.9	0.33	4881
Philippines	110.1	0.05	194.1	0.09	276.5	0.12	-
Pitcairn Islands	51.6	0.05	53.9	0.05	46.2	0.05	11
Samoa	22.3	0.16	37	0.27	41.6	0.30	190
Solomon Islands	205.6	0.12	463.6	0.28	606	0.36	1711
Tokelau	15.4	0.04	39.3	0.11	64.7	0.18	99
Tonga	528.3	0.72	551.4	0.75	557.5	0.76	1125
Tuvalu	97	0.13	177.9	0.23	249.5	0.33	224
Vanuatu	250.3	0.35	301.1	0.42	345	0.48	980
Wallis and Futuna	127.1	0.48	147.9	0.56	153.2	0.58	102

* = partially covered by the present model
\# = biomass estimate derived from all three EEZ areas

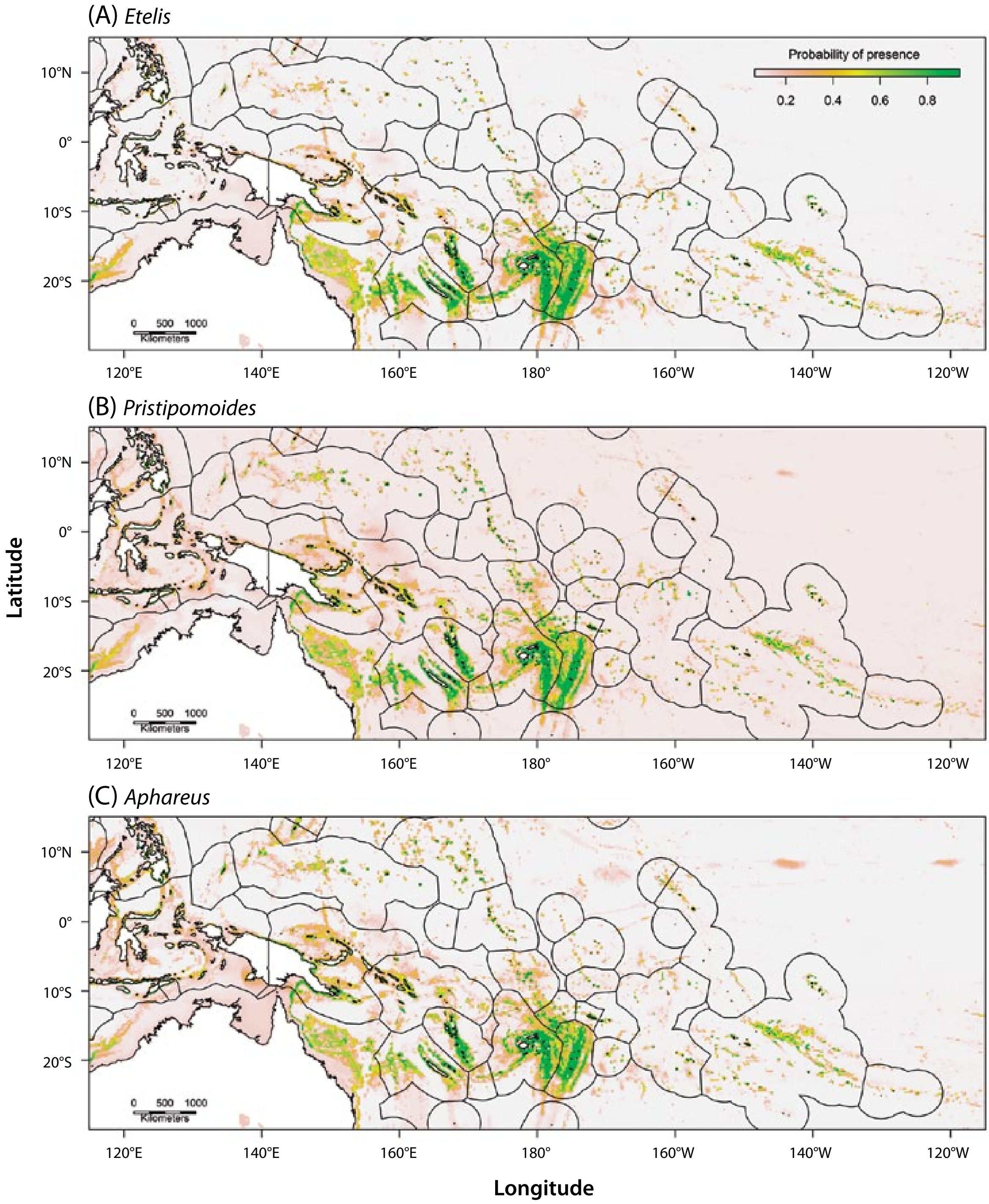


Figure 2. Predicted distribution of Etelis *(A),* Pristipomoides *(B) and* Aphareus *(C) in the western and central Pacific Ocean.*

The amount of predicted habitat also varied among species groups, with the proportion of cells predicted to contain suitable habitat highest for *Aphareus* and lowest for *Etelis* in almost all EEZs (Table 2).

Rudimentary assessments of deepwater snappers in the Pacific Islands region provide preliminary estimates of unexploited biomass for 23 PICTs based on data from depletion experiments and estimates of the length of the 200-m isobaths within each country (Dalzell and Preston 1992). The relationship between estimated unexploited biomass for each country and predicted habitat area from this study is positive (Fig. 3), supporting the assertion that opportunities for significant development of deepwater snapper fisheries are likely to be limited in PICTs where predicted habitat area is low.

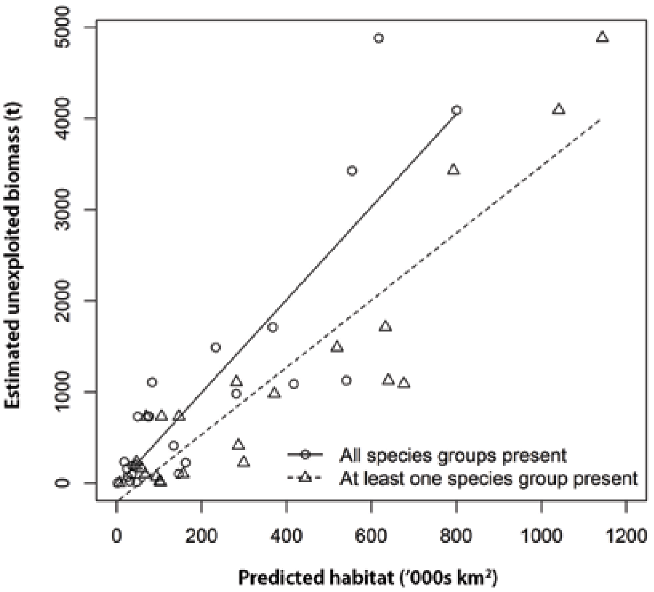


*Figure 3. Relationship between estimated unexploited biomass (source: Dalzell and Preston 1992) and predicted suitable habitat of deepwater snapper within the EEZs of 23 Pacific Island countries (estimates of unexploited biomass were not available for all countries — see Table 2). Each data point represents an EEZ, and data are shown for predicted habitat when all three species groups (*Etelis, Pristipomoides, Aphareus*) and at least one species group were predicted to be present within an EEZ.*

Conclusions

- ✓ The maps of deepwater snapper habitat provide a useful baseline for the development of monitoring programmes and spatial management plans for deepwater snappers.
- ✓ Opportunities for development of deepwater snapper fisheries are likely to be limited for many countries and territories north of approximately 15°S due to the relatively small area of predicted habitat for the three main deepwater snapper species groups.
- ✓ The predicted habitat does not consider abundance, and so it will be necessary to obtain information on the local abundance of deepwater snapper species to estimate potential yields. However, the relationship between estimated unexploited biomass and predicted habitat area is positive, suggesting that opportunities for significant development of deepwater snapper fisheries are likely to be limited in countries and territories where predicted habitat area is low.
- ✓ The larger area of predicted habitat for *Aphareus* and *Pristipomoides* compared with *Etelis* might indicate greater potential for exploitation of these species. However, *Aphareus* and *Pristipomoides* are usually found in lower abundance than *Etelis* and often fetch a lower market price.
- ✓ The accuracy and precision of predicted deepwater snapper habitat from the models are only as good as the available oceanographic data. The resolution of these data is very coarse (0.25°) and much of the Pacific Ocean remains unsurveyed. Bathymetric data have been estimated from satellite data for unsurveyed areas.
- ✓ Detailed bathymetric surveys will be required if more accurate and precise habitat information is desired for deepwater snapper or other resources.

References

Dalzell P. and Preston G.L. 1992. Deep reef slope fishery resources of the South Pacific: A summary and analysis of the dropline fishing survey data generated by the activities of the SPC Fisheries Programme between 1974 and 1988. Inshore Fisheries Research Project, Technical document no. 2. South Pacific Commission, Noumea, New Caledonia.

Acknowledgements

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For more information:

Ashley Williams
Deepwater Snapper Scientist, SPC
ashleyw@spc.int

Simon Nicol
Principal Fisheries Scientist
simonn@spc.int

Bagan and pole-and-line fishing trials in Kavieng, Papua New Guinea

Industrial pole-and-line fishing has seen its "boom and bust" days in the Pacific Islands region, thriving in some places throughout the 1970s and 1980s and then almost disappearing by the mid-1990s. Nowadays, the only industrial pole-and-line fishery still operating in the region is run by the Tri Marine Group in the Solomon Islands, with four pole-and-line boats as part of its fleet that includes purse-seine vessels.

Pole-and-line fishing can be adjusted to target specific fish species and sizes. In the Pacific Islands region it is mostly used to target skipjack tuna and, to a lesser degree, large yellowfin tuna, for the canning factories. Bycatch species include rainbow runner, frigate mackerel, dolphin fish, and small yellowfin tuna. However, in the region no part of the fish goes to waste. Whatever the canning factories do not use is sold by the crew or taken home for the family. Unlike purse-seine or longline fishing, pole-and-line fishing almost totally excludes bycatch of protected species such as marine mammals, sharks or turtles. This is why pole-and-line fishing is generally considered to be one of the most "environmentally friendly" tuna fishing techniques.

Pole-and-line and *bagan* fishing trials

During September 2014, a two-week, small-scale pole-and-line fishing trial was conducted in Kavieng, Papua New Guinea (PNG), using the *bagan* bait fishing method to supply live bait for the operation. The trial was conducted under the auspices of the Pacific Islands Forum Fisheries Agency (FFA)/DEVFISH and the PNG National Fisheries College (NFC), with support from SPC. Both pole-and-line and *bagan* fishing methods were reviewed in order to assess the potential revival of industrial pole-and-line fishing in PNG's New Ireland Province (NIP). Two advisors, Dr Antony Lewis and William Sokimi, were engaged to work with NFC Commercial Fishing Operations staff to undertake the review.

Dr Lewis is a well-known fisheries scientist in the Pacific Islands region and a former head of SPC's Oceanic Fisheries Programme. He is a former coordinator of several large-scale tuna tagging projects on chartered pole-and-line vessels in the western and central Pacific Ocean (WCPO) area and has also carried out tuna and baitfish studies and small-scale, pole-and-line fishing in PNG. William Sokimi is SPC's Fisheries Development Officer (Fishing Technology) and a former pole-and-line and tuna longline Captain/Fishing Master with wide experience in many aspects of tuna fisheries in the WCPO area.

This study was the third phase of the work carried out by FFA/DEVFISH Fisheries Development Officer, Robert Stone, who made two previous visits to initiate the construction of the *bagan* platform and the restoration of the fishing vessel, and to run the first fishing trials.

Pole-and-line fishing vessel

The FTV *Malui* is a 15-m, fibreglass pole-and-line fishing vessel built in Indonesia, brought to Kavieng in 1997 (by a local fisherman), and bought and restored by NFC in 2009 to be used as an experimental and training platform.

The restored FTV Malui is ready for fishing.

Bagan

A *bagan* is a moored platform used to catch food fish and small baitfish for the pole-and-line fishery. Fishing takes place at night, using powerful lamps to attract baitfish. The lamps are turned off one-by-one in order that only one lamp is left on over a wide net that is lifted when a sufficient number of baitfish have been attracted to the light.[1]

Bagan fishing is widely practiced in Indonesia. In 2013, four Indonesian fishermen were hired by the FFA/DEVFISH project to supervise the construction of the *bagan* at Nago Island, off Kavieng.

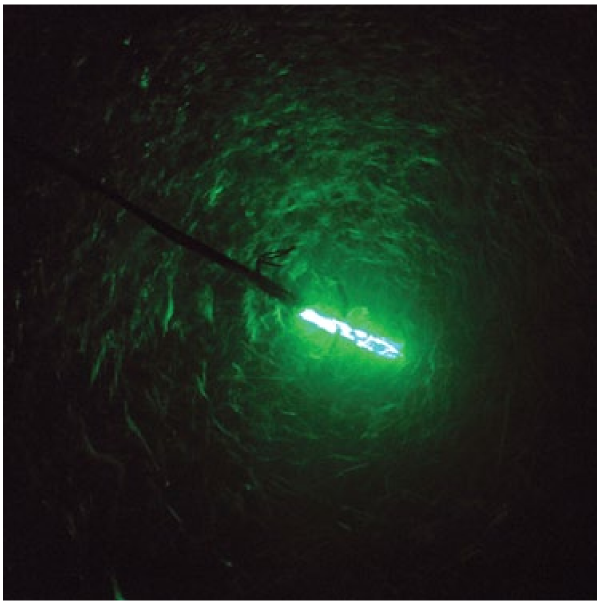
Bagan and pole-and-line fishing activities

The first week of the trial was used to work on both the *bagan* platform and the FTV *Malui* and prepare them for the trials ahead. From the second week onwards, the fishing trials took place with six nights spent on the *bagan* catching baitfish (including silver sprat, blue sprat, gold-spot herring, hardy heads, cardinals and the spotted sardinella) and four days on the boat pole-and-line fishing. The operation involved 10 or more people, including NFC staff and hired casuals.

Bait fishing was conducted at two locations fringing Kavieng Harbour. These areas were far from the main bait fishing grounds that were used on pole-and-line fishing days but were convenient to start off the operations, and were close to the NFC base in case major adjustments needed to be made to the system. Thirteen bait fishing operations produced 143 2-kg buckets of usable bait, which was sufficient to almost fill the three bait tanks on the FTV *Malui* for each of the four pole-and-line trips. Throughout the trials, improvements were made to the gear and technique in order to increase efficiency. The system could be refined even more if this were to be a long-term process.

The *bagan* bait fishing procedure is very similar to the *bouke-ami* system in terms of luring and centralising bait around a light at night. In Indonesia, most systems use a series of above-water lamps that are all turned on at dusk to lure baitfish towards the *bagan*. The net — a lift net made from light weight nylon filament — is lowered immediately after the lights are turned on. When a sufficient number of baitfish have aggregated around the *bagan*, the lights are gradually turned off until only a single dim light is left on and centrally located above the netting area. After an adequate amount of time has been given for the bait to aggregate under the light the net is lifted and the baitfish are entrapped.

During the fishing trials in Kavieng, two 500-W HydroGlo underwater lights and six Coleman (250 lumen) lamps were used. The underwater lights had a dimmer switch that further enhanced the close aggregation of the baitfish around the remaining light. An echo sounder was also used to better observe the aggregation of the baitfish and to signal the optimum time to close the net. Without an echo sounder, the net can be prematurely closed if the baitfish are not given sufficient time to draw in closer to the light. The echo sounder picks up this movement and can identify when the baitfish have reached the proper depth for entrapment.



Baitfish aggregated around an underwater light before the net is closed.

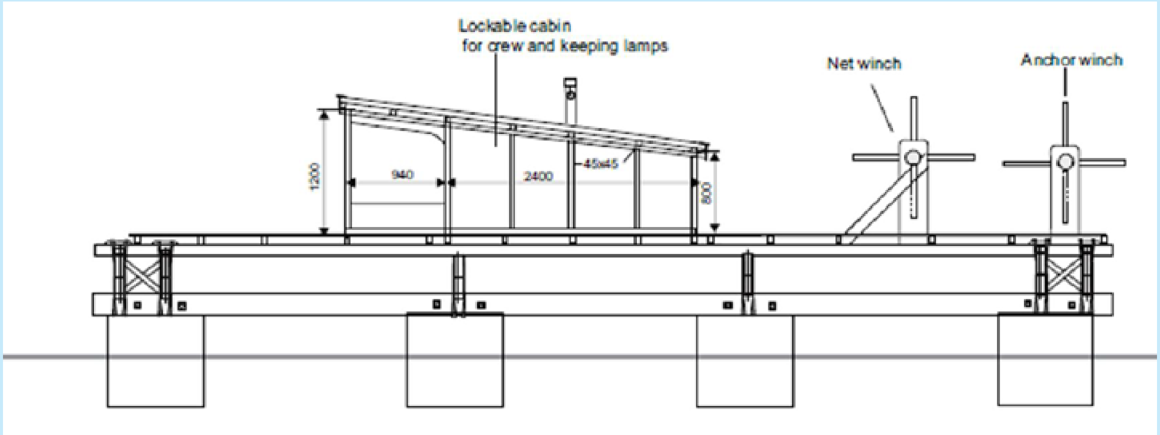
Pole-and-line fishing was carried out at two fish aggregating device (FAD) locations. Overall, the fishing was poor, probably because the season was not optimal for skipjack tuna in the area. Schools of juvenile yellowfin tuna were encountered close to the FADs and in running schools, but they could not be enticed to encircle the vessel like skipjack usually do. They were attracted to the bait, and passed beneath the vessel but not within range of the lures. The "sprays"[2] and chumming techniques worked reasonably well, but the sprays were only fitted on the bow. Using stern sprays could have made a difference to catching yellowfin tuna.

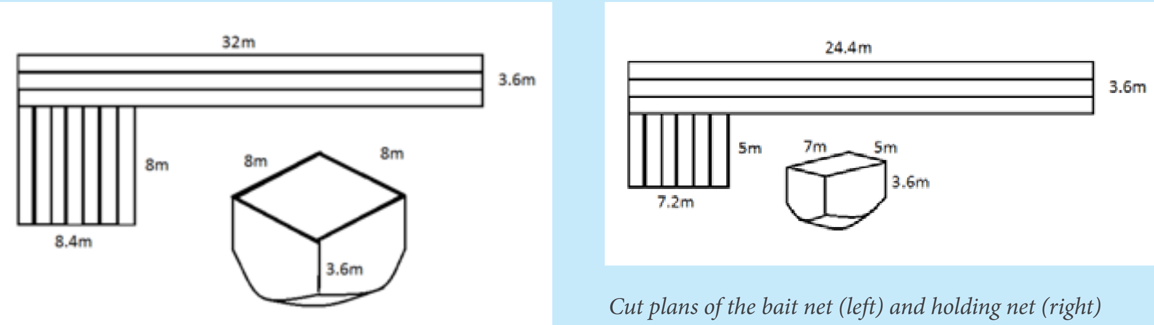
[1] See for more details: http://www.spc.int/DigitalLibrary/Doc/FAME/InfoBull/FishNews/137/FishNews137_13_SharpBagan.pdf

[2] The "sprays" are flattened nozzles spaced about 70 cm apart around the bow area that sprays or sprinkles water on to the sea surface to excite and confuse tuna into thinking there is a lot of bait activity around the vessel. The sprays also partly "hide" the fishermen hovering above the water with their poles.

Bagan characteristics

✓ *Bagan* frame: 10 m x 10 m
✓ *Bagan* net: 8.4 m x 8.4 m x 4 m deep, on frame; windlass with pulleys
✓ Net mesh: 5 mm square mesh, nylon; stretched mesh: 7 mm
✓ Holding/keeper net: 6 m x 4 m x 4 m
✓ Lighting: 5–6 Coleman electric lamps (250 lumen) + 2 x 500 w HydroGlo lights
✓ Buckets: 2.0 kg each (estimated)





Cut plans of the bait net (left) and holding net (right)

The bagan platform ready for the trials

Results of the trials

In a briefing session with NFC staff and the local fishermen involved during the trials, several technical issues and possible improvements were identified for all operations. However, after the trials, it was determined that a revival of the pole-and-line fishery in NIP, at least on a commercial scale, was unlikely under the prevailing circumstances. It was also estimated that the FTV *Malui* was not properly adapted to assess the feasibility of such a revival.

