Fisheries Newsletter

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Editorial

We open this issue with a short update of SPC's Oceanic Fisheries Programme on advances in fisheries science for the "discrete stock", as the authors put it, of South Pacific albacore. Discrete but essential for some domestic tuna fisheries of the region, such as those of American Samoa, Cook Islands, Fiji, French Polynesia, New Caledonia, Samoa and Tonga, this stock had been little studied before.

The deepwater bottomfish fisheries held very good promise in the late 1970s but, 30 years down the track, very few countries in Oceania still have rising or stable catches. Nevertheless, there has recently been renewed interest in this fishery and Mike McCoy was contracted to assess the management schemes currently in place in the region and try to understand the reasons "why some deepwater bottomfish fisheries have ceased and others have continued" (see p. 26).

You will also read here about: light-cast sportfishing and the ornamental trade in Kiribati and the Cook Islands (if you ever question SPC staff's taste for missions in these places, check out the picture below...); a real breakthrough in the Monkey River prawn aquaculture experiments at USP; a type of hook that was used hundreds of years ago and seems to reduce the catch of non-targeted species today, and more. Enjoy.

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Franck Taunga Smith, an experienced flyfishing guide, practices his art in Kiritimati lagoon, Kiribati (Photo: Éric Clua).

in This Issue

SECRETARIAT OF THE PACIFIC COMMUNITY
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OCEANIC FISHERIES PROGRAMME

Advances in fisheries science for South Pacific albacore

South Pacific albacore fisheries

There is a discrete stock of albacore tuna in the South Pacific that is separate from the North Pacific stock. Distant-water longline fleets of Japan, Korea and Chinese Taipei, and domestic longline fleets of several Pacific Island countries, catch adult albacore over a large proportion of their geographic range (Fig. 1). The Chinese Taipei fleet in particular has targeted albacore consistently since the 1960s, although to a lesser extent since 2000. In recent years the longline catch has increased considerably, with the development (or expansion) of small-scale longline fisheries targeting albacore in several Pacific Island countries, notably American Samoa, Cook Islands, Fiji, French Polynesia, New Caledonia, Samoa and Tonga. A troll fishery for juvenile albacore has operated in New Zealand's coastal waters since the 1960s, and in the central Pacific (near the sub-tropical convergence zone) since the mid-1980s. Driftnet vessels from Japan and Chinese Taipei targeted albacore in the central Tasman Sea and in the central Pacific near the sub-tropical convergence zone during the 1980s and early 1990s. Surface fisheries are highly seasonal and occur mainly from December to April. Longline fisheries operate throughout the year, but the catch is very seasonal, with the fishery operating in the south (mostly south of 35° S) during late summer and autumn, moving north in winter.

South Pacific albacore fisheries science has advanced over the last two years. The Oceanic Fisheries Programme (OFP) at the Secretariat of the Pacific Community has completed two stock assessments for the species on behalf of the Western and Central Pacific Fisheries Commission in 2008 and 2009. This has included an evaluation of the biological assumptions that have underpinned past assessments. Significant research programmes have also begun through the 9th European Union Development Fund project, "SciFish", with activities designed to improve our knowledge on their reproductive biology, growth and movement dynamics implemented. Significant work has also begun to characterise the interaction between South Pacific albacore catches and the oceanography of the South Pacific. The results so far are outlined below.