According to William Sokimi, a possible alternative to further evaluate the feasibility of a pole-and-line operation in the area would be for the NIP administrative council to enter into an agreement with Tri Marine Group, and have one of their fully manned boats with trained crew carrying out pole-and-line fishing operations over a set term during the peak skipjack season in NIP waters. The results of the experiment would give a better idea of the economical feasibility of a pole-and-line operation in NIP.

A bagan *could be used to catch food fish for a community*

A *bagan* could be a good tool to contribute to community food security because it targets stocks of species that are still healthy in most parts of the Pacific Islands region. But, if a *bagan* is to be owned and run by a community, several issues will need to be addressed, such as: Who has the right to use it? Who pays maintenance costs? How will the catch be sold and/or distributed? Community-owned and operated fishing tools are not common in the Pacific Islands region, as they are in many parts of Asia; sorting out these logistical and operational issues will require innovative ideas.

A bagan *could also be a good tool to produce live bait for pole-and-line operations*

In PNG and the Solomon Islands, many coastal fishing ground owners have closed off their territories to bait fishing activities. However, if they were trained in *bagan* operations and could earn a living from harvesting their own baitfish, they might be willing to supply bait to pole-and-line boats. However, because pole-and-line fishing requires live bait, which has a very limited lifespan, the timing of the bait fishing needs to be closely matched with the timing of the pole-and-line fishing. Pole-and-line operators are, therefore, reluctant to rely on outside entities to provide live bait. Yet again, these are logistical issues that can be overcome with careful planning and motivation. The system could work, but it would require consistent and reliable community involvement. How to obtain it will be the biggest challenge to be faced, if such an operation were to be set up.

For more information:

William Sokimi
Fisheries Development Officer, SPC
williams@spc.int

All images in this article by William Sokimi

Fishing crew anxiously waiting for a school of juvenile yellowfin tuna approaching the vessel.

Pacific Islands fisheries observers

Sixty-seven fisheries observers were trained in 2014 by SPC with financial support from the Pacific Islands Forum Fisheries Agency. National training courses were conducted in a number of countries and one subregional training was held at the Vanuatu Maritime College for Fiji, Nauru, Samoa, Tonga, Tuvalu and Vanuatu. A national training was held in early 2014 for the Marshall Islands national fisheries observer programme. Refresher training courses were conducted in Tonga and Tuvalu, and an upgrade training was conducted for Nauru and Solomon Islands.

Fisheries observer basic training runs for seven weeks, two weeks of which include general training in sea safety, basic first aid, firefighting, occupational health and safety, and restricted radio communication. Another five weeks of training focus on fisheries observer professional development. The basic training enables new recruits to undertake all the current basic tasks that a certified Pacific Islands Regional Fisheries Observer (PIRFO) is expected to carry out on either a purse-seine or longline vessel. It includes a module on the basics of fish biology and a module to teach how to raise awareness among fishermen and other possible tag finders about the importance of recording and filling out the correct information on tag recovery forms. Making sure that found tags are returned is important, but of little use if the information provided with the tag is incorrect. Staff of SPC and country PIRFO trainers deliver the five-week training, while colleges and maritime schools conducted the two-weeks training.

More information on PIRFO training and certification can be found at: http://www.spc.int/oceanfish/en/certification-and-training-standards

Glen English (SPC Observer Training and Support Officer) demonstrates how to identify fish and fish organs during a biological sampling session.

Observer refresher training

This is an extra training that gets new observers up to speed with new forms and new sampling protocols. Refresher training can be short or long, depending on how much the coordinator and trainers want to cover. A refresher training should be discussed with regional experts in case there is an opportunity to introduce updates, and so that they can be involved in coordinating training activities and ensuring consistency among programmes.

Observer gear-type upgrade training

Occasionally, usually because of time and resource constraints, a Basic Training on a single gear type may be delivered. The resultant Observer Certificate should reflect this (e.g. Certified to work on longline vessels only). In such cases, an Upgrade Training may also be delivered later to ensure that observers can then have their limited certificate upgraded to an "all-gear types" certificate.

For more information:

Siosifa Fukofuka
Observer Training and Support Officer (EU-SciFish Project), SPC
siosifaf@spc.int

2014 PIRFO training.

Type of training	Fiji	Tuvalu	Samoa	Tonga	Vanuatu	Nauru	Marshall Islands	Solomon Islands	America Samoa
Basic	2	6	1	1	2	1	14		1
Refresher		12		11					
Gear-type upgrade						4		12	

Niue coconut crab assessment and training

From 17 November to 5 December 2014, the Fisheries Division of Niue, in collaboration with SPC's Coastal Fisheries Programme, Science and Management Section, conducted a series of surveys to determine the status of coconut crabs on the island. The first two weeks were devoted to field surveys, followed by one week of interviews with long-time hunters, restaurant staff and other people involved in using, selling or exporting coconut crabs.

Previous coconut crab assessments on Niue took place in 1988, 1990 and 1997. Then, apart from of an assessment made in 2008 — the results of which were never published — no assessment has been made in the 17-year interim period.

Coconut crabs are highly prized as food and their ease of capture has contributed in their disappearance in many island countries. For Niueans, coconut crab is a local delicacy, eaten regularly and used in celebrations; it is sold locally or sent to compatriots living abroad. It is also used for eco-tourism, with visitors taking guided tours to view crabs in natural habitats. It is, therefore, important to ensure that coconut crabs remains abundant in Niue. On top of the reduction in biodiversity, which could badly affect the fragile Niuean ecosystem, the collapse of the coconut crab stock would have negative consequences for some traditional, sociological and economical aspects of life in Niue.

The current legislation prohibits the interference, taking or killing of coconut crabs with a thoracic length of less than 36 mm, individuals in berry and/or with a soft shell. Another regulation prohibits the export or the facilitation of export from Niue of coconut crabs in any form during the period from 1 December to 28 February each year, without the written approval of cabinet. This regulation remains in force although it has not been enforced following the initial written approval of cabinet to exempt the provision. Recent research and observations support the need for effective management and regulatory procedures in place to protect this iconic species in order to avoid unsustainable harvesting. There is no specific monitoring system in place to monitor compliance with these regulations, with the focus to date largely being on information and awareness.

The main objectives of the 2014 assessment were to gather information on the population size structure and distribution, and provide an estimate of population abundance. The study endeavoured to determine if changes in the population structure had occurred since the coconut crab surveys of the 1980s and 1990s, or when compared with unpublished results of the 2008 survey. Secondary objectives were to train local staff of the Department of Agriculture Forest and Fisheries (DAFF) in coconut crab assessment methods, and to develop survey protocols so that in the future, DAFF staff would be able to conduct assessments of coconut crab populations on their own.

The sampling design was developed using findings from previous studies and local knowledge. The timing of the survey coincided with the dark phase of the moon and during the summer wet season, which is the period when coconut crabs emerge from underground to begin foraging and migrating towards the coastline. In Niue, crab distribution is related to the distance from the coastline and type of vegetation cover. For these reasons, Niue's land area was divided into six habitat categories for the assessment:

1. 1 km from the coastline (primary forest)
2. 1 km from the coastline (light/scattered forest)
3. 1–2 km from the coastline (primary forest)
4. 1–2 km from the coastline (light/scattered forest)
5. >2 km from the coastline (primary forest)
6. >2 km from the coastline (light/scattered forest)

Habitats that were not surveyed included: the coastal and interior fern-land because this type of vegetation provides very poor habitat for coconut crabs; tapu areas in order to respect traditional obligations; and the limestone pinnacle area (particularly on the eastern portion of the island) due to the ruggedness of the terrain — a habitat suitable for coconut crabs but rather hostile for surveyors.

At each surveyed site within the selected habitat categories, bait trails were made and bait (opened coconut halves) was tied to tree roots or limestone coral. Three teams of three surveyors each set bait during the afternoons and then conducted night searches for coconut crabs. For each crab sampled, thoracic and cephalothoracic lengths, sex (if female: presence or absence of eggs), dominant colour, and weight were recorded.

The survey team is undergoing the data analysis. The final report should be completed and available to the public in March 2015. At the end of the field work, the survey team leader, assisted by SPC's Coastal Fisheries Science and Management Adviser, provided a brief summary of methods used, and preliminary results of overall population size structure and catch per unit of effort (number of crabs recorded per bait set) via an hour session on the local radio and at a public meeting.

Bait (opened coconut halves) was marked with red ribbons.

This coconut crab has a thoracic length of 31 mm. It is below the 36 mm size limit and so must be released alive.

For the early 1990s assessment, researchers on Niue had collaborated with coconut crab specialists from Vanuatu. The link was revived in 2014, when Malcolm Linawak, from the Vanuatu Fisheries Department, joined the SPC team for the Niue surveys. The arrangement facilitated coconut crab-related knowledge sharing between the two countries.

The information gathered from the three-week mission and the results of the 2014 survey will be used to determine if the management measures currently in place need to be revised, or if their proper enforcement and monitoring would be sufficient to ensure that the coconut crab population remains healthy. Preliminary results indicate an increase in population numbers. However, in comparison with the unpublished findings of the 2008 survey, the average thoracic length has decreased from 27 mm to 25 mm for females, and from 33 mm to 30 mm for males. It has been estimated that of the total population, less than 2% of females and less than 26% of males are above the legal minimum catch size of 36 mm thoracic length. These results suggest that the reproductive viable population may be declining. Increasing the minimum size catch limit is, therefore, required.

The Fisheries Division will inform communities about the status of the coconut crab resource and encourage their collaboration to address key management issues, monitor population numbers and establish harvesting levels.

Ian Bertram provides details on the survey's findings on a local radio station.

For more information:

Nadia Helagi
Data Manager, Niue Division of Agriculture, Forestry and Fisheries
nadia1.helagi@mail.gov.nu

Ian Bertram
Adviser, Coastal Fisheries Management and Science Section, SPC
ianb@spc.int

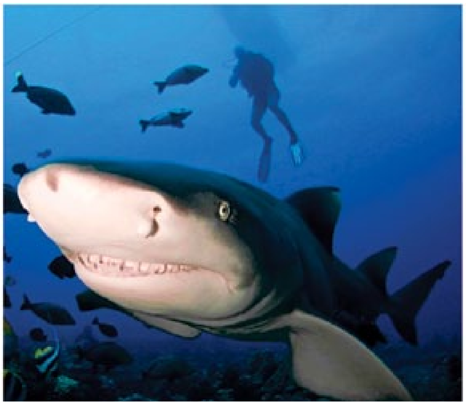
All images in the article by Ian Bertram.

The limestone pinnacle area was too rugged to be surveyed.

Sharks and humans: How to reinforce the partnership

Regional workshop, CRIOBE, Moorea, French Polynesia, 13–17 October 2014

Éric Clua[1] and Serge Planes[2]



A sole priority: Take action!

If the conclusions of the Pacific Coral Reef Institute (IRCP) workshop held on Moorea (French Polynesia) from 13 to 17 October 2014 had to be summed up in just a few words, the above statement, as simple as it is incisive, would probably be the best description. This symposium dealt with the overall topic of the sustainable development of shark populations in the South Pacific, particularly in response to pressures from humans. The meeting was funded at the initiative of the Pacific Fund for Scientific and Cultural Cooperation (French Pacific Fund), a French funding mechanism that promotes exchanges between French and English speaking territories in the Pacific, to work together on shared problems. Funding was also provided by the French Polynesia Shark Observatory (ORP), the IRCP and the French Ministry of Ecology, Sustainable Development and Energy. Sharks are a topic of concern and in order to better understand the priorities for ensuring sharks' protection while maintaining their contributions to island economies, about 30 specialists from various countries and territories (Australia, Colombia, Fiji, France, French Polynesia, New Caledonia, the United Kingdom, the United States of America, and Samoa), divided equally between members of research agencies[3], non-governmental organisations[4], regional organisations[5], governmental bodies[6], and the private sector (commercial divers, veterinarians, journalists) met to determine the wording of a message to Pacific Island decision-makers and managers.

Sharks, pillars of aquatic ecosystem processes

Specialists at the meeting first agreed on two key points for their discussions: 1) the disquieting disappearance of sharks and rays in the Pacific, even if this region of the world may appear to have been spared more than others, and 2) the need to look at the decrease in stocks from the perspective of the major role these animals play in marine ecosystems, both coastal and offshore. Not only do sharks contribute to the good health of ecosystems — by promoting biodiversity — but also to ecosystem productivity, a crucial point that could be translated by the statement, "The greater the number of sharks, the more fish there will be to catch!". The main factor in the decline of shark and ray populations is overfishing. Immediate action must be taken to reduce fishing mortality for sharks by all possible means.

1 Adviser, French Regional Technology and Research Office, French High Commission in French Polynesia. Email: eric.clua@gmail.com
2 Director of the French Island Research Centre and Environmental Observatory (CRIOBE). Email: serge.planes@criobe.pf
3 National Scientific Research Centre in France; the French École Pratique des Hautes Études; and James Cook University in Australia.
4 Malpelo Foundation; Islands First; Pew Charitable Trusts; World Wildlife Fund.
5 Western and Central Pacific Fisheries Commission; Secretariat of the Pacific Community; Secretariat of the Pacific Regional Environment Programme.
6 Department of Environment, French Polynesia.

Some of the 30+ workshop participants.

Overfishing is enemy #1

In spite of efforts over the past few years, particularly to reduce the shark fin trade, it is important to realise that the overall demand for shark and ray products is rising. In that regard, rays seem to be paying the price for the efforts made to spare sharks, which is a major risk for certain species of these flat, cartilaginous fish. The problem of the ongoing demand has simply modified supply, which adapts itself to new prohibitions and controls. In the specific case of the Pacific, for example, artisanal coastal fisheries have developed, which are completely outside any existing measures, whether for the purposes of statistics or control. Given that, the recent progress made in regards to including shark species on the Convention on International Trade in Endangered Species of Wild Fauna and Flora endangered list (Appendix II) will likely prove to be inadequate because the list only regulates the international trade of the species involved and not fishing. Effective long-term solutions are should be based on introducing strict quotas and fishing limits for sharks, subject to the development and more widespread use of new technologies such as video surveillance to efficiently control fisheries.

Inset 1: The Institute for Pacific Coral Reefs

The Institute for Pacific Coral Reefs (IRCP) is part of the École Pratique des Hautes Études (an applied higher studies institution), one of the leading scientific agencies of the French Centre for Insular Research and Observatory for the Environment (CRIOBE), based in Moorea, French Polynesia. This institute is designed to support regional dynamics in the area of transferring technical and scientific knowledge and skills to those involved in managing reef and coral ecosystems, with non-governmental organisations, associations or technical departments as the main beneficiaries. Among its activities, IRCP holds an average of two regional workshops on different topics each year, either in French Polynesia or in a Pacific Island country (e.g. recently Fiji and the Solomon Islands). IRCP benefits from recurring support from the French Pacific Fund, which makes it possible to hold these workshops, which are so valuable because of their very "applied" nature.

See: www.ircp.pf

Sanctuaries: Effective tools, as long as…

Among the major topics at the workshop, specialists gave close consideration to the current process based on setting up large zones where sharks are protected. French Polynesia banned shark fishing in 2006 (except for the mako fishery, which was only banned in 2012) inside its exclusive economic zone. Palau and New Caledonia have recently set up the same type of shark protection zone. But above and beyond these decisions, which are widely covered by the media, how effective are they in protecting sharks? This question is all the more relevant when we consider that tuna fishing continues to take place within those zones, with its bycatch that includes sharks. Even though bycatch sharks may not be kept onboard, catch-related mortality rates are high. Workshop participants agreed that although sanctuaries are not a miracle solution, they are effective, particularly if they include an efficient fisheries control system and shark population monitoring.

Ecotourism[7]: An interesting economic lead

"A live shark is worth far more than a dead one!" This is now a well-known statement, although specialists have rightly noted that ecotourism is based on coastal shark species, whereas pelagic species, which are rarely used for tourism purposes, are disappearing. There is still a strong feeling, however, that this non-destructive alternative use of sharks and rays can generate significant economic benefits. To ensure sustainable management, those benefits must be shared by all those who use the sea and who contribute to keeping sharks alive, especially fishers, whose income is affected. Ecotourism can also raise safety issues for professionals and spectators, which is why rules of proper conduct need to be developed and enforced. Such standards also have to respond to the need to ensure that the animals remain in good health to avoid any impacts on the ecosystem's equilibrium. If all of these conditions are met, then the advantages of ecotourism will surpass its potential disadvantages and this activity will contribute to the sustainable development of Pacific Island states.

Sharks: The very heart of Pacific Island cultures

All Pacific Island peoples accord a special place in their culture to sharks and rays. A totem animal that may be worshipped as a god, a vehicle between the land of the dead and that of the living, or a cosmogonical guide for intrepid sailors, the shark is feared but, more especially, respected. While it is difficult to place a price on such cultural values (existence, hedonic, or heritage values), they are, nevertheless, very significant in the Pacific Islands region. The fact is, that all that ancestral knowledge

The Beqa shark feeding site, Fiji (image: Éric Clua).

[7] In the context of this article, ecotourism means a tourism activity based on watching sharks and rays in their natural habitat, with or without feeding to attract them.

Inset 2: Oceania Chondrichthyan Society

The Oceania Chondrichthyan Society was founded in 2005 as a joint initiative by Australia, New Zealand and Papua New Guinea, to work in the areas of education and scientific studies to support the protection of chondrichthyan fish species (i.e. sharks, rays and other shark-like species). More specifically, it brings together scientists working in those areas in the Pacific. The society supports projects and offers grants on a regular basis to students for research projects and to take part in international meetings where they can promote their work. OCS supports the development of "participatory science", as long as it is carried out with precise objectives and in a form accessible to those involved so that it remains acceptable at a scientific level. OCS meets on a regular basis and the next meeting is a joint meeting with the New Zealand Marine Sciences Society from 6–9 July 2015 in Auckland, New Zealand.

Contact: andrew.chin@jcu.edu.au; See: http://oceaniasharks.org.au/

Inset 3: French Polynesia Shark Observatory

The French Polynesia Shark Observatory (ORP) was set up in 2010 at the urging of its main proponent, Nicolas Buray, who holds a master degree from the École Pratique des Hautes Études in the ecology of lemon sharks in Moorea. The goal of this observatory is to collect and compile all available information on the various shark and ray species found in French Polynesia in order to estimate their stocks, map their distribution and monitor changes in various island populations over the long term. More specifically, it contributes to: 1) the protection of endangered species and strategic habitats, and the management of sites with many tourism activities; 2) strengthening and developing of scientific knowledge (population structure, monitoring the movements of certain migratory species through photo-identification); 3) carrying out research programmes (biopsies, deploying buoys); and 4) promoting the image of French Polynesia's sharks outside the territory, and to developing educational projects and raising awareness among decision-makers and the general public.

Contact: requinsdepolynesie@gmail.com
See: http://www.requinsdepolynesie.com/index.php

Inset 4: "Sharks, Restoring the Balance" Initiative

This initiative, designed to be international in scope, is being carried out jointly by the World Wildlife Fund and TRAFFIC (a wildlife-trade surveillance network). Its goal is to promote responsible fisheries that minimise the impact on shark populations around the world, improve regulations on the trade in shark products, and decrease consumer demand because this is the cause of overfishing of sharks and rays. In the Pacific, the first direction the initiative is taking is to promote sharks' cultural value so as to gain strong support from Pacific Island indigenous communities. A small collection of legends from several Pacific Island countries will be published for that purpose in 2014. The initiative also plans group work on developing a code of good conduct to create sustainable shark-based ecotourism in the Pacific, with the scientific support of James Cook University in Australia.