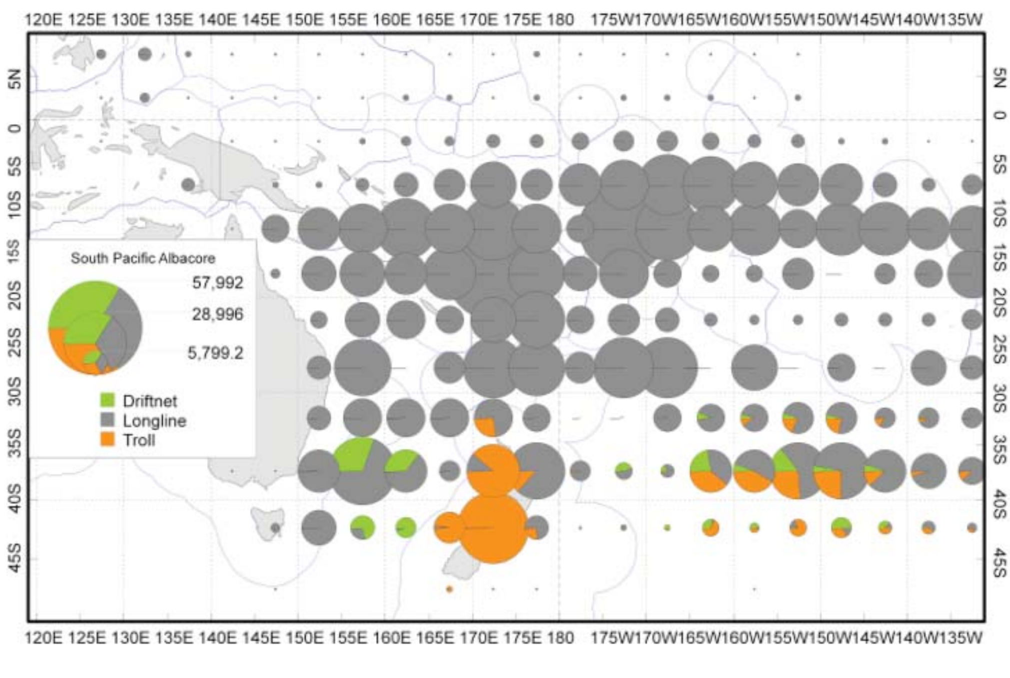

Figure 1. Total catch (in metric tonnes) of South Pacific Albacore from 1958-2008 in the western and central Pacific Ocean.

Recent developments in South Pacific albacore — Oceanographic relationships

The relationships between albacore tuna longline catch per unit of effort (CPUE) and environmental variables are being undertaken at high resolution. Analysis is being undertaken for American Samoa, Cook Islands, Fiji, French Polynesia, New Caledonia, Vanuatu and Samoa. Analysis for New Caledonia is complete and has demonstrated that a large part of albacore CPUE variability can be explained by seasonal, interannual and spatial variations of habitat. The latitudinal movement of sea surface temperature (SST) isotherms appeared to drive the migration of albacore and the seasonality of catches. At the exclusive economic zone scale, higher CPUEs are associated with warm waters in the intermediate layer. In Figure 2 (left panel), the effect on CPUE is highest around 20–21°C. Albacore CPUE also varied in response to the east–west currents in the surface layer, with increasing CPUE for moderate westward currents. In the austral winter, longline CPUE appeared to depend on prey densities (Fig. 2, middle panel). Albacore CPUE was highest at moderate prey densities in the epipelagic layer[1] at night, and for quite low prey densities in the mesopelagic layer[2] by day. Basin-wide oceanographic events also influenced albacore CPUE in New Caledonia, with above-average CPUEs during strong El Niño episodes (Fig. 2, right panel).

Recent developments in biological knowledge

Stock assessments for South Pacific albacore require estimates of biological parameters that describe population dynamics. However, some of the estimates used have been quite uncertain, either because of missing or scarce biological data, or because data had not yet been analysed. Sustainable fisheries need continued reproductive output, and so stock assessments use spawning biomass in stock status indicators and reference points. Past stock assessments for South Pacific albacore reported on spawning biomass as the product of numbers at age, weight at age, and maturity at age. The dynamics of tuna however are more complex. The sex ratio of tuna changes with size, with maturation being an interaction between the age and size of an individual with some faster growing individuals beginning reproduction younger than slower growing individuals, and egg production increasing more rapidly with increasing length. A more accurate method for measuring spawning biomass is spawning potential because it includes age-related and sex-related effects on reproductive output. This can be calculated as the product of numbers at age, maturity at age, proportion of females at age, fecundity at age, and the fraction spawning at age. Sensitivity analysis demonstrated that reference points based on spawning potential can differ significantly from those based on spawning biomass for South Pacific albacore.

For albacore, the proportion of males increases with size (Fig. 3). Sex ratio data were supported by an increase in natural mortality for mature females (Fig. 3), but differences between sexes in growth or vulnerability may also contribute to this observation. A preliminary study of the age, growth and reproductive biology of albacore was completed by Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) in 2008. This study used representative samples of albacore from the Australian