Contact: icampbell@wwf.panda.org

related to oral traditions and so rarely put into writing, is increasingly being lost to the collective memory. Workshop specialists unanimously agreed on the need for this ancestral knowledge to be regained in general with the full collaboration and contribution of indigenous communities who hold such knowledge. They also concluded that traditional culture does not necessarily include the concept of resource conservation. Science also needs to contribute to discussions by indigenous communities.

Addressing sharks' negative image

In the belief systems of modern societies, which have growing influence in the Pacific Islands region, sharks have inherited the undeserved image of "maneaters". This false idea on the part of the general public needs to corrected because their opinions have a determining effect on political decision-makers and can affect decisions to ensure the protection of these animals. Developing tools such as the participatory science that the Oceania Chondrychtyan Society (see inset 2) and the French Polynesia Shark Observatory (see insert 3) promote can also play a significant role in this process, which has now led to the "social licence" concept, which carries significant weight in public life. The most recent example is in Western Australia, where public pressure following several fatal attacks put an end to public preventive shark capture campaigns, which, in any case, had not proven to be effective in managing the problem.

This workshop proved to be an important stage in regional dynamics to protect sharks, dynamics which will continue particularly through the initiative "Sharks, Restoring the Balance" (see inset 4).

For more information:

Serge Planes
Director, CRIOBE
planes@univ-perp.fr

Selling and marketing fish in the Solomon Islands

Robert Pomeroy[1]* and Di Yang[1]

More than half of all households in the Solomon Islands are involved in some sort of fishing activity, with the percentage of households involved increasing with increasing distance from urban areas (Govan et al. 2013). A common characteristic of these households is a heavy reliance on marine resources for food (MECM 2008; ADB 2010). In order to effectively manage the fisheries in the Solomon Islands, improved information on fish resources within the Solomon Islands is needed. The objectives of the Solomon Islands Mobile Platform project (Hapi Fis, Hapi Pipol) were to: 1) provide the Solomon Islands Ministry of Fisheries and Marine Resources (MFMR) with information to improve MFMR's decision-making capacity on fisheries management; and 2) establish a baseline of information on fish sellers and marketing for management and development activities in the country (Rhodes et al. 2013).

Methodology

The Hapi Fis, Hapi Pipol project focused on four coral reef fish markets in Honiara, Guadalcanal Province: Ball Beach, Maro Maro, Fishing Village and Honiara Central Market (HCM). Honiara is the capital of Solomon Islands and is where the commercial demand for seafood is considered to be the greatest. Each of the four markets surveyed has different characteristics in the type and scope of fish sales. All Honiara fish markets provide sales opportunities for the selling of coral reef and nearshore pelagic fish, while HCM and Fishing Village also sell invertebrates and pelagic fish. Among the four markets, HCM is the largest and is a mixed market, selling a large assortment of fresh, prepared and imported food items, meats, clothes, curios and housewares, among other local and imported items.

Initial survey development followed market visits in October 2012. A fish seller survey was developed and carried out over a three-month period in 2013. The fish seller survey consisted of 98 questions grouped into several categories, including demographic characteristics, business assets, business operations, fish purchases, fish transportation, fish selling, processing, operating expenses, and perceptions and attitudes about the business. The initial market reconnaissance identified approximately 100 fish sellers operating at the four markets. This served as the sample population for the survey.

Results

Demographic characteristics

According to the survey, most fish sellers (76%) in the seven provinces that supplied fish to Honiara were males. Guadalcanal and Honiara provinces had more female fish sellers. The average age of both male and female fish sellers was 33; with males having a broader age range than females.

The number of years selling fish varied from 1 to 35 among all respondents. The average male and female fish seller had nine and eight years of experience, respectively. Thirty-four percent of respondents (22% male, 12% female) reported that their primary occupation was as a full-time fish seller. For males, the next most common occupations were fishermen (16%) and farmers (11%). Over 10% of females reported that their second primary occupation was as a teacher. Seventy-seven percent of respondents indicated that they did not have a secondary occupation. The data on primary income source showed that fish selling was the dominant income source (63%) for fish sellers. The majority of respondents (68%) did not have a secondary income source. Nearly 40% of fish sellers in the survey had a primary education, 40% had a secondary education, and 21% had a college education or above.

Business assets

On average, each fish seller owned 7.49 baskets, which was the top asset owned by fish sellers in all seven provinces (Fig. 1). In addition, a canoe (1.59 per each) and an "esky"[2] (1.51 per each) were the second and third most commonly owned business asset by respondents.

Business operations

Single business enterprise was the major (55%) type of business structure, followed by a partnership (26%) and family business (19%). Most respondents (61%) started their business using their own money. Family

[1] Department of Agricultural and Resource Economics, University of Connecticut, USA
[2] An "esky" is also called an "ice chest" in Micronesian countries and in American Samoa.
* Email: robert.pomeroy@uconn.edu

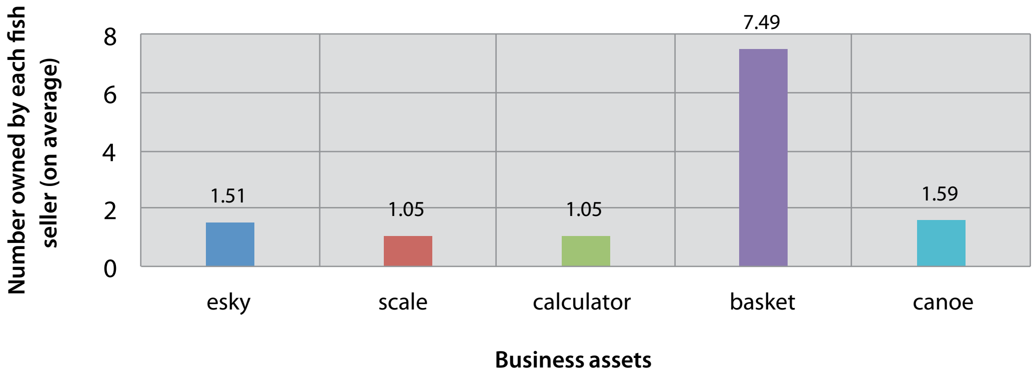


Figure 1. Average number of business assets owned by fish sellers, Solomon Islands.

employees (29%) were the majority among all four kinds of employees, which also included fully paid employees (19%), partially paid employees (14%) and others (21%). Over half of all respondents (53%) kept business records of both purchases and sales (e.g. amount, price).

Of the 100 fish sellers, 73 fished for their own business, and 96% did not buy fish from other fish sellers. More than 63% of fish sellers bought fish directly from fishermen. The survey also found that 85% of all respondents processed fish themselves, and 94% needed to transport fish from the point of purchase to the market. Almost half of all fish sellers sold fish to value-adders (e.g. restaurants, stall owners).

In an average week, fish sellers sold 19,694 kg (90.3%) of fish to the retail market, 1,850 kg (8.5%) to the value-adder market, and 265 kg (1.2%) to other fish sellers (Fig. 2). The trade from Central Island Province had the biggest share of both the retail market (26.8%) and value-adder market (37%).

Fish purchases

The majority of primary purchases are made locally. For example, 80% of fish sellers in Guadalcanal Province purchased fish in Guadalcanal Province; 81% of fish sellers do not have a secondary place to purchase fish. Nearly 90% of respondents competed with other fish sellers. In Central Island Province, fish sellers purchased 6,368 kg of fish weekly on average, which was the highest amount (35.9%) among all six provinces (Fig. 3). This was followed by Western Province (4,748 kg; 26.9%),

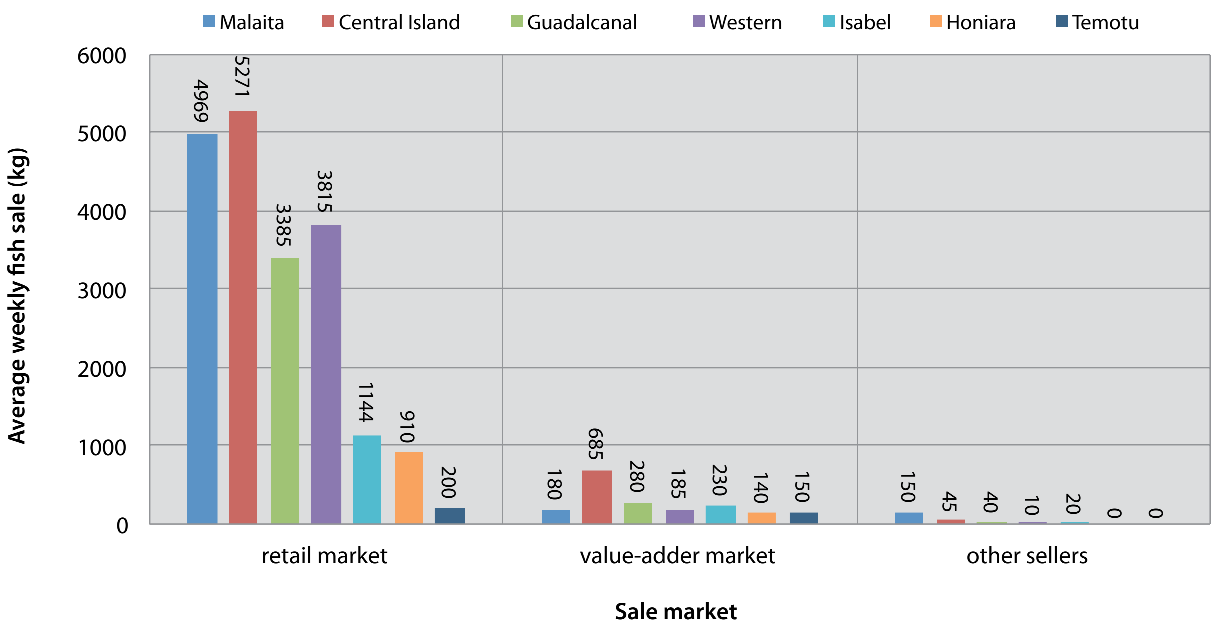


Figure 2. Average weekly fish sales in Honiara, Solomon Islands.

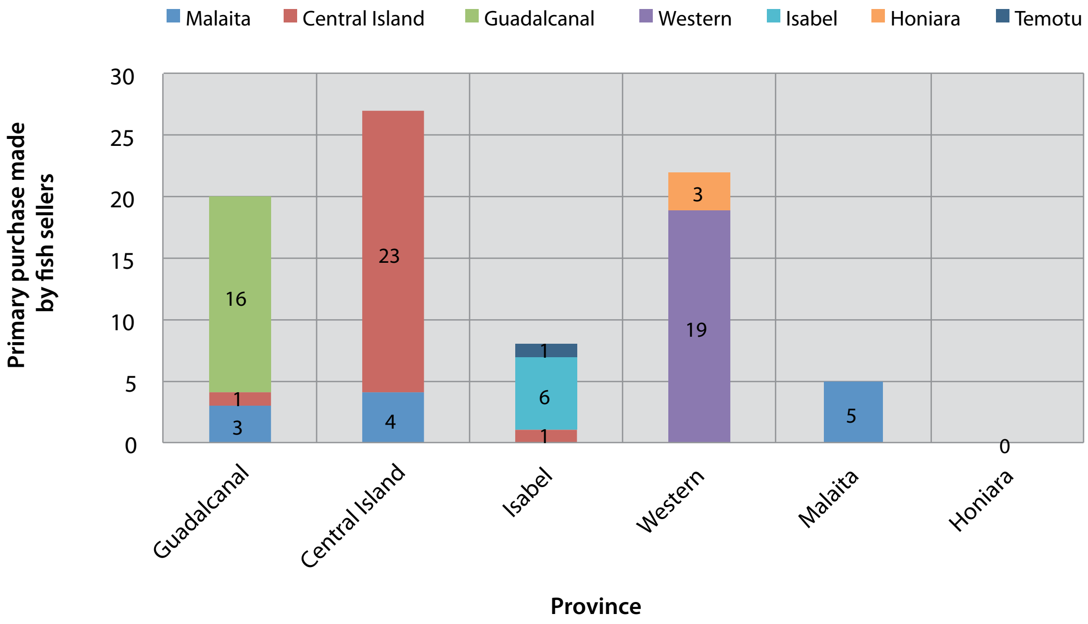


Figure 3. Primary fish purchase distribution by province, Solomon Islands.

Guadalcanal Province (3,811 kg; 21.5%), Isabel Province (1674 kg; 9.4%), and Malaita Province (1,160 kg; 6.5%). Respondents reported not purchasing fish in Honiara.

The top three factors that determined how respondents selected fish to purchase were size (36.6%), quality (23.2%) and species (19.5%). Only one respondent made a purchase based on the price of the fish. Most buyers were willing to purchase fish from skilled and/or experienced fishermen and the price variation was relatively small on the market. On average, the number of days in a week that fish sellers purchased fish was: 2.3 days in Central Island Province, 2.1 days in Guadalcanal Province, 2.0 days in Malaita Province, 1.9 days in Isabel Province and 1.8 days in Western Province.

Sixty respondents indicated that the type of fish they purchased varied by time of year, with 44% of sellers reporting that they were always able get the quantity of each species they want. Sixty-nine respondents purchased fish with cash, and only two respondents used a credit card.

The survey found that the majority of fish sellers (94.4%) purchased fish by weight, while only a small number of sellers (5.6%) purchased fish by lot[3], and no fish seller purchased fish by piece. Respondents indicated that the top three factors that determined the price at which to purchase fish were the quality (18%), competition (13%) and price agreement between fishermen (11%). Among all respondents who purchased fish, 46 (57.5%) indicated that they did not bargain for the purchase price. The survey also found that for all respondents who purchased fish, most provided certain services to the fishermen they bought from. Food was the major service provided (52.6%), followed by gear (21.8%), credit (5.1%), boat (1.3%) and cigarettes (1.3%). Fourteen respondents (17.9%) not provide any service to the fishermen they bought their fish from.

Nearly half of all respondents (49%) indicated that the weather was the most important factor affecting the supply and price of fish, while the number of fish buyers and fishermen was the second factor affecting the supply and price of the fish.

Fish transportation

The majority of respondents (92.7%) reported that they transported fish by boat, while the remainder (7.3%) transported fish by car or truck. According to the survey, almost all respondents (96.4%) had problems with transportation. Mechanical problems that caused delays was the most mentioned problem (26.5%) (Fig. 4). In addition, the cost of fuel (25.3%) and inefficient transport services (21.7%) were the second and third most mentioned transportation issues. Weather, mentioned by 19.2% of respondents, was also a problem in transporting fish. The cost of fuel was the most prominent problem in Central Island Province.

Fish selling

The majority of respondents (82%) reported that they sold fish at the Honiara Central Market, while the remainder of respondents sold fish at the Ball Beach/

3 A lot is a pile of fish of either one species or mixed fish species.

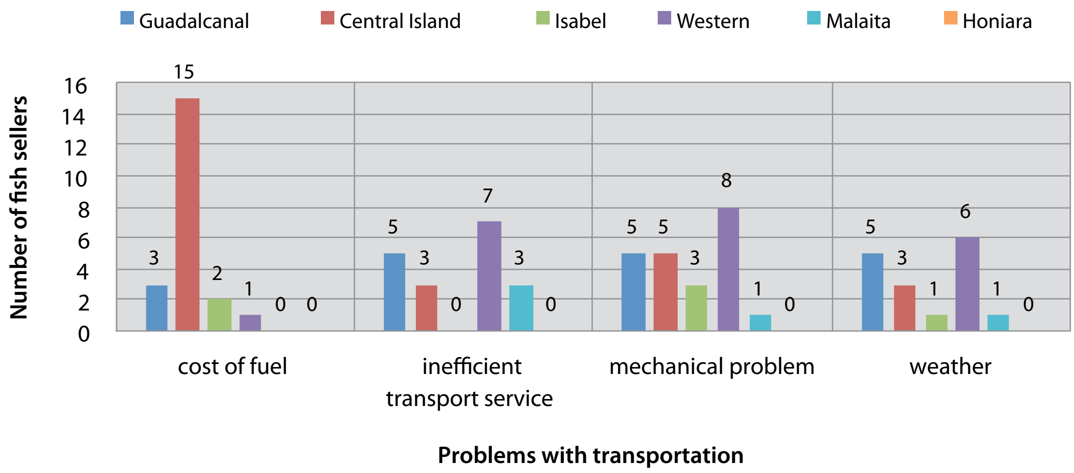


Figure 4. Problems with transporting fish as reported by fish sellers, Solomon Islands.

Waikiki (14%), Maro Maro (3%) and Hotel (1%) markets. The majority of respondents (86%) did not have a second market to sell fish. The top three reasons why fish sellers chose their primary market were more customers (62.2%), only available place (22.0%), and accessibility (7.3%).

The majority of respondents (43%) sold fish two days a week on average, while the remaining respondents sold fish three days a week (24%) and one day a week (13%). Nearly half of fish sellers (46%) indicated that it took two days to sell one esky full of fish, on average. The majority of fish sellers (83%) sold fish by weight. In an average week, 18,396 kg of fish were sold at the Honiara Central Market; 2,166 kg were sold at the Ball Beach/Waikiki; 778 kg were sold at the Maro Maro; and 150 kg were sold at the Hotel market.

The factors that determined the price at which to sell fish were demand and supply (33%), quality and species (23%), and standard and/or current selling price (13%). Almost 30% of fish sellers (29.8%) received information on market price and supply by observing the retail market; however, more than half of fish sellers (57%) did not discuss prices and supply among themselves. The majority of respondents (79%) agreed that market price was influenced by large fish sellers. More than 60% of respondents indicated that they did not have a certain location at the market to sell their fish, and 67% provided services different from other sellers in order to sell their fish.

Nearly 80% of fish sellers reported that they had return or main customers, and 90% of fish sellers agreed with the fact that there were certain periods of high demand by customers. The highest daily demand for fish occurred from the afternoon to the evening. The majority of consumers (79%) had a specific request for fish, and the top three factors that consumers considered when they made purchases were species (38%), price (30%) and size (9%).

Processing

The majority of respondents (97.7%) preferred to purchase processed fish. Over half of respondents (54%) sold gutted fish, and forty respondents (40%) sold whole fish. The majority of fish sellers (69%) gutted fish before selling them and nearly twenty percent of them (19%) did not process the fish in any way. The primary way (95%) to maintain the freshness of fish was to keep them in ice. Nearly half of respondents (47%) had experienced loss due to spoilage. Almost sixty percent of the fish sellers (59%) had fish left over in the esky.

Expenses

The cost of purchasing an esky-load of fish varied from SBD[4] 1,510 to SBD 2,086 depending on the province, with Western Province being the most expensive. The expense for selling one esky varied from zero to SBD 2,000, depending on the market (Fig. 5).

For the respondents who purchased fish from Isabel Province, it took 4.9 days to buy, transport and sell one single esky-load of fish on average, which was the longest time among all provinces. At the Honiara Central Market, it took 3.9 days to buy, transport and sell one esky-load of fish, on average; this is followed by Malaita Province, in which it took 3.2 days on average. For those who sold fish at the Ball Beach/Waikiki market, it took only 1.1 days to buy, transport and sell one esky, which was the shortest time for all provinces.

The majority of respondents (89%) did not borrow money to operate their business and for those who did, five respondents borrowed from a family partnership,

[4] The local currency is the Solomon Islands dollar (SBD). SBD 1.00 = USD 0.13 (January 2015).

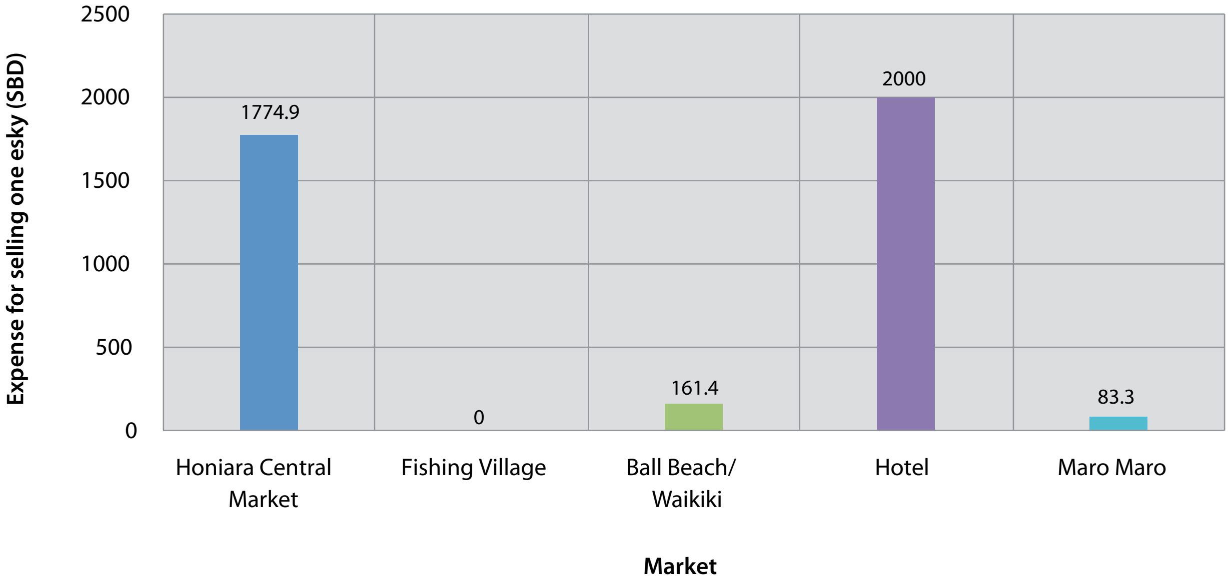


Figure 5. The expense for selling one esky-load of fish in different markets.

four from relatives, and two from a bank loan and/or community funds.

The main expense in buying and selling one esky-load of fish in the six provinces was ice, followed by market fees and fuel.

Perceptions and attitudes

Price (33.3%), supply (27.3%) and costs (16.2%) were the top three business problems that fish sellers faced. The largest proportion of respondents (17.3%) had no answer to solve them, more than 10% of respondents (12.2%) tried to minimize the cost, and another group of respondents (12.2%) chose to negotiate with suppliers.

Nearly half of respondents (47%) indicated that they noticed a decrease in the amount of fish landed during the last five years, and Western Province (29.8%) and Malaita Province (25.5%) were the top two provinces where this has been observed the most. On the other hand, 45% of respondents noticed an increase in the amount of fish landed during the last five years, and Central Island was where this was noticed the most. The majority of respondents (32.7%) showed that they thought the decrease was due to overfishing. As for reasons for the increase, over ten percent of respondents (12.2%) thought it was due to the high demand for fish and another nine percent of respondents thought it was due to the expectation of higher profits in the fish business.

More than eighty percent of respondents (84%) noticed changes in the species and size of fish over a five-year period, and this was the case for all provinces. Respondents suggest that the reasons for this change were overharvesting (48%) of fish in general, and the harvesting of juvenile fish (i.e. those that had not reached sexual maturity at the time of capture) (6%). Another group of respondents (12%) mentioned that they did not know the reason for changes in fish species and sizes. The majority of respondents (91%) indicated that they could sell more fish if production was increased.

Over half of respondents (54%) indicated that the price they paid for fish has been increasing during the last five years and less than twenty respondents (18%) indicated that there was no change in the price they paid to purchase fish. The primary reason for a change in purchase price was the increase in costs of goods and services (18%), increase in demand for fish (13%), and competition with other fish sellers (11%). More than one-third of respondents (33%) indicated that they did not know the reason. The majority of respondents (73%) indicated that the selling price had been increasing over the last five years. The primary reasons for that were due to expenses incurred for fish purchases (33%) and a greater demand for fish from consumers (27%); nearly 15% of respondents did not have an answer. The majority of respondents (56%) wanted improved facilities such as water, cold storage room, and toilets at the retail markets. Eight percent of respondents wanted to establish a fish market association and seven percent wanted to have more space for fish sellers. The survey showed that vendors are willing to work with the Ministry of Fisheries who are able to provide training opportunities (92%) and market information (88%), establish a sellers association (87%) and improve market services (87%). This will also provide an avenue of education and

Fish seller, Honiara market (image: Malo Hosken).

management for the ministry.

Among vendors, 63% derived their household income exclusively from fish sales, while 55% of vending operations were sole proprietorships and 52% kept business records. Fish selling in Honiara is a male-dominated (74%) enterprise. The average age of fish sellers was 33, and the average number of years of vending experience among all respondents was 9. The exclusive sale of gutted fish at the main market inhibited evaluations of fish reproductive life history.

Preliminary findings from the Hapi Fis, Hapi Pipol market survey program have provided useful insights into the operation and sale of reef fish in Honiara's four main markets. These insights are allowing initial trend assessments on the volume, origin and composition of fish sales (as resource types), findings that were previously unavailable to management decision-makers. From these initial survey results, MFMR can now conceptualize the amount of fishing pressure being placed on the country's reefs from commercial fishing efforts.

Acknowledgements

Support by the Solomon Islands Ministry of Fisheries and Marine Resources enabled the successful development of the Hapi Fis, Hapi Pipol project. Funding for the core project was provided through the US Agency for International Development Grant No. LCP LWA Award No. LAG-00-99-00048-00 through the Coral Triangle Support Partnership, a consortium of non-governmental organizations led by the World Wildlife Fund and Conservation International and The Nature Conservancy.

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Samoa Aquaculture Section team fully involved in giant clam farming

Since the official opening of the Samoa Fisheries Marine Multispecies Hatchery at Toloa in early 2014, the Aquaculture Section of the Fisheries Division, under the Ministry of Agriculture and Fisheries, has been very busy working on giant clam spawning and larvae rearing activities. In order to meet the Fisheries Division's annual targets and work plan related to giant clam spat production and distribution to coastal communities, the Aquaculture Section has carried out two successful spawning events after a first unsuccessful trial. At the same time, the aquaculture team staff have built their capacities and skills in hatchery operations and giant clam rearing during two training sessions run by Cletus Oengpepa, an international expert on giant clam farming and a long-time World Fish Center fellow, and Ruth Garcia Gomez, SPC Mariculture Officer. These spawning and training activities were also an opportunity for staff who were already involved in spawning activities in the past to share experiences and skills with newly recruited staff.

During and after these two practical trainings, the aquaculture team was able to successfully spawn smooth giant clam (*Tridacna derasa)* specimens on two occasions, achieving 30–60% survival rates and growth rates of 2–4 cm after 4 months, which can be considered as very promising results.

Broodstock of *Tridacna derasa* is owned by a community of Vaisala village on the big island of Savaii. The broodstock has been well looked after for more than 10 years within the village-owned fish reserves. After the trials, broodstock were transported to the Savaia village-owned fish reserve, where the Fisheries Division has been keeping its broodstock for many years. Surprisingly, although broodstock specimens have been maintained in a close and protected bay of Savaia village, no juveniles have been observed during the invertebrate stock assessments conducted in previous years. A thorough stock assessment is being conducted to assess the survival of juveniles at all clam nurseries established around Upolu Island. It will be interesting to discover whether juveniles are still absent from the Savaia village area.

The production and distribution of giant clam juveniles to coastal communities who have been involved in the protection and management of their fisheries resources under the community-based fisheries management program (CBFMP) is in line with one of the Fisheries Division's long term goals: to ensure national food and nutritional security by encouraging village level fish and shellfish nurseries. In addition, it should help enhance natural stocks in the lagoon and reefs of Samoa.

Villagers from Tafagamanu moving the brooders to the hatchery.

To conclude, future plans of the aquaculture team are to continue with giant clam spawning activities at the newly established marine multispecies hatchery; broadening the range of species being spawned to *Tridacna gigas* and *T. maxima*; improve current farming strategies and operations to increase fertilisation as well as survival and growth rates; and improve existing capacities and skills of technical staff involved in aquaculture-related activities.

For more information:

Ulusapeti Tiitii
Principal Fisheries Officer, Samoa Fisheries Division
sapeti.tiitii@maf.gov.ws

Unity Roebeck
Senior Fisheries Officer, Samoa Fisheries Division
unity.roebeck@maf.gov.ws

Ruth Garcia Gomez
Aquaculture Officer, SPC
ruthgg@spc.int

Tridacna noae is back

The giant clam Tridacna noae *was first described by Röding in 1798, distinguishing it from other species based on the characteristic spacing of the scales on the ribs of the shell. In 1947, McLean described it as very similar in general appearance to* T. maxima. *So much so that, over the years, it lost its recognition as a distinct species and came to be identified as a "maxima" clam.*

However, recent evidence based on genetic analyses (Su et al. 2014; Borsa et al. 2014) shows that it is indeed a distinct species. While the shell of the animal provides few clues to reliably distinguish it from *T. maxima*, marked patterns on its mantle give it away. Indeed, *T. noae* clams can be identified by the presence of discrete teardrops on their mantle (see pictures), typically bounded by white margins. These oval patches tend to line the edge of the mantle, but they can also be found more widespread throughout the mantle. Another, albeit more difficult to observe, distinction between the two species is that *T. maxima* always shows a neat row of eyes on the edges of the mantle, whereas these are more spread out in *T. noae*.

Interestingly, reef aquarium enthusiasts have always distinguished *T. noae* from *T. maxima* specifically because of the teardrop-shaped patterns on the mantle, referring to them simply as "teardrop maxima". Due to their distinct features, teardrop maxima are also known to sell for a higher price on the aquarium trade market. Thinking that they were maxima clams, however, has meant that *T. maxima* clams and *T. noae* clams were interbred in hatchery facilities.

Tridacna maxima *(top) and* T. noae. *The latter shows the typical teardrop markings on the mantle, which are absent from* T. maxima *(image: Colette Wabnitz).*

Tridacna noae *(image: Serge Andréfouët).*

Collaboration between SPC, fisheries departments, and aquarium industry operators throughout the Pacific Islands region, has allowed for the sampling of maxima clams in a wide range of countries. Remarkably, reefs in a few countries appear to be home to greater numbers of *T. noae* than *T. maxima*, while in others *T. noae* are hard to find in the wild. Through a project set up in partnership with researchers at the Institut de Recherche et Développement (IRD) based in Noumea, New Caledonia, these samples were then analysed, with results not only consolidating the recent findings that *T. noae* is a new species, but also providing information as to its distribution range (Fauvelot et al. in prep.). Partners have also worked to promote the spawning of *T. noae* clams only, with at least one successful documented trial.

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For more information:

Colette Wabnitz
Fisheries Scientist (aquarium trade), SPC
colettew@spc.int

Cecile Fauvelot
Researcher, IRD
cecile.fauvelot@ird.fr

A workshop to learn the basics of coral identification

Since 2006, the University of the South Pacific (USP), the Centre de Recherches Insulaires et Observatoire de l'Environnement (CRIOBE) and the Institute for Pacific Coral Reefs (IRCP, www.ircp.pf) have joined in a partnership to develop and offer several workshops on USP's campus in Fiji or Solomon Islands, which are funded by the French Embassy (Pacific Fund). The two main key objectives of these workshops are to: 1) increase capacity of USP, government and non-governmental organisation staff members involved in coral reef monitoring, and 2) allow USP students to learn different techniques of coral reef monitoring (corals, fish, invertebrates).

On 9–12 September 2014, the international workshop on "Taxonomy, Biology and Ecology of Coral, and Reef Monitoring" was organised at USP's campus in Fiji, in close collaboration with SPC. The workshop was coordinated by David Lecchini, Vetea Liao, Antoine Puisay and Cécile Berthe from CRIOBE on Moorea, French Polynesia. Fifty-five people from Fiji, French Polynesia, Solomon Islands and Wallis and Futuna participated.

The first goal of the workshop was to teach coral taxonomy to USP students and staff members, government and NGO staff involved in coral reef monitoring in the South Pacific. Following an introduction to coral taxonomy, participants worked in the lab on recognising skeletal morphological features for coral identification. In the field, participants recorded coral genera that were present in the study site of Muaivuso.

The second goal of the workshop was to compare four methods used to survey benthic substrates (including coral) in the field:

1. The line intercept transect method (LIT) — measuring the length of every category of substrate along a 25-m transect. Each participant conducted at least two transects.
2. The point intercept transect method (PIT) — recording the substrate category every 50 cm along a 25-m transect. Each participant surveyed at least two transects.
3. The point intercept quadrat method (PIQ) — a rope that forms a grid of 10 cm x 10 cm squares within a quadrat (50 x 50 cm); the category of substrate present at every intersection is recorded. Each participant surveyed at least two quadrats.
4. The individual counting and cover estimate quadrat (ICCEQ) — the percentage cover of every type of substrate is directly estimated within a quadrat (50 cm x 50 cm) and every colony of coral is counted. Each participant surveyed at least two quadrats.

The coral and substrate data collected in the field at Muaivuso were analysed by all participants on the last day of the workshop at USP. They compared the difference in coral abundance and species richness obtained with the four techniques. Each participant had the opportunity to give his or her opinion about the advantages and disadvantages of each technique.

Top: Viliame Salabogi (Fiji Fisheries Department) uses the point intercept transect method to record coral and substrate data.

Bottom: Ro Iva Meo (Fiji Fisheries Department) and Ronal Lal (USP student) using the point intercept quadrat method to record coral and substrate data.

(Images: David Lecchini)

For more information:

David Lecchini
Associate Director, Institute for Pacific Coral Reefs
lecchini@univ-perp.fr

Fafa Island, a very special management area

In December 2013, the declaration of Fafa Island Resort and reef as a Special Management Area (SMA)[1] marked two landmarks in Tongan fisheries legislation: first, Fafa became the first non-community island to be declared an SMA; and second, Fafa became the first SMA island declared as a total fish habitat reserve (FHR) in Tonga. At the official opening held on the Island on 4 February 2014, the Honourable Minister of Agriculture and Food, Forests and Fisheries (MAFFF), Sangster Saulala, said in his address that this marked an historic day in Tonga.

Fafa Island Resort is 7 km north of Nuku'alofa, Tonga's capital. Established in 1983, it is one of Tonga's premier ecotourism destinations. The 18-acre island has 13 traditional built *fales* for guests, and is serviced by approximately 30 staff, many of who live on the island.

Local authorities were first approached in 2010 by the island's owner, Rainer Urtel, with concerns about the decrease in marine life and the dubious "fishing" methods carried out by some individuals around the island — the use of crowbars and hammers as aids to extract sea cucumbers, lobsters or octopus from the reef was common practice.

Both the Department of Environment and Department of Fisheries were consulted to compare the respective pros and cons of SMAs placed under the jurisdiction of the Department of Fisheries, and marine protected areas (MPAs) placed under the jurisdiction of the Department of Environment. SMAs are monitored and maintained by the island communities they have been granted to. Each island SMA committee, established when an SMA is put in place, is also empowered to enforce compliance within the SMA. For MPAs, compliance can only be carried out by Department of Environment officers. It was, therefore, decided that an SMA would be better suited to Fafa if it were made possible for a non-community island to be granted one.

An SMA that would be a total FHR also seemed important for both the Department of Fisheries and Fafa Island Resort operators. Previously, SMAs granted to community islands allowed fishing activities to be controlled by the island SMA committees, usually with only a small part of the SMA declared an FHR.

Establishing a total FHR at Fafa would make enforcement much easier for authorized officers because it is always easier to ensure that no fishing takes place, rather than control the type of fishing that takes place, gear used, catch size, and the size of individual specimens caught. A total FHR would also provide the Fisheries Department with a relatively wide and well-protected area for their comparative marine life abundance studies or experimental aquaculture operations.

Additionally, as an ecotourism resort with many returning international guests, it was important to provide guests with a lively and colourful coral reef environment around the small island.

Opening ceremony of the Fafa Island Special Management Area.

1 According to Namo Gillett (2009): [In Tonga] an SMA grants a community management control of its inshore resources; in effect, providing a community with the basic tools and skills for better management initiatives. The main objectives of a management plan are to 1) enforce the authority to exclude outsiders from entering an SMA, 2) establish marine parks, and 3) implement restrictions on harvested resources, including, size limits and catch amounts. See: http://www.spc.int/DigitalLibrary/Doc/FAME/InfoBull/FishNews/130/FishNews130_27_GillettM.pdf

At the official opening of the SMA, the Minister for Commerce, Tourism and Labour, Dr Viliami Latu, expressed the importance for the various ministries to support ecotourism in Tonga — tourism, fisheries and agriculture being the mainstays of the country's economy. For resort operators, the ability to "sell" Fafa Resort as being set in a marine reserve would be a real marketing advantage. Conservation has become a very topical subject; the support for this initiative received from the Tongan government should be highly appreciated by the resort's guests.

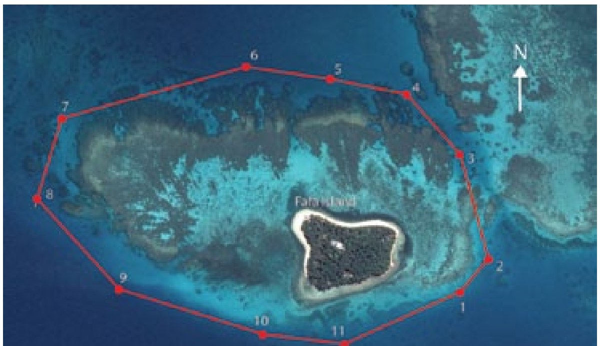
A baseline survey was carried out in February 2013 by a team of divers over a four-day period. The resulting data raised concerns about an extensive build-up of algae on the reef, due to the lack of algae-eating fish, was killing corals; no fish over 30 cm in length and no commercial invertebrate (e.g. trochus, sea cucumbers, octopus or lobsters) could be found. It was clear that the reef was being overfished and action needed to be taken to protect it.

Over the following months, consultation meetings were held at the Department of Fisheries, after being advertised on radio and in the press, and local people were encouraged to participate and express their views and concerns.

The benefits of an SMA/FHR so close to Tonga's capital, which has experienced a decline in fish stocks, was promoted, with forecasts provided of improved fish stocks in a 5–10 km area around the SMA.

A management plan was drawn up and submitted to the Fisheries Management Advisory Committee (FMAC) and then submitted to the Honourable Minister for the Ministry of Agriculture and Food, Forests and Fisheries (MAFFF), Mr Sangster Saulala, for approval. The boundaries of the SMA were defined, and the area enclosed, totalling 485 hectares. The SMA was gazetted in Crown Law, along with the management plan.

The Tongan government declared Fafa Island and reefs an SMA on 4 December 2013, under the Fisheries Management Act 2002.



Boundaries of the Fafa Island Special Management Area.


Fafa Island rangers.

The islands SMA committee and rangers have been empowered to stop, board and search any vessel if they believe an offence has been committed within the SMA. In serious cases, those caught can be taken to court and may face penalties up to TOP 50,000 (± USD 25,000). After nearly one year of operating the SMA, only a handful of incidences of illegal fishing have occurred.

Guests are now regularly reporting sightings of large size fish, sea cucumbers, octopus and even lobsters, which had almost disappeared from the area.

The Department of Fisheries has also used the SMA to restock juvenile trochus and giant clams produced at its aquaculture facility, and has started an experimental *Kappaphycus* algae nursery in collaboration with SPC.

The island SMA committee meets the costs of maintaining and monitoring the SMA, with funding coming from Fafa Island Resort. It is hoped that in the near future, projects such as the farming of *Kappaphycus* seaweed and half pearl oyster aquaculture will make the SMA self-funding.

The island also hosts "Education Days" that promote conservation awareness in schools and the local community.

For more information:

Vincent Morrish
Fafa Island Resort manager
fafa@kalianet.to

Siola'a Malimali
Deputy Secretary for Fisheries, MAFFF
siolaamalimali@gmail.com

Vili Moale
Principal Fisheries Legal Adviser, MAFFF
vmoale@tongafish.gov.to

Poasi Fale Ngaluafe
Principal Fisheries Officer, MAFFF
poasif@tongafish.gov.to

SSF Guidelines endorsed... What are the next steps?

Nicole Franz

Fishery Planning Analyst, FAO

In June 2014, representatives of over 100 countries, representatives from various UN agencies and related organisations, and observers from 65 intergovernmental and international non-governmental organisations (NGOs) gathered in Rome for the 31st Session of the FAO (Food and Agriculture Organization of the United Nations) Committee on Fisheries (COFI). On that occasion, COFI endorsed the Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication (SSF Guidelines).

The SSF Guidelines have a long history. COFI tasked FAO in 2011 with developing these guidelines in a participatory manner. Between 2011 and 2013, over 4,000 representatives of governments, civil society organisations CSOs), academia and other stakeholder groups from over 120 countries directly contributed to developing the content and principles of the SSF Guidelines: civil society organisations organised over 20 national and regional consultations, and FAO organised three regional consultations, including the FAO/SPC Pacific Islands Regional Consultation on the Development of Guidelines for Securing Sustainable Small-Scale Fisheries. The consultation was held in Noumea, New Caledonia on 12–14 June 2012, and the 38 participants representing governments, the fishing industry and CSOs from 17 countries and territories in the Pacific Islands region shared experiences of small-scale fisheries policies and practices, and provided inputs to the thematic areas of the SSF Guidelines.

In May 2013 and February 2014 the SSF Guidelines development process moved into its final phase: government representatives, together with representatives from CSOs and other stakeholders met for a technical consultation in Rome to negotiate the final text of the SSF Guidelines, going through the text word by word. The outcome of this process was then presented to the COFI meeting in June for finalisation and endorsement.

So, what are the SSF Guidelines?

The SSF Guidelines are the first international instrument dedicated entirely to the immensely important — but until now often neglected — small-scale fisheries sector.

The guidelines represent a global consensus on principles and guidance for small-scale fisheries governance and development. They were developed for small-scale fisheries in close collaboration with representatives of small-scale fisheries organisations in a process facilitated by FAO. The guidelines are directed at all those involved in the sector, and intend to guide and encourage governments, fishing communities and other stakeholders to work together and ensure secure and sustainable small-scale fisheries for the benefit of small-scale fishers, fish workers and their communities as well as for society at large.

The objectives of the SSF Guidelines are to:

- ✓ enhance the contribution of small-scale fisheries to global food security and nutrition, and support the progressive realisation of the right to adequate food;
- ✓ contribute to the equitable development of small-scale fishing communities and poverty eradication, and improve the socioeconomic situation of fishers and fish workers within the context of sustainable fisheries management;
- ✓ achieve the sustainable utilisation, prudent and responsible management, and conservation of fisheries resources consistent with the Code of Conduct for Responsible Fisheries and related instruments;
- ✓ promote the contribution of small-scale fisheries to an economically, socially and environmentally sustainable future for the planet and its people;
- ✓ provide guidance that could be considered by States and stakeholders for the development and implementation of ecosystem friendly and participatory policies, strategies and legal frameworks for the enhancement of responsible and sustainable small-scale fisheries; and
- ✓ enhance public awareness and promote the advancement of knowledge on the culture, role, contribution and potential of small-scale fisheries, considering ancestral and traditional knowledge, and their related constraints and opportunities.

Underpinned by a human rights approach, these objectives are critical to empower small-scale fishing communities — including vulnerable and marginalised groups — to participate in decision-making processes, and to assume responsibilities for the sustainable use of fishery resources.

The SSF Guidelines are divided into three main parts.

Part I: Introduction

This part specifies the objectives, nature and scope, and the guiding principles by which the SSF Guidelines are to be implemented as well as their relationship with other international instruments.

Part II: Responsible fisheries and sustainable development

This part provides guidance for fisheries-specific topics such as responsible governance of tenure and sustainable resource management, but also for crucial inter-sectoral issues such as social development, employment and decent work; value chain, post-harvest and trade; gender equality and disaster risks; and climate change.

Part III: Ensuring an enabling environment and supporting implementation

This part provides guidance on how to realise the principles and recommendations of the SSF Guidelines through policy coherence, and institutional and supporting implementation; information, research and communication; capacity development and implementation; and support and monitoring.

Making it happen: Achieving the objectives of the SSF Guidelines

The SSF Guidelines will only be effective if their provisions are put into practice. As a set of guiding principles, however, the SSF Guidelines go beyond direct fisheries activities, linking fishing and the larger aspects of life of SSF communities. A more integrated approach is needed to achieve these objectives.

The overall strategic approach for implementing the SSF Guidelines will build on the inclusive and consensus-seeking spirit and environment that characterised the development process. Accordingly, implementation must be based on participation and partnerships, with implementation anchored at the national and local levels within a framework of regional and international collaboration, awareness raising, policy support and capacity development. This strategic approach aims to have the principles of the SSF Guidelines mainstreamed into policies, strategies and actions at the international, regional, national and local level. This requires support and collaboration between a diverse group of stakeholders, including governments, CSOs, development partners, NGOs, academia, regional organisations, and the private sector.

Preparing the net – India (image: Nicole Franz).

In June 2014, COFI also welcomed FAO's proposal for a Global Assistance Programme (GAP) to support the implementation of the SSF Guidelines without delay. During the COFI meeting, the role of governments in the implementation of the SSF Guidelines, and regional and local fisheries organisations to ensure ownership of the SSF, was also emphasised. It was also recommended to build on existing experiences and institutional structures and processes. COFI members agreed to the structure of the GAP based on three main components, supported by an additional one component on programme management, collaboration and monitoring.

✓ *Raising awareness and providing policy support: Knowledge products and outreach*

The SSF Guidelines can only be implemented if the relevant parties with the abilities to make a difference are aware of their existence and contents. Partnerships play a crucial role to ensure that all stakeholders — particularly fishers, fish workers and their communities — are reached.

Potential stakeholders and partners include those in the fisheries sector and those in related fields (e.g. NGOs, regional economic communities, national cross-sectoral planning and/or coordination agencies). This should create a broad awareness and understanding of the SSF Guidelines across regions and countries, and among different stakeholder groups. High levels of awareness are fundamental for long-term commitment to the SSF Guidelines and provide a basis for other impact-oriented implementation support.

✓ *Strengthening the science-policy interface: Sharing of knowledge and supporting policy reform*

There is a need to strengthen the knowledge base surrounding small-scale fisheries and to promote policy reforms that use the latest available knowledge that combines sustainable management and socioeconomic development.

This component promotes an increased understanding of the issues, challenges, opportunities and approaches relevant to achieving the sustainable use of aquatic resources and securing livelihoods. It supports the mainstreaming of the SSF Guidelines and their principles in relevant governance, resource management and development strategies and plans.

✓ *Empowering stakeholders: Capacity development and institutional strengthening*

SSF stakeholders and their communities can and should be effective partners in implementation. This requires attention to organisational structures for fair and effective representation. Capacity development is the backbone of implementing the SSF Guidelines.

Developing capacity is closely linked to empowerment, which ensures that small-scale fishers and their communities are able to take an active role in shaping the future of the sector and of their own livelihoods. Capacity development is required at different levels, for different stakeholder groups and with respect to different skills and abilities. This creates some of the key building blocks for a long-term process of continuous improvement of the situation of small-scale fishers, fish workers and their communities and increased contribution of the sector to food security and poverty eradication.

✓ *Supporting implementation: Programme management, collaboration and monitoring*

This component is expected to provide results in the form of transparent and efficient programme management and strengthened collaboration, leading to overall more effective implementation of the SSF Guidelines.

On 8–11 December 2014, FAO organised a Workshop on the Development of a Global Assistance Programme in Support of the Implementation of the Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication in Rome to further discuss GAP with a large number of partners, including SPC. Based on these discussions and the outcome of other related meetings FAO will draft GAP as an umbrella programme to support the im-plementation of the SSF Guidelines. Importantly, the final paragraph of the SSF Guidelines calls for regional plans of action to be developed under GAP, and SPC can play a major role in facilitating this for the Pacific Islands region.

Want to know more?

The implementation of the SSF Guidelines and GAP will depend highly on available resources and on partnerships. FAO, therefore, calls on resource partners, regional organisations, national governments, CSOs and other stakeholders to join forces to achieve the objectives set out in the SSF Guidelines.

The SSF Guidelines webpage has more information (www.fao.org/fishery/ssf/guidelines), and the final PDF version of the Guidelines are now available (www.fao.org/3/a-i4356e.pdf)

Contact:

Email: SSFGuidelines@fao.org

Twitter: @FAOfish #SSFGuidelines

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Oceanographic characterisation of the Pacific Ocean and the potential impact of climate variability on tuna stocks and tuna fisheries

Simon Nicol,[1*] Christophe Menkes,[2] Jesus Jurado-Molina,[1] Patrick Lehodey,[3] Thomas Usu,[4] Brian Kumasi,[4] Berry Muller,[5] Johann Bell,[1] Laura Tremblay-Boyer[1] and Karine Briand[1]

The way that ocean-climate systems impact tuna population dynamics in the western and central Pacific Ocean (WCPO) varies at different spatial and temporal scales (Bour et al. 1981; Lehodey et al. 2003). Changes in oceanic conditions (e.g. sea temperature, current speeds, direction, location, depth, upwellings, convergences) create a mosaic of different physical habitat conditions that influence tuna migrations — both vertical and horizontal — as tuna continually move into preferred habitats. Because individual tuna species display different habitat preferences and different physiological adaptations, they respond differently to oceanographic and climate changes (Fromentin and Fonteneau 2001). Within species, the habitats exploitable by tuna are also influenced by animal size, with larger adults often able to exploit a greater range of habitats than juveniles (Brill 1994). Oceanographic variability also impacts the biological and environmental conditions affecting larvae survival and the subsequent quantity of recruitment into juvenile and adult ages (Govoni 2005; Lehodey 2000; Lehodey et al. 2006; Rothschild 2000).

The tuna industry in the WCPO extends beyond the enterprise of fishing by Pacific Island nations. Economic wealth is generated through the sale of fishing licenses to foreign fleets, servicing of domestic and foreign vessels, and land-based processing of tuna catches into value-added products for sale on global markets (e.g. canned tuna, loins and/or steaks, fish meal, fertiliser, omega 3 oils). As an example, in Papua New Guinea, tuna represents approximately USD 1.5 billion annually in fish value and potentially over USD 4 billion annually in retail value. The industry annually generates about USD 8 million in salaries and wages from over 15,000 jobs (including casual and full-time positions) and about USD 14 million in direct domestic commerce, and significantly more in indirect commerce. Changes in tuna distribution and abundance may lead to changes in fishery distribution and catch rates, which could have potential impacts on regional and national economies, food security and social implications for Pacific Island countries and territories.

The following description presents an oceanographic characterisation of the Pacific Ocean and a review of the potential impacts of ocean-climate dynamics on tuna species and their fisheries. Included are interannual changes in regional oceanography that are related to natural climatic phenomena such as El Niño Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO), and how tuna and fisheries are likely to respond to these periodic climatic episodes. We also include a discussion on the vulnerability of tuna species and fisheries to future climate scenarios. Comprehending available information on climate variability and change, and its impacts on fisheries is important for: 1) fishermen, fishery managers and other stakeholders; 2) the development of tuna fishery management plans that guide government decision-making over the short term; and 3) developing and adapting strategies that minimise the disruption that changes in tuna availability may have on national economies and the subsequent ability of Pacific Island countries to achieve their development aspirations.

Major currents in the Pacific Ocean

Surface water circulation in the Pacific Ocean is dominated by two large gyres centred at approximately 30°N and 30°S (Fig. 1). Between these two gyres is the Pacific equatorial current system, which includes two westward-flowing currents, the North Equatorial Current and the South Equatorial Current (NEC and SEC) and two eastward-flowing counter-currents, the North Equatorial Counter Current and the South Equatorial Counter Current (NECC and SECC). The NEC and SEC flow at approximately 15–20 cm s^{-1} across the Pacific Ocean under the influence of trade winds in each hemisphere. Along the Philippine coast, near latitude 14°N, the NEC

[1] Secretariat of the Pacific Community
[2] French Institute of Research for Development
[3] Collecte Localisation Satellites
[4] Papua New Guinea National Fisheries Authority
[5] Marshall Islands Marine Resources Authority
[*] Email: SimonN@spc.int

bifurcates, with one branch turning into the northward-flowing Kuroshio Current (KUR) and the southward-flowing Mindanao Current (MC). The KUR forms the western boundary of the north Pacific subtropical gyre and the MC feeds the NECC (Toole et al. 1990). Surface velocities of the MC are approximately 120 cm s^{-1}. Current speeds of the KUR can vary between 60 cm s^{-1} and 120 cm s^{-1}. The NECC flows between the NEC and SEC at 5–10°N, counter to the direction of the easterly trade winds. At depths of 100–250 m, part of the MC flows directly to the equator. The SECC is developed in the western Pacific, typically at latitude 10°S, and divides the SEC into two branches. The subequatorial branch of the SEC is more variable in strength (~ 10 cm s^{-1}) and direction than the equatorial branch, which can reach up to 50 cm s^{-1} in the eastern Pacific. The equatorial branch of the SEC dissipates at the eastern edge of the warm pool, and weak eastward-flowing currents are observed in the warm pool. The subequatorial branch enters the Coral Sea south of Solomon Islands and divides into the southward-flowing East Australian Current (EAC) and the northward-flowing North Queensland Current (NQC). The EAC defines the western boundary of the South Pacific Subtropical Gyre. The NQC flows into the Hiri Current, entering the Solomon Sea and toward the equator through the Solomon and Vitiaz straits, eventually feeding into the NECC. In the western Pacific, the deepest parts of the equatorial and subequatorial SEC (100–250 m) as well as the deepest parts of the MC that flows to the equator, converge to form the Equatorial Under Current (EUC). The EUC is a tube of eastward-flowing current centred around 150–200 m below the surface in the western Pacific, and 30–75 m in the eastern Pacific at a velocity of 100 cm/sec. These currents are not constant over time; their strength typically changes seasonally. Currents also vary from year to year depending on climatic conditions and especially under the influence of ENSO.

Major ocean surface currents are wind-driven and contribute to the transportation of heat, dissolved oxygen, salts, carbon dioxide and nutrients. Hence, large water masses often have differences in temperature, salinity and oxygen. Ocean processes inducing the movement of water masses such as upwelling are especially involved in phytoplankton production. The phytoplankton growth rate is known as primary productivity and constitutes the amount of food and energy available to higher trophic levels. Areas of high productivity with high concentrations of planktonic organisms are usually found in regions with strong upwelling, which bring nutrient-enriched water from underlying cold layers to surface waters. Conversely, areas of downwellings are areas of low primary production. Consequently, areas where currents diverge or converge (Fig. 1) are important because these result in downwelling and upwelling areas as well as smaller features (fronts, eddies, turbulence) that enhance local productivity, and may create zones of forage availability that are attractive for tuna (Grandperrin 1978).

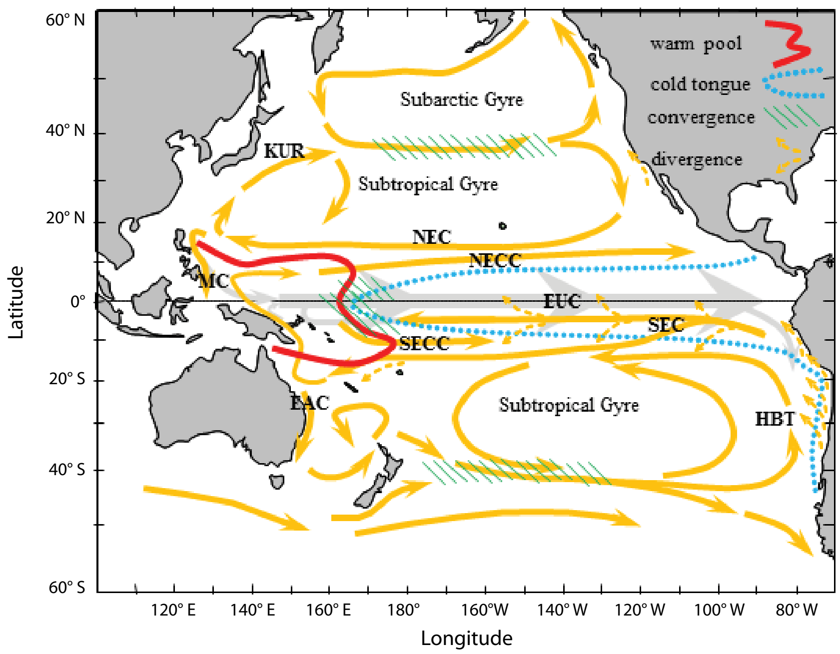

Figure 1. Direction of major currents in the Pacific Ocean. NEC = North Equatorial Current, SEC = South Equatorial Current, NECC = North Equatorial Counter Current, SECC = South Equatorial Counter Current, KC = Kuroshio Current, MC = Mindanao Current, EAC = East Australian Current, EUC = Equatorial Under Current, HBT = Humboldt Current, KUR = Kuroshio Current.

Thermal structure of the Pacific: the warm pool and cold tongue system

The eastern and central equatorial Pacific Ocean is characterised by cold nutrient-enriched waters that rise to the surface via an upwelling process and form a band with high primary production, commonly known as the "cold tongue" (Fig. 2). This upwelling area may support up to 30% of the world's primary production (Chavez and Barber 1987). In contrast, the western equatorial Pacific is characterised by low primary production and high sea surface temperatures (SST > 29°C). The surface equatorial layer west from 160°E (~ 0–200 m depth) has the warmest surface temperatures in the world and is commonly known as the "warm pool". The eastern edge of the warm pool is identified by a salinity front (at about 34.8 psu) and the 28.5°C isotherm (Fig. 2). The intense atmospheric convection in the western Pacific in combination with the weakening of the SEC following the weakening of the trade winds as they enter the western Pacific, results in mean rainfall greatly exceeding evaporation. This maintains the contrast between the fresh western Pacific waters and the high salinity waters in the east, and induces a convergence zone between the cold tongue and warm pool (Fig. 2).

The surface warm pool waters move seasonally to the north during the boreal summer and to the south during the austral summer following the course of the sun (Fig. 3). At the equator, seasonal variations of the warm pool are weak. Tuna migrations in the western and central equatorial Pacific have been hypothesised

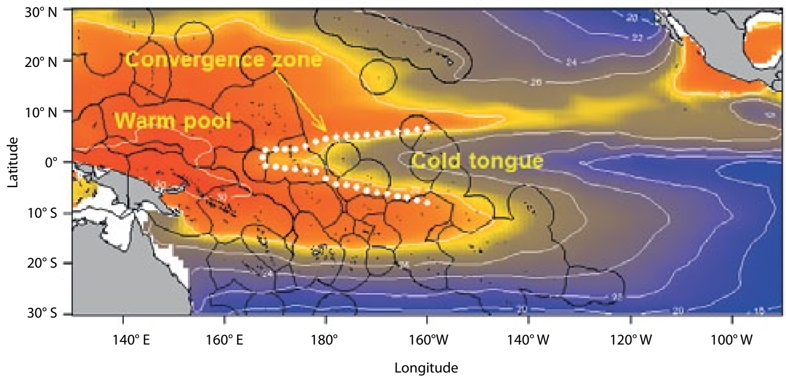

Figure 2. Mean sea surface temperature distribution in the Pacific Ocean in October 2007. The location of the warm pool, cold tongue and the convergence zone in the equatorial Pacific are highlighted. Temperature isotherms are separated by 2-degree intervals.

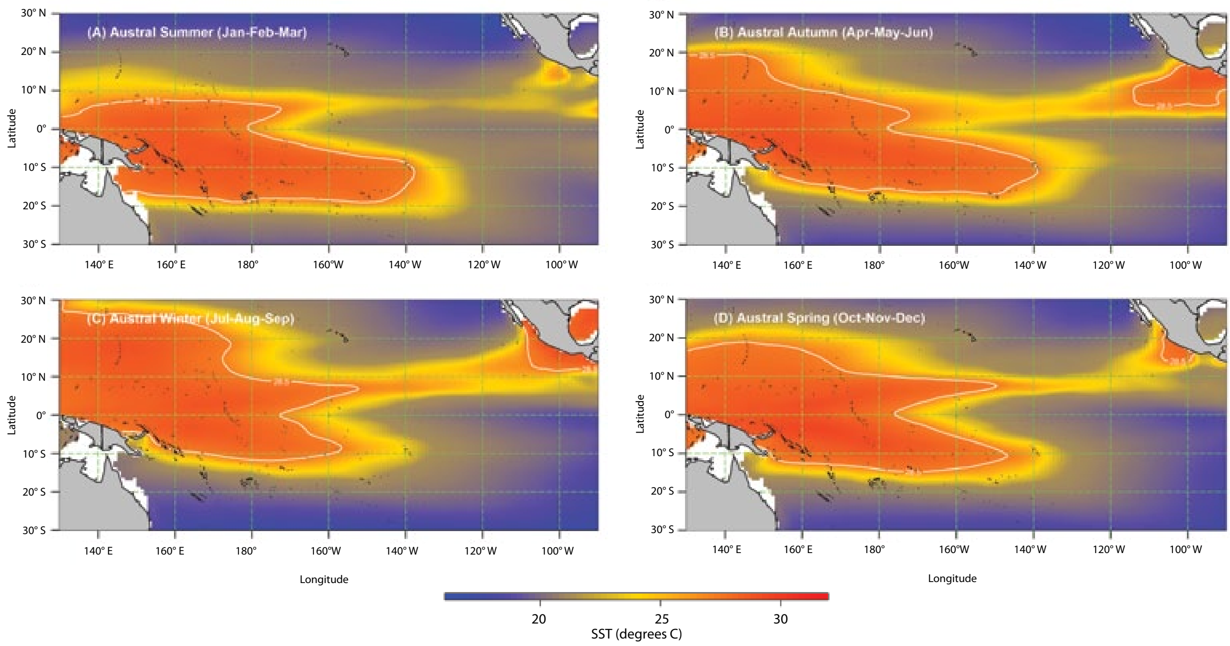

Figure 3. Seasonal variability of the warm pool–cold tongue system in the Pacific Ocean: A) austral summer, B) austral autumn, C) austral winter, D) austral spring. Data are averaged over the period 1990–2012, with El Niño and La Niña phases removed. The 28.5°C temperature isotherm is highlighted to indicate the warm pool boundary. Source: Simple Ocean Data Assimilation (http://www.atmos.umd.edu/~ocean/).

to correlate with the position of the warm pool–cold tongue convergence zone (Lehodey et al. 1997). The eastern Pacific nutrient-rich zone supports high forage abundance, which concentrates in a band several hundred kilometres wide along the eastern edge of the warm pool. Tuna are likely to follow the movements of this convergence zone due to high prey species concentrations (Lehodey 2001). Tuna fisheries, particularly purse-seine fisheries targeting skipjack tuna, appear also to track the position of the warm pool–cold tongue convergence zone.

Oxygen distribution

The dissolved oxygen levels in surface waters of non-coastal areas are mainly determined by the rate at which oxygen is transferred from the atmosphere, which is dependent on temperature and surface mixing. Consequently, the oxygen distribution at the surface is not homogeneous throughout the Pacific. The richest areas of surface dissolved oxygen are found at higher latitudes, where the water is colder and oxygen is more soluble. In contrast, the equatorial and western areas of the Pacific (especially the warm pool) are regions with lower surface oxygen concentration, around 4.5 ml L^{-1} (Fig. 4).

Dissolved oxygen concentration is also determined by phytoplankton production and the rate at which the oxygen-rich surface waters are submerged via ocean currents and mixing. At high latitudes, some cold and dense surface waters rich in O_2 are pushed below the lighter and oxygen poorer subtropical area via a subduction process (mid-latitude convection). These waters gradually lose O_2 as it is utilised in the remineralisation of organic matter by bacteria. Dissolved oxygen at any point in the water column is a balance between the original O_2 content, the effect of remineralisation of organic matter, and the rate at which water is replaced through ocean circulation. In regions of high remineralisation, consumption of O_2 can exceed replenishment from ocean circulation, causing part of the water column to become oxygen depleted, resulting in hypoxic to anoxic conditions. Areas of strong oxygen depletion usually occur in strong biologically productive areas. Figure 4 plots the concentration of dissolved oxygen at the surface and at the 16°C thermocline. There is small variation in O_2 concentration across the surface layer of the Pacific Ocean although at the 16°C thermocline, the higher productivity of the eastern Pacific is evident.

The performance of pelagic fishes, such as tuna, is related to the dissolved oxygen availability and the capacity of their respiratory and circulatory systems. Tuna cannot maintain their metabolic rate when oxygen decreases to 1 mg L^{-1} but the lower lethal level varies considerably among species (Brill 1994). As a result, dissolved O_2 distribution in the water column also influences the horizontal and vertical distribution of tuna because they require adequate levels of dissolved oxygen for their survival and growth.

Inter-annual variability

The ENSO phenomenon is a climatic process contributing to most of the strong interannual variability observed in ocean atmosphere dynamics in the WCPO. ENSO's strongest signature is measured between 10°N and 10°S in the ocean of the tropical Pacific but its climate consequences extend worldwide. ENSO is an irregular climatic oscillation of three to seven years and involving warm (El Niño) and cold (La Niña) phases evolving under the influence of the dynamic interaction between atmosphere and ocean (Philander 1990). The ENSO phenomenon induces major changes in wind regimes and current direction, influencing, in particular, the eastern extension of the warm pool (Fig. 5). Under average conditions, the convergence zone of the warm pool oscillates weakly around 180°, but very large displacements occur with ENSO signal changes. In addition, during normal conditions, a shallow thermocline is found (~ 15–50 m) in the eastern Pacific that deepens progressively towards the west (~ 150 m in the warm pool). During an El Niño

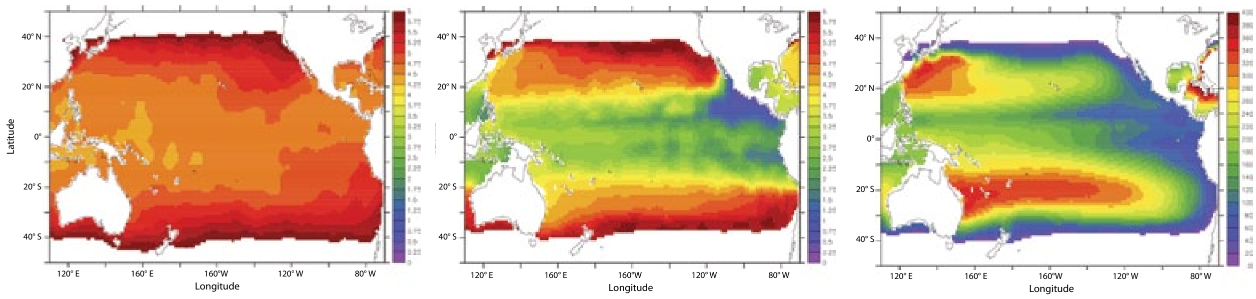

Figure 4. Annual distribution of dissolved oxygen (mg l^{-1}) in the Pacific Ocean (left panel) at the surface; (middle panel) 16°C thermocline; and (right panel) depth of the 16°C thermocline in meters.
Source: http://iridl.ldeo.columbia.edu/SOURCES/.LEVITUS94/.ANNUAL/.O2/

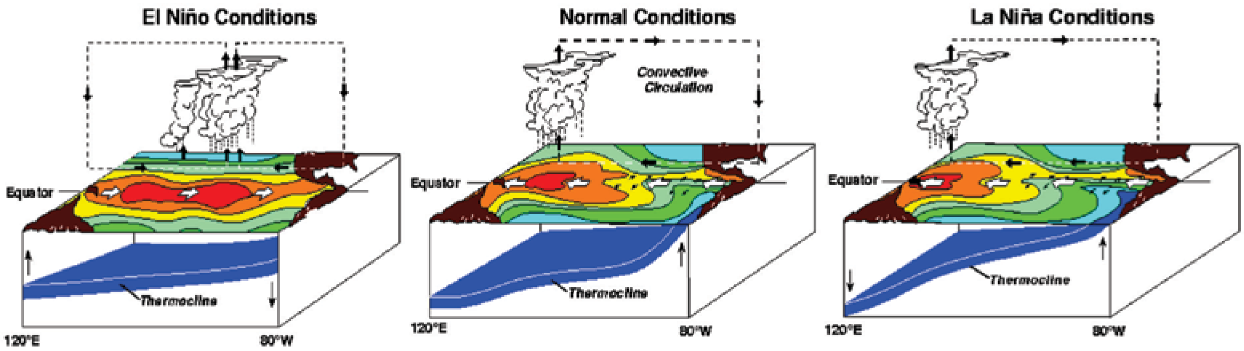

Figure 5. Interaction between the ocean and atmosphere in the equatorial Pacific, and variability in trade winds, warm pool, convection and thermocline depth under the different ENSO climatic conditions. (Source: http://www.pmel.noaa.gov/tao/elnino/nino-home.html).

event there is an eastward displacement of the warm water mass of the warm pool and the thermocline deepens in the central and eastern Pacific, while shallowing in the western Pacific (Fig. 5). In some extreme cases, this results in the relocation of the convergence zone to the east by more than 50° of longitude. During a La Niña event, the warm pool is displaced westwards and is typically confined to the extreme west of the equatorial Pacific (Picaut et al. 1996), resulting in a deeper thermocline in this area (>200 m). The dynamics of an El Niño and La Niña phase usually start in the western Pacific at the beginning of the year and peak in the central Pacific or in the eastern Pacific during the following austral summer, typically 9–15 months later.

Historically, there is considerable variability in the ENSO cycle from one decade to the next. The 1980s and 1990s featured a very active ENSO cycle, with two extreme El Niño episodes (1982/1983 and 1997/1998) and two strong La Niña episodes (1988/1989 and 1998/1999). This period also featured two consecutive periods of El Niño conditions during 1991–1995 without an intervening La Niña episode. Since the beginning of the 2000s, three moderate El Niño episodes (2002/2003, 2006/2007 and 2009/2010) and two moderate La Niña episodes (2007/2008 and 2010/2011) have been recorded. How El Niño impacts the WCPO is not always consistent in latitudes outside of the 10°S–10°N equatorial zone. For example during the 1997–1998 El Niño, there were few climate impacts observed in the South Pacific at higher latitudes (i.e. > 10°S) in comparison to the 1986–1987 El Niño. By contrast, both the 1986/1987 and 1997/1998 events had catastrophic impacts in the 10°S–10° N band.

Several indices are used to quantify the strength of ENSO events; among them, the Southern Oscillation Index (SOI) is defined as the difference between the standardised sea level pressure at Tahiti and Darwin. As convective masses are displaced to the east during El Niño events, the atmospheric pressure decreases in the eastern Pacific and increases in the western Pacific (and vice versa during La Niña events). Hence, SOI is negative during El Niño and positive during La Niña. Prolonged periods (usually more than three months) of increasingly negative SOI values define El Niño episodes whereas prolonged periods of positive SOI values coincide with La Niña episodes. Another commonly used method is based on the ONI 3.4 Index, which is the departure in monthly SST from its long-term mean averaged over the ONI 3.4 region (5°N–5°S, 120°–170°W) as shown in Figure 6. In contrast to the SOI, the ONI 3.4 index is positive during El Niño events (temperatures are warmer than usual in the central Pacific) and negative during La Niña events. Regular monitoring and short-term predictions of the ENSO signal are available from the Australian Bureau of Meteorology (http://www.bom.

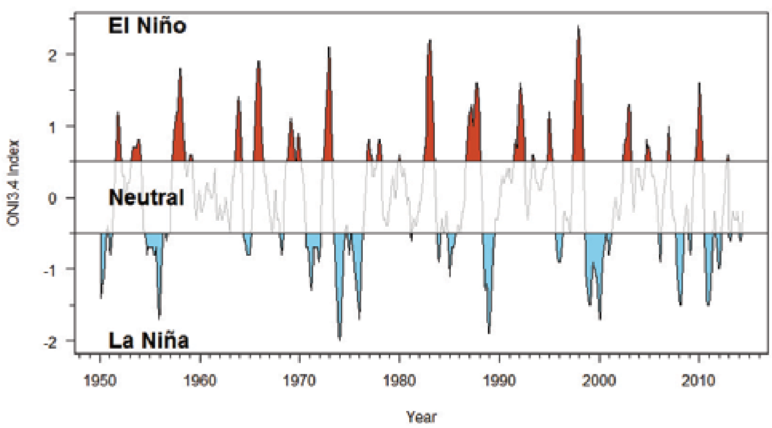

Figure 6. Evolution of ONI 3.4 Index from 1950 to 2014, corresponding to the three months running mean SST anomalies from ONI 3.4 region. Values above 0.5 correspond to El Niño periods, while values below -0.5 correspond to La Niña periods. (Source: http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears_1971-2000_climo.shtml).

gov.au/climate/enso/ index.shtml) and a climate forecast discussion of world model predictions is available at http://www.pmel.noaa.gov.

El Niño events affect tuna habitat and distribution in the Pacific Ocean. For example, the longitudinal distribution of the skipjack tuna catch in the equatorial Pacific has been associated with ENSO events (Lehodey et al. 2011). The spatial extension of skipjack-preferred habitat toward the east during El Niño events results in higher fishing effort in the central Pacific as the warm pool–cold tongue convergence zone moves eastwards (Fig. 7). However, El Niño eastward development produces a shallowing of the thermocline in the warm pool and stronger wind stresses than usual in the western Pacific, eventually leading to an increase of primary production in the western equatorial Pacific (due to mixing of the water and increasing upwelling events). Tuna habitat in the western Pacific improves with this addition of primary productivity and this may explain the increasing catches in western countries (Solomon Islands or Papua New Guinea) during the later part of an El Niño event (Lehodey 2001). In contrast, during La Niña events, a chlorophyll-rich cold tongue extends as far west as 160°E and the skipjack habitat retracts; consequently, fishing effort decreases in the central Pacific (Fig. 7).

Changes in the thermocline depth in the warm pool due to ENSO events also potentially affect catchability. The habitat of adult bigeye and yellowfin tunas includes the thermocline and deeper layers. In the western Pacific, El Niño produces the shallowing of their preferred thermal and feeding habitats (Lehodey 2004). The opposite effect happens during La Niña periods, with a deepening of the thermocline that extends the yellowfin and bigeye tuna vertical habitat. Hence, the optimal fishing depths for longline fisheries that target adult bigeye and yellowfin tunas may be squeezed during El Niño and expanded during La Niña events. For South Pacific albacore, higher catch rates are recorded from the southern subtropical areas of the Pacific Ocean six months before, or at the onset of, El Niño episodes (Lu et al. 1998). This pattern could be linked to the shallowing of the mixed layer depth in equatorial waters, and a reduction in extent of the 18–25°C isotherms in the water column, which are the preferred temperature range of adult albacore. Impacts on catchability for skipjack tuna appear less likely. Skipjack inhabits the epipelagic layer (0–100 m depth) and consequently,

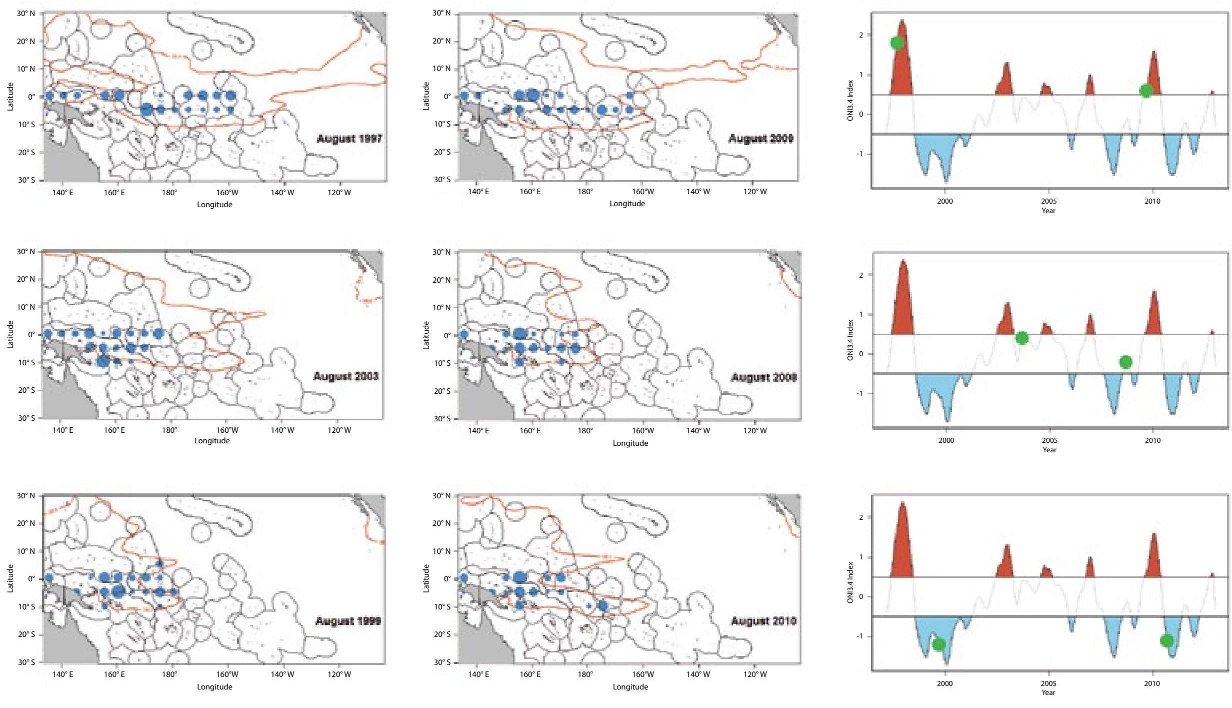

Figure 7. Examples of the distribution of purse-seine fishing effort during El Niño, Neutral and La Niña phases of ENSO. Blue circles are the square root of the number of fishing days by 5-degrees of longitude and latitude. The 28.5°C sea surface temperature isotherm as an indicator of the warm pool boundary is represented in red. The upper plots are fishing efforts for August 1997 and August 2009 (El Niño phases), mid plots are fishing efforts for August 2003 and August 2008 (Neutral phases), and the lower plots are fishing efforts for August 1999 and August 2010 (La Niña phases). The plots on the extreme right indicate the strength of the ENSO phase (green circles). Sources: WCPFC Public Domain fishing data and http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears_1971-2000_climo.shtml.

changes in thermocline depth produced by ENSO events are probably negligible for this species.

In addition to impacts to tuna migration and local availability, ENSO-related variability also affects recruitment and, therefore, the abundance of tuna populations. Previous studies based on predictions from the statistical population dynamics model Multifan-CL (Fournier et al. 1998) suggests a potential link between tuna recruitment and climatic fluctuations, and indicate that tuna species respond in a different way during ENSO events. Results from the SEAPODYM[6] model (Lehodey et al. 2008; Langley et al. 2009) suggested increasing skipjack and yellowfin tuna recruitment in the central and the western Pacific during El Niño events that might be a result of four mechanisms:

1. The extension of warm surface waters (26–30°C) farther east, resulting in favourable conditions for spawning of these two species.
2. Enhanced food for tuna larvae due to higher primary production in the west.
3. Lower predation of tuna larvae.
4. Larvae retention in these favourable areas as a result of ocean currents.

The situation is reversed during La Niña events, when the westward movement of cold waters reduces the spawning success of yellowfin and skipjack tunas in the central Pacific. During La Niña events the bulk of recruitment is centred in the warm waters of the western equatorial Pacific. A study also shows that the extent of the warm pool might be a good indicator for monitoring the effect of environmental variability on yellowfin tuna recruitment (Kirby et al. 2007). The extension of the warm waters in the central Pacific during El Niño events that extends the tropical tuna spawning grounds may conversely reduce those of albacore (Lehodey et al. 2003).

On larger time scales, variations in the strength of the mid-latitude westerly winds produce climate “regime shifts”, like those recorded in 1925, 1947, 1976–1977, 1989 and possibly 1997–1998 in the Pacific Ocean, which had a major impact on the ecosystem and fisheries (Beamish et al. 1999; Chavez et al. 2003; Hare and Mantua 2000; Peterson and Schwing 2003; Polovina 2005;). Regime shifts are characterised by abrupt ENSO-like changes that can last for several decades, commonly associated with the Interdecadal Pacific Oscillation (IPO) or closely related Pacific Decadal Oscillation (PDO). The PDO may be dependent on ENSO because it has been hypothesised that this signal is a residual of successive El Niño and La Niña events (Newman et al. 2003). Its signal is greatest in the North Pacific. It has only a weak signal in the western tropical Pacific, but is also strong in the subtropical South Pacific and in the central and eastern Pacific (Mantua and Hare 2002). It has been hypothesised that the dominance of either El Niño or La Niña events during multi-year periods, possibly in correlation with the PDO, could lead to regimes of high and low productivity in the tuna population (Kirby et al. 2004; Lehodey et al. 2003; Lehodey et al. 2006). However, particularly strong shifts in the environment were not always detected in tuna recruitment time series (Briand and Kirby 2006), which implies that the relationship between tuna recruitment and climatic oscillations is not linear and might depend on several interrelated factors including the adaptation of spawners to environmental variability.

[6] SEAPODYM = spatial ecosystem and population dynamics model.

Potential climate change effects on tuna stocks and fisheries

Recent modelling simulations suggest that increasing greenhouse gas effects on ocean dynamics could also affect the future distribution and abundance of the four main tuna species (bigeye, yellowfin, albacore and skipjack) in response to changes in water temperature, dissolved oxygen, ocean currents and ocean acidification as well as indirect changes in food web structure (Bromhead et al. 2014; Lehodey et al. 2010, 2011). The analysis is based on the Institut Pierre Simon Laplace, coupled climate model (IPSL-CM4) and the multi-model means from the Coupled Model Intercomparison Project Phase 3 (CMIP3) multi-model dataset. These state-of-the-art simulations formed the basis of the Intergovernmental Panel on Climate Change (IPCC) fourth assessment report (AR4) (Solomon et al. 2007). IPCC-AR4 often presents a multi-model average across a large number of relatively independent climate projections to account for the intermodal variability. This averaging tends to remove opposing biases in the models and is considered a suitable method for obtaining useful output, although it can also remove climate extremes that may be real. While there is uncertainty about the effect of climate change on tuna fisheries, considerable research is underway and a number of observations and hypotheses have been proposed.

Climate effects on future temperature and oxygen

Increases in average sea temperatures have been observed around the globe. SST is estimated to have increased by 0.67°C from 1901 to 2005, especially in the warm pool area (Bindoff et al. 2007; Cravatte et al. 2009). In addition, simulations from IPSL-CM4 suggest that in the tropical Pacific, SST is projected to increase by 1.5°C to 6°C under the worst (IPCC-A2) scenario by 2100. At a depth of 80 m, water temperature is expected to rise by 0.5°C in 2035 and by 1.5°C in 2100 (Ganachaud et al. 2011). SST in the central and eastern equatorial Pacific are expected to warm more than those in the western Pacific. The size of the warm pool is also projected to increase by 250% in 2035 and by 770% in 2100 under the worst scenario (Ganachaud et al. 2011), although there is considerable uncertainty on how the dynamics of the warm pool will change (Brown et al. 2014). Because O_2 concentration in water depends on temperature, these models also projected a minor O_2 decrease by 2100 in surface waters, due to the reduced solubility of O_2 in warmer water. In subsurface waters, the increased temperature and stratification of the ocean at higher latitudes are expected to lead to a decrease in O_2 transfer from the atmosphere to the ocean due to less ventilation and advection, resulting in lower O_2 concentrations in the tropical thermocline (Ganachaud et al. 2011). There are also considerable uncertainties about the regional patterns of predicted O_2 changes.

Climate effects on future current and circulation patterns

Increases in SST affect the atmospheric pressure patterns, which are responsible for wind generation. It has been hypothesised that changes in wind strength and direction might modify not only weather conditions, but also the strength and direction of major surface currents. Recent observations indicate that the South Pacific gyre has increased in strength due to a southward intensification of extra tropical winds (Roemmich et al. 2007). This has altered the complex current system of the southwest Pacific and changed the structure of water temperature in the region. Simulations suggest that the currents of the upper water column across most of the tropical Pacific Ocean are expected to decrease in the future, particularly as a result of weakened wind regimes at low latitudes and strengthened winds in the subtropical Southern Hemisphere (Ganachaud et al. 2011). The transport of water from the SEC at the equator is expected to decrease by 10–20% in 2100. Greater changes are predicted for the SECC, for which velocity would decline by 30–60%. Consequently, eddies and upwellings associated with the SEC and SECC are also expected to decrease due to weakening tropical circulation. Shallowing of the maximum mixed layer depth by up to 20 m is also expected in the tropical Pacific (Ganachaud et al. 2011).

Changes in circulation may also alter the timing, location and extent of the upwelling processes upon which most oceanic primary productivity is reliant. Long-term simulations from six climate models tend to suggest a weakening of primary production in the tropics although with considerable differences in patterns and amplitude among models (Henson et al. 2013). Using one climate model (IPSL-CM4, Leborgne et al. 2011) and a detailed regional study, a 9% phytoplankton decrease is projected in the warm pool, with a 20–33% decrease in the archipelagic deep basins in the southwestern areas. Zooplankton is projected to decrease in these regions and nutrients will also decrease in the equatorial cold tongue. The implication is that a decline in the upwelling system in the central and eastern equatorial Pacific may lead to reduced regional productivity. This productivity currently moves with currents to the western equatorial Pacific and is a critical feature on which tuna stocks depend. Note that modelling biological production is a major challenge because models need to integrate the projected changes in the physical and chemical features of the ocean. Globally, the upwelling in the Pacific Equatorial Divergence Province has been very poorly simulated by most IPCC models over the past 50 years, so predictions remain uncertain (Ganachaud et al. 2011). Most recently, Matear et al. (2014) constructed a higher resolution model and forecasted climate conditions in the WCPO until 2060. They noted that with the increase in model resolution and consequent ability to capture finer-scale processes they did not observe significant changes in primary productivity in the warm pool.

Climate effects on future tuna distributions and fisheries

The projected warming of the tropical Pacific Ocean may have two primary effects on the spatial distributions of the four tuna species. The first involves potential changes in spawning location, timing and recruitment success. This effect will mainly depend on the phenological adaptation of each species, but the early life stages of each tuna species are expected to be more sensitive and vulnerable than adults to changes in SST and O_2 (Lehodey et al. 2011; Bromhead et al. 2014). The second potential impact relates to changes in the distribution of the fish outside the spawning season. Increased stratification of the water column may alter the vertical distribution of tuna and affect their access to deep-forage organisms. Temperature and O_2 changes in subsurface waters are expected to have less impact on skipjack, which inhabit the surface layer. In contrast, such changes are expected to have a greater impact on species swimming between the surface and subsurface (yellowfin and albacore tunas), and to deeper layers (bigeye tuna). Bigeye tuna might be less affected due to their higher tolerance for low O_2 levels unless anoxic conditions or "dead zones" (O_2 concentration < 1 ml L^{-1}) develop.

The expected changes in vertical and horizontal tuna distribution are likely to have consequences for fishing operations. The location of prime fishing grounds may change, and the catchability of tuna by surface and longline fisheries might be altered in ways similar to those observed during ENSO events. In particular, fishing grounds might be displaced farther eastward along the equator, or shift to higher latitudes (Bell et al. 2013; Lehodey et al. 2012, 2013). Regardless of where fishing is concentrated, increased stratification could enhance catch rates of the surface-dwelling skipjack and yellowfin tunas where SST remains within their preferred ranges. Similarly, changes in O_2 would constrain yellowfin tuna to the surface layer, leading them to be more vulnerable to capture by the surface fishery (Lehodey et al. 2011). Simulations on the future distribution of the South Pacific stock of albacore were highly dependent on changes in O_2, with the core range moving eastwards and to higher latitudes if projected decreases in O_2 in the equatorial region occur (Lehodey et al. 2014).

Tuna are affected by the water stratification resulting from ocean circulation. The effects of changes in circulation in combination with warmer water temperatures are expected to affect the habitat and catch of some tuna species. For example, a shallowing of the thermocline in the west (such as during El Niño events) implies higher yellowfin tuna catch rates by the surface fishery in the warm pool because of the vertical habitat contraction for this species (Lehodey 2000). Tuna spawning areas are also projected to change with the decreasing trends in major currents that decrease the formation of eddies and increase the stability of water masses. Spawning tuna are expected to avoid areas where temperatures are too high to prevent overheating problems and spawning areas are expected to expand to eastern areas and higher latitudes (Lehodey et al. 2011). Spawning areas would differ among tuna species because bigeye and albacore tunas spawn where SST is greater than 24–25°C, whereas skipjack prefer temperatures greater than 28–29°C.

The projected changes in productivity could also have a potential impact on tuna spawning. Spawning areas might shift to the eastern equatorial region where primary productivity is projected to remain relatively high, bringing food supply for larvae; therefore, changes in productivity might have some direct effects on the abundance and/or distribution of larvae and juveniles and recruitment success (Lehodey et al. 2011). Tuna populations would also appear to be affected by changes in the micronekton productivity they feed upon. Decreases in micronekton forage would likely increase natural mortality of tuna and lower their overall production in the region. Potential changes in tuna distribution are expected because these species tend to follow productive areas. It has been suggested that the eastward shift of the convergence area might lead to a decrease of the tuna population in the warm pool where primary productivity is relatively low (Lehodey et al. 2011). In addition, increasing rainfall might increase the supply of nutrients in the archipelagic waters of Papua New Guinea and develop potential feeding areas. Where there are no physiological constraints, the highly mobile nature of tuna is expected to assist them in adapting to changes in the micronekton prey availability by moving to new favourable foraging grounds (Lehodey et al. 2011).

Relationships between tuna and their environment, combined with their life cycle, can lead to a complex interaction, including feedback loops and non-linear effects. However, this complexity can be modelled by the dynamic model SEAPODYM (Lehodey et al. 2008; Senina et al. 2008) that simultaneously evaluates interactions between environmental changes, biological function and spatial dynamics of tuna populations. Preliminary simulations of global warming on albacore (Lehodey et al. 2014), skipjack (Lehodey et al. 2012) and bigeye (Lehodey et al. 2010, 2013) tuna have been carried out with this model. Preliminary results suggest a declining abundance and a shift in populations towards the eastern Pacific due to the weakening of the equatorial upwelling and equatorial current systems predicted by the IPSL model. In addition, El Niño-like conditions are hypothesised to become more frequent under some climate change scenarios (Timmermann et al. 1999, 2004), and an eastward shift of purse-seine fisheries in the WCPO can also be expected under these conditions (Lehodey et al. 1997; Fig. 7).

Climate change presents important challenges and implications for tuna fisheries. Fishing fleets should be able to adapt to changes in the spatial distribution and abundance of tuna stocks. Domestic fleets that do not have agreements to fish beyond national boundaries may, however, be more vulnerable to fluctuations in tuna biomass within their exclusive economic zone. For the longer term sustainability of these fleets it may be necessary to develop access agreements or capacity to fish in areas outside their current national boundaries. Land-based processing facilities are likely to be the most vulnerable to changes in tuna distribution. These facilities provide significant local employment and indirect commerce to Pacific Island countries and territories (e.g. American Samoa, Fiji, Marshall Islands, Papua New Guinea, Solomon Islands). Greater variability in the supply of tuna to these plants may have consequences for employment security and other development issues such as gender and youth (e.g. lack of employment opportunities or irregular employment may disadvantage women and youth). Developing strategies to ensure the supply of tuna or encouraging industry diversification will need to be considered to "climate proof" this aspect of the industry.

Fisheries policy will need to implement actions that minimise the impacts of environmental change on the sustainability of the industry without compromising short- and long-term development opportunities. Large-scale changes to the tuna industry will incur costs. When and how future climate change will alter tuna distributions and abundances, however, is highly uncertain. To implement appropriate and timely climate adaptations it is essential to identify early signs of change to avoid premature or unnecessary implementation of adaptations. Ongoing research has identified organisms in lower trophic levels than tuna that act as effective early warning indicators of environmental change due to their sensitivity to changes in water chemistry. Because these organisms are the prey of tuna, analysing the composition of tuna stomachs has proven to be a very effective method for monitoring these lower trophic levels. This is potentially a very cheap and effective approach for government and industry to implement "an early warning system" for climate effects as tuna stomachs are a byproduct of tuna catches. Only analysing the stomachs and modelling data are required.

Climate considerations for regional food security

Pacific Island countries and territories have the highest rates of diabetes and obesity on record, driven by changes in lifestyle and increasing imports of inexpensive, nutritionally poor, energy dense food. Health agencies are promoting high rates of fish consumption to help combat the chronic non-communicable disease problems, but rapid population growth is reducing the per capita availability of coastal fish resources needed for good nutrition. Allocating more of the region's tuna resources to local food security, and facilitating access to tuna in rural and urban areas at low cost, have been prioritised as key activities to resolve this issue. Without such action, increases in the economic benefits derived from tuna fisheries may be lost to increasing health costs.

Integrating the analyses of present-day human population levels and those projected for 2020 and 2035 with the area of coral reef (as a proxy for reef fish production) in each Pacific Island country, indicates that 16 of the 22 countries and territories will either increasingly fail to produce enough reef fish to meet their basic or traditional needs for fish, or have trouble distributing the fish from remote reefs to urban centres. The problem is particularly significant in Melanesia, where the great proportion of the region's people live.

To provide the amount of fish recommended for good nutrition, or to maintain traditionally higher levels of fish consumption, tuna will need to provide 12% of the fish required by all Pacific Island countries by 2020, increasing to 25% by 2035 (Bell et al. 2011). In relative terms, the percentages of the region's tuna catch needed in 2020 and 2035 to fill the gap in domestic fish supply are small — 2.3% and 6.2% of the average present-day industrial tuna catch, respectively (Bell et al. 2011). The greatest quantities of tuna will be required in Kiribati, Papua New Guinea and Solomon Islands (Bell et al. 2011). In addition to promoting small-scale artisanal tuna fisheries to supply tuna for this purpose, it will be necessary to continue to utilise small tuna and bycatch caught by industrial purse-seine fisheries. Access to this resource most effectively occurs when purse-seine vessels unload their catch to carrier vessels, which then transfer the fish to land-based processing plants. The ports where this unloading occurs are typically where the greatest demand for tuna for food security occurs. If tuna distributions follow the predicted eastward expansion in core range in response to future climate scenarios, access to this resource for Kiribati may become more stable. Conversely, for western Pacific countries such as Solomon Islands and Papua New Guinea it may become more variable. Importantly, all current forecasts of tuna resources for the Pacific in association with future climate scenarios predict a decline in the total biomass of tuna. How viable offloading small tuna will be under a reduced tuna biomass scenario versus processing these size classes and returning the product as canned tuna to Pacific Island countries is yet to be determined.

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Re-examining the shark trade as a tool for conservation

Shelley Clarke[1]

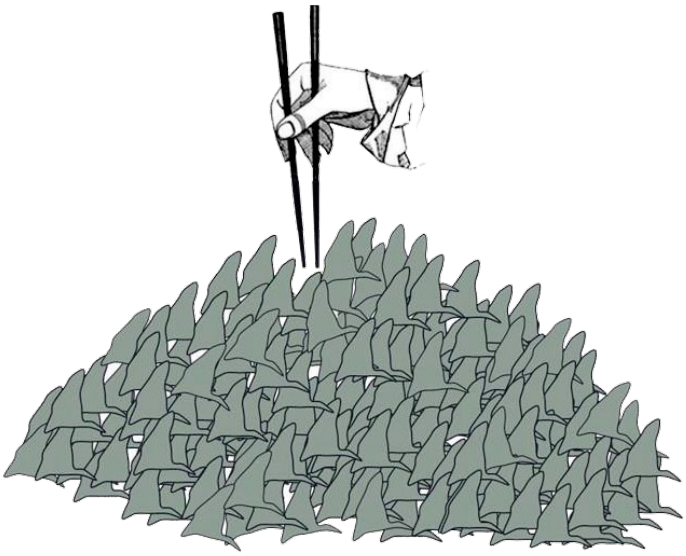
Shark encounters of the comestible kind

Telling the tale of public fascination with sharks usually begins with the blockbuster release of the movie "Jaws" in the summer of 1975. This event more than any other is credited with sparking a demonization of sharks that has continued for decades (Eilperin 2011). In recent years, less deadly but equally adrenalin-charged shark interactions, including cage diving, hand-feeding and even shark riding, have captured the public's attention through ecotourism, television and social media. These more positive encounters (at least for most humans), in combination with many high-profile shark conservation campaigns, have turned large numbers from shark haters to shark lovers, and mobilized political support for shark protection around the world.

But let us step back for a moment from this information age version of history. The most ancient and widespread way that humans have interacted with sharks is through eating them. While some traditional societies have worshipped sharks as protective spirits for millennia, consumption was also part of the relationship (Dell'Apa et al. 2014). Societies such as the Chinese have used the serving and consumption of sharks as a token of respect and a way of reinforcing power since the Ming Dynasty (1368–1644 AD; Clarke et al. 2007).

Demand for this luxury product is one of the reasons why there are extensive and centuries-old trade networks linking China with far-off countries (Schwerdtner Mañez and Ferse 2010). Ironically, despite its venerated status, the Chinese refer to shark fin simply as yú chì (鱼翅, fish fin) rather than using the Chinese words for shark (shāyú, 鲨鱼). This may be the reason why some surveys report that consumers do not always know that the product is derived from sharks (Clarke et al. 2007). The Chinese are not alone in failing to recognize sharks on their plates: sharks have long been used, often under other names, as the "fish" in fish and chips in Europe, Australia, New Zealand and elsewhere. Therefore, while sharks have become conspicuous as entertainment since the 1970s, they have been important as commodities for centuries.

In September 2014, the implementation of multiple new listings for sharks and rays by the Convention on International Trade in Endangered Species (CITES) of Wild Fauna and Flora (Box 1), underscored the need to re-kindle interest in using trade information to complement fisheries monitoring. These CITES listings are a spur to integrate international trade information with fishery management mechanisms in order to better regulate shark harvests and to anticipate future pressures and threats. To highlight both the importance and complexity of this integration, this article will explore four common suppositions about the relationship between shark fishing and trade and point to areas where further work is necessary.



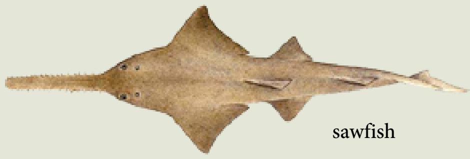
The most ancient and widespread way that humans have interacted with sharks is through eating them.

[1] Technical Coordinator-Sharks and Bycatch, Areas Beyond National Jurisdiction Tuna Project, Western and Central Pacific Fisheries Commission. Email: shelley.clarke@wcpfc.int

Box 1.

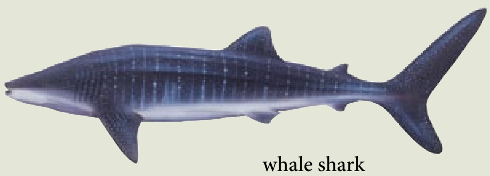
Shark and ray listings by the Convention on International Trade in Endangered Species (CITES)

- CITES was established to prevent the international trade in wild animals and plants from threatening their survival.
  - ✓ Species listed under CITES Appendix I are prohibited from trade under all but exceptional circumstances.
  - ✓ Species listed under CITES Appendix II can be internationally traded under permits authorized by national authorities.
- Because CITES governs trade it can encourage and complement the work of fishery management organizations that are responsible for sustainable fishing practices (Clarke et al. 2014a).
- The following CITES listings for sharks and rays are now in effect:
  - ✓ Appendix I: all sawfishes



sawfish

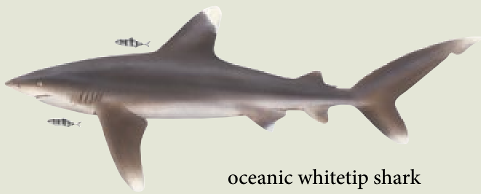
  - ✓ Appendix II: whale shark, great white shark, basking shark, oceanic whitetip shark, porbeagle shark, scalloped hammerhead shark (and look-alikes smooth and great hammerhead sharks), and all manta rays.



whale shark

great white shark

basking shark



oceanic whitetip shark

porbeagle shark

scalloped hammerhead shark

manta ray

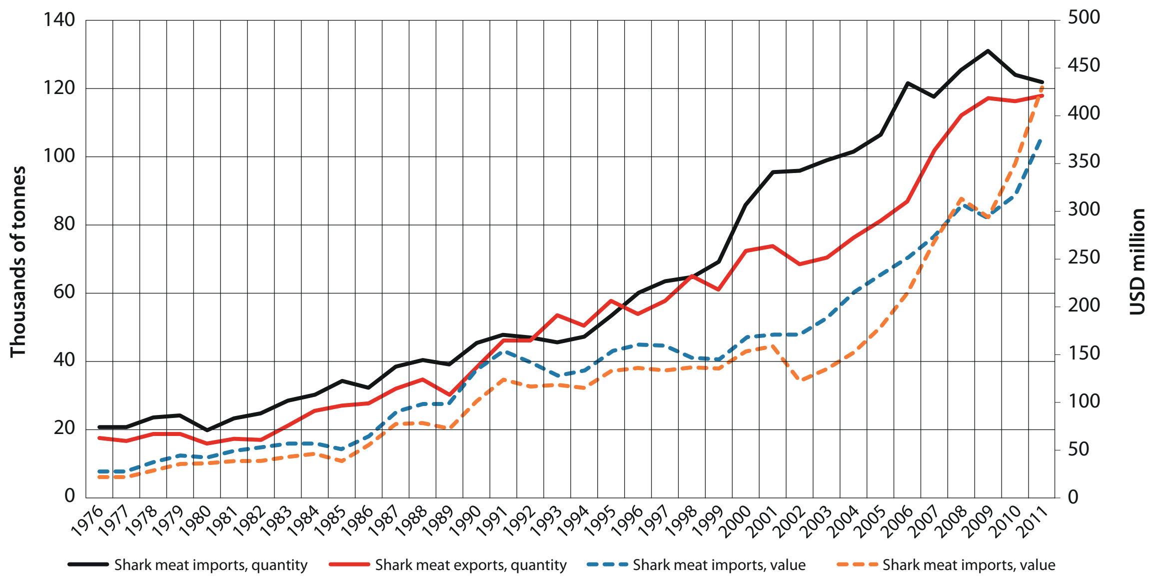
Supposition #1: Banning finning will reduce shark mortality

FOUR WAYS NOT TO FIN A SHARK

- Retain shark with fins attached
- Remove fins but maintain a 5% fins-to-carcass ratio
- Kill the shark (e.g. for gear retrieval) but discard it whole
- Release the shark without killing it

Many conservation campaigns have attacked the shark fin trade on grounds of animal cruelty (live finning), unnecessary waste (discarding of shark carcasses at sea), being unsustainable (overexploitation), or a combination of these. As a result shark finning — the practice of removing a shark's fins and discarding its carcass at sea — is banned in many fisheries. Setting aside for the moment the issue of whether all the different formulations of these bans are enforceable (e.g. the 5% fins-to-carcass ratio), it is important to note that even under perfect enforcement, finning bans may fail to reduce shark mortality. This is because finning bans do not regulate the number of sharks killed, only the way in which they are killed. For fisheries that primarily want sharks for their fins, unless there are catch controls in place in addition to the finning controls, for example as in New Zealand's Quota Management System (MPI 2014), an unlimited number of sharks with valuable fins can be retained and landed, with the fins sold and the carcasses dumped. Alternatively, there may be high demand for shark meat and, therefore, no incentive to fin sharks and discard carcasses at sea. A recent analysis in the Pacific found that even before the finning ban, overfished oceanic whitetip and silky sharks were more likely to be retained than finned (Clarke et al. 2013a). With or without a demand for shark meat, as long as the fishery is able to accommodate the storage and transport of shark carcasses to port, a prohibition on finning sharks may make no difference to shark mortality rates. Bans on finning in the absence of catch controls also do not prevent fishermen from intentionally killing and discarding sharks; for example, to reduce bait loss on future sets.

A recent FAO analysis of global trade statistics reveals that imports of shark, skate, ray and chimaera meat increased by 42% between 2000 and 2011 (Fig. 1). Imports by Brazil, currently the world leader, increased eight-fold during this period, while more traditional importers such as Italy have maintained their market share. There are at least three possible reasons for this rise in the shark meat trade. The dramatic increase in shark meat imports may be a consequence of finning bans, which, if complied with, would encourage landings of sharks whose fins are intended for trade. Alternatively, these statistics



Source: FAO

Figure 1. The world trade in shark meat has grown steadily since 1976 and has roughly doubled since the late 1990s to over 120,000 tonnes per year (Source: Clarke and Dent in press).

may reflect a demand for protein that makes shark meat attractive regardless of the market for fins (Clarke and Dent in press). Finally, better recording of products as "shark" (see below) rather than unidentified fish might explain the trend. In any case, it is important to distinguish between increases in utilization and changes in the number of sharks being killed.

For all of these reasons, there is growing recognition that shark management and conservation must look beyond simply regulating finning, but effective measures to control shark mortality within sustainable limits remain to be adopted and verified in most national and international waters. One benefit of an increasing demand for shark meat should be that it is easier to identify shark carcasses (as sharks, if not always to species) at transhipment, port and border inspection posts as compared to shark fins which can be dried and packed away with other cargo.

Box 2.

Three types of adjustments may be required when interpreting shark fin trade statistics:

1. Shark fins must be distinguished from shark meat.
2. Processed fins must be distinguished from unprocessed fins or else the same fins may be double counted.
3. Frozen fin weights must be reduced (usually by an assumed factor of four) to account for water content.

With many countries' trade statistics it is not possible to make all of these adjustments. It is possible to do so for Hong Kong trade statistics and this is why data from Hong Kong is often used as an indicator of the global trade (Source: Clarke and Dent in press).

Supposition #2: Consumers are being influenced by shark conservation campaigns

Some shark conservation campaigns have focused their efforts on Chinese consumers in the hope that increased awareness of threats to sharks would reduce their consumption of shark fin. A report in the *New York Times* in mid-2013 quoting both campaigners and traders, suggested that the trade had declined as much as 70% from 2011 to 2012 (Tsui 2013). While there is no question that the shark fin trade in Hong Kong and China has contracted (Clarke and Dent in press), both the scale of the contraction and its causes are debatable.

A forthcoming study of Hong Kong shark fin trade statistics — the most accurate proxy for global trends (Clarke 2004) — documents that imports have been dropping since 2003 (see Fig. 2) and that the media-reported declines of 70% from 2011 to 2012 reduce to ~25% when calculated using the proper adjustments for water content and commodity codes changes (Eriksson and Clarke 2015) (see Box 2). China's trade statistics for shark fin are less reliable than Hong Kong's due to commodity coding issues, but there are also media reports of a dip in demand in the northern capital, often attributed to new rules for government hospitality expenses announced in late 2012. Additional support for the effect of these rules, which restrict purchases of "shark

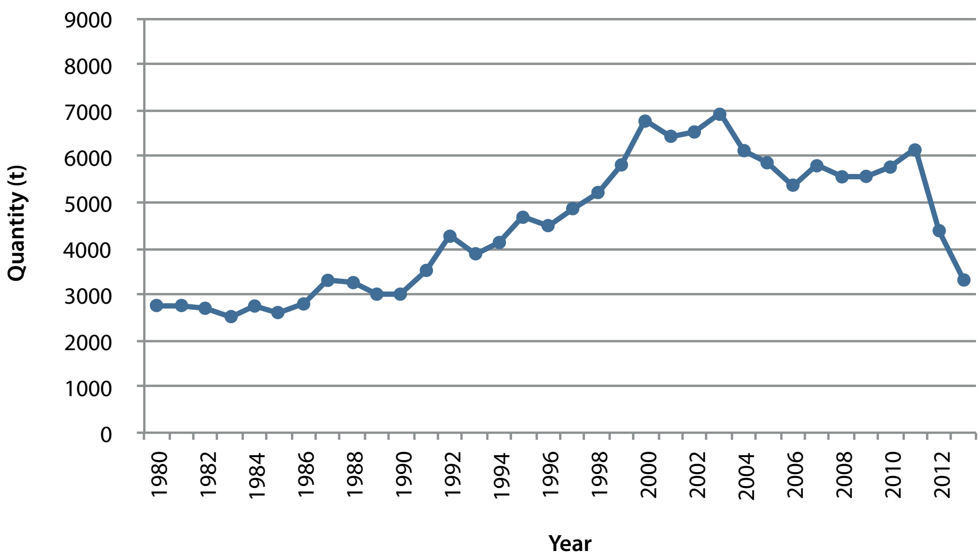


Figure 2. Adjusted shark fin imports by Hong Kong peaked in 2003 and fell thereafter as shark catches decreased. Larger declines in 2011–2012 are at least partially due to reduced consumption. (Source: Hong Kong Government Census and Statistics Department data).

fin, bird's nest and other luxury dishes", comes from reports of declining sales of other luxury seafoods such as abalone, sea cucumber, lobster and crab (Clarke and Dent in press).

But are shark conservation campaigns having any effect on Chinese consumers? It seems impossible to answer this question definitively, but independent interviews of 20 Beijing-based restaurateurs conducted just before the new government hospitality rules were announced offer some insight. All respondents agreed that consumption was falling, but there were divergent views on whether the conservation campaigns were the reason. Some stated that diners were shunning shark fin dishes because they are unhealthy, passé, or, most importantly, likely to be made from artificial materials given the threatened status of sharks and the expected shortage of real fins (Fabinyi and Liu 2014). Without fully understanding the scale or cause, it still seems safe to conclude that the demand for shark fin in China is waning and that sounds like good news for sharks.

Less encouraging is the finding by the new Food and Agriculture Organization (FAO) analysis (Clarke and Dent in press) that Thailand has surpassed Hong Kong as the world's largest exporter, and its main trading partners — Japan and Malaysia — may be among the world's top four importers, particularly of small, low-value fins. Not only do these markets show no sign of slowing down, they are all among the world's top shark fishing nations and, thus, the full scope of their shark fin markets may be even larger than trade-based estimates suggest (Clarke and Dent in press). When we add to this the facts that most consumer-orientated conservation campaigns target shark fins rather than meat, and that shark meat consumption is both growing and often unrecognized as "shark", it is clear that the campaigns have more work to do.

Supposition #3: The trade will collapse when shark stocks become overfished

A third thorny issue at the intersection of shark fishing and trade is the ability of shark populations to support the global fin and meat trades. While many argue that shark populations have already begun to collapse, how have the high trade volumes for fins and meat been maintained for this long?

FAO maintains the only ongoing worldwide compilation of shark, skate, ray and chimaera (chondrichthyan) catches, and if we tally their catches reported as "shark" and "unidentified sharks and rays" they are 20% lower in 2010 than they were in 2000. The amount of catch reported as "skates and rays" is 16% lower. The amount of catch reported specifically as "sharks" has increased but this could be due to greater

Shark fin sales in Beijing have reportedly declined due to changing tastes and fears that the high-priced dish will be made from artificial materials. (Source: Fabinyi and Liu 2014) (image: S. Clarke).

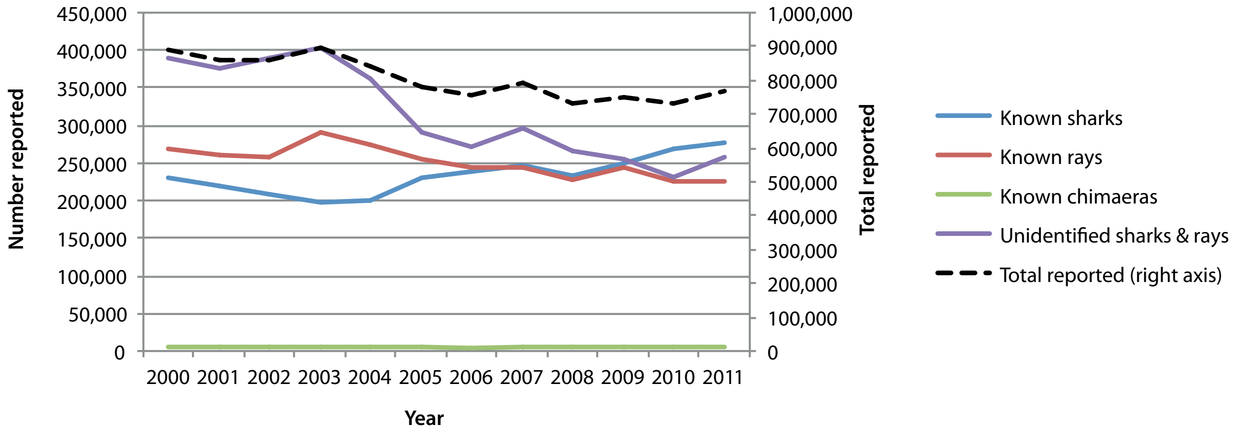


Figure 3. Although the reported catches of "sharks" have increased since 2000, the catches of "rays" and unidentified "sharks and rays" have decreased such that overall catches show a decline of ~15% (source: Clarke et al. 2014b).

species-specific reporting rather than a real increase in catch (Clarke et al. 2014b) (Fig. 3). A fallback to levels of ~11–23% less than the peak is also visible in the Hong Kong shark fin import data for 2004–2011 (see Fig. 2). Despite the potential for the relationship between shark catch and trade to resemble the relationship between chicken and egg, Davidson et al. (in prep.) conclude that the decline in reported chondrichthyan catches is due to overfishing, not a result of decreases in fishing effort or market demand.

Given the reproductive rates of most shark species, it may be surprising that these observed declines in catch and trade statistics are not larger. One possible contributing factor is species substitution. As shown in a forthcoming analysis, the relatively productive and distinctive blue shark is becoming a larger component of reported shark catches compared to the less productive, but equally distinctive and more valuable, mako shark. Therefore, it is likely that the shark fin trade is even more dependent on blue shark than it was in 2000 when that species supported at least 17% of the market (Eriksson and Clarke 2015).

There are already some visible signs of overexploitation in catch and trade statistics, and these may be damped down by substitution of more productive species for those whose populations have already collapsed, for example the oceanic whitetip shark (Clarke et al. 2013a). While there are complications in the data that hamper definitive conclusions, better catch reporting must be encouraged and more focused shark catch and trade analysis is certainly warranted.

Supposition #4: Prohibiting shark catches will curtail trade and reduce pressure on shark populations

It is easy to assume that forbidding fishermen to catch sharks will lead to a suppression of the shark trade and a conservation benefit for shark populations. But here, too, the devil is in the detail: both the ability and desire of fishermen to avoid catching and killing sharks need to be strong for this supposition to hold.

In tuna and billfish fisheries, sharks are caught alongside these target species in large numbers. Methods to reduce unwanted shark catches are a topic of active research but solutions appear to vary by fishery and may have economic or operational consequences (Clarke et al. 2014b; Restrepo et al. 2014). Under two forms of catch prohibition — no-retention measures for certain species and area-specific prohibitions for all species (sometimes referred to as "sanctuaries") — sharks, if caught, must be released with minimal harm. However, studies in the Indian and Pacific Oceans have shown that 81–84% of sharks do not survive their encounter with purse-seine gear (Poisson et al. 2014; Hutchinson et al. 2014). In longline fisheries it is estimated that 12–59% of commonly caught shark species will die before reaching the vessel (Clarke 2011; Gallagher et al. 2014), 10–30% of those that survive haulback will die through handling (Clarke et al. 2013b), and 5–19% of those that survive handling will die after release (Clarke et al. 2014b). With such high potential mortality rates for released sharks, it is not clear whether no-retention and "sanctuary" measures can reduce overfishing to sustainable levels.

Whenever discarding sharks is seen by fishermen to come at a cost — for example loss of saleable products or increasing the likelihood that the next set will catch the same unwanted shark — enforcement must be strong. Small Island Developing States often struggle to find the resources to conduct intensive patrols at sea. Even if catch prohibitions in "sanctuaries" are strongly enforced, vessels that want to continue to catch and retain sharks, or to kill unwanted ones, may move to other jurisdictions with fewer rules and less monitoring (such as the high seas) and continue to fish the same stocks.

Trade data can help to highlight areas where existing fisheries controls may need to be strengthened. For example, the Marshall Islands declared itself a shark "sanctuary" in 2011 by prohibiting both catch and trade. Nevertheless, Hong Kong government records show imports of 7.2 t of dried unprocessed Marshallese shark fins in 2012 and 2.5 t in 2013 (HKSARG 2014). Similarly, United States trade records show 16 t of frozen shark exported to Palau in 2012 and 15 t in 2013 (NOAA 2014). While Palau may not have banned the trade in sharks, these exports suggest that the demand exists, either nationally or for onward trade, and this demand could undermine Palau's designation as a shark "sanctuary" in 2009. These examples provide further impetus for integrating fishery and trade monitoring programmes.

Conclusion

This article has highlighted a number of ways that management of both shark catch and trade data can be integrated for conservation benefit (see Table below).

Humankind's appetite for sharks has never been greater. While this poses a threat to shark populations, it also represents a powerful opportunity to strengthen fisheries management by using trade statistics as new tools for conservation.

Despite recent reductions in the shark fin trade, these mako caudal fins are some of the world's most valuable seafood products (image: T. Miyamoto).

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Issues	Recommendations
Monitoring trade data can help interpret stock status and identify future threats, but it is dangerous to focus on single products and markets (e.g. shark fins in China) because trade patterns may shift while catches remain high (e.g. increase in demand for shark meat).	Fisheries management and trade measures need to focus on effective control of shark mortality, whether or not it is due to finning.
Consumers are influenced by a number of factors, only some of which relate to conservation concerns. Even consumers with preferences may not always be able to identify unlabelled shark products.	Conservation campaigns focused on shark fins need to recognize the growth in the shark meat trade.
Despite overfishing, trade levels can appear stable or to be increasing due to improvements over time in species-specific catch reporting and substitution of more abundant species when less productive populations crash.	Better catch and trade data are key to identifying early warnings of shark overexploitation.
Prohibiting shark catches should be complemented by improvements in bycatch reduction, adequate enforcement and development of trade surveillance programmes.	Fishery and trade data should be used in conjunction to monitor compliance with regulations and overall stock status.

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Secretariat of the Pacific Community, Fisheries Information Section, BP D5, 98848 Noumea Cedex, New Caledonia

Telephone: +687 262000; Fax: +687 263818; cfpinfo@spc.int; http://www.spc.int/fame