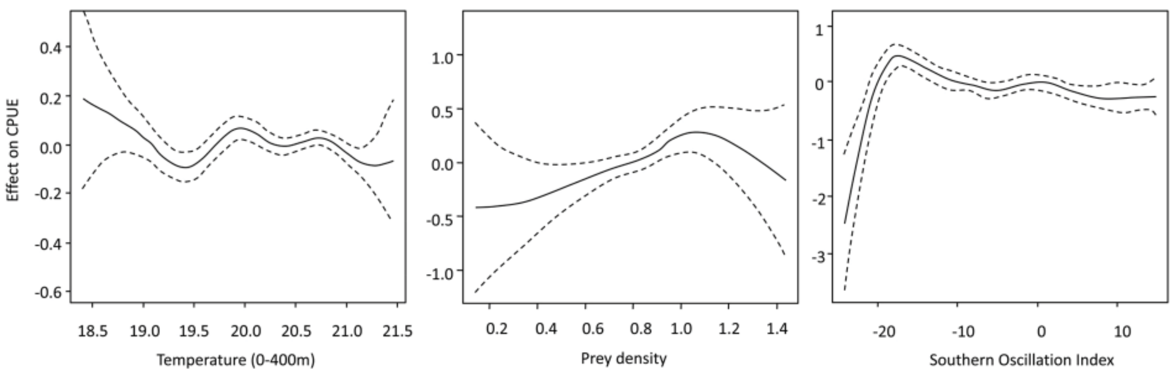

Figure 2. Effects on CPUE of water temperature in the depth range 0–400 m (left panel), prey density (middle panel) and Southern Oscillation Index (right panel). Above zero effects represent higher CPUE and negative values lower CPUE. Extreme values on the x-axis should be interpreted with caution as the Generalized Additive Models (GAM) poorly estimated at these margins.

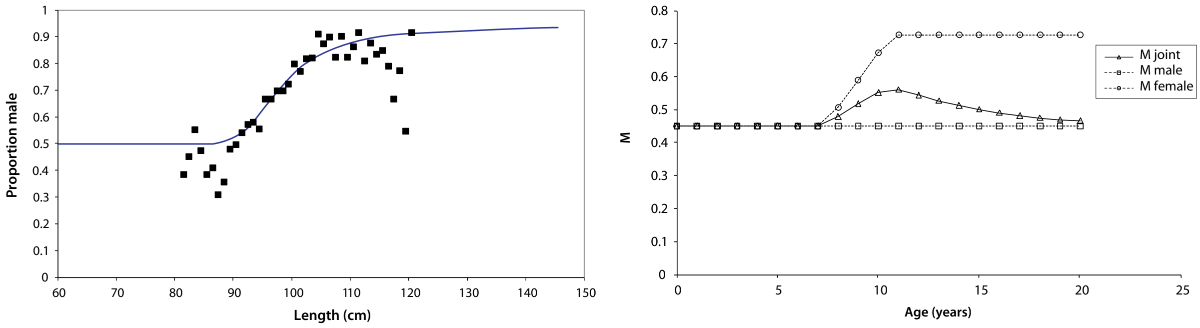

Figure 3. The relationship between sex ratio (proportion of males) of South Pacific albacore and length (left panel) and estimated natural mortality curve (right panel).

Eastern Tuna and Billfish Fishery to estimate the age structure, growth rates, sex ratios and maturity of albacore off the east coast of Australia. The oldest albacore sampled in this study was 14 years and the average maximum length was 103 cm fork length (FL), with males growing slightly larger than females. There were more males than females sampled, particularly in the larger size classes, and 50% of females were mature by 82 cm FL and four years of age. The maturity information differed from that used in the stock assessment, indicating that there may be regional variation in age at maturity. Information on fecundity at length and spawning fraction at length are extremely uncertain for South Pacific albacore.

OFP and CSIRO are now collaborating on a larger project that will expand the preliminary biological study from Australia. It will investigate spatial variation in reproductive and growth biology of albacore across the western and Central Pacific Ocean (WCPO). As part of this collaborative project, a large-scale sampling programme was implemented in 2008 to collect biological samples (gonads and otoliths, Fig. 4). The objective was to collect samples from approximately 100 albacore in each of 25 grids across the WCPO (Fig. 5). During SPC observer training workshops, fishery observers were trained to extract samples, and have already collected several hundred. Sampling will continue until the end of 2010.

The sophisticated stock assessment models used in the WCPO integrate catch, size and tagging data. Catch and size data are collected annually for South Pacific albacore, but only a small tagging dataset is available. Over 17,000 albacore were tagged with conventional tags in the convergence zone of the South Pacific during dedicated tagging programmes between 1985 and 1992.

These tagging programmes have provided the most useful information to date on the potential movement patterns, growth rates and exploitation rates of South Pacific albacore. However, there is a need to obtain more contemporary data to refine our knowledge of albacore movements and exploitation rates.

As part of the SciFish project, a tagging study was developed with the overall objective of obtaining better estimates of exploitation rates, movement patterns, and growth rates of albacore. The first phase of albacore tag-

Figure 4. South Pacific albacore gonad (left panel) and otoliths (right panel).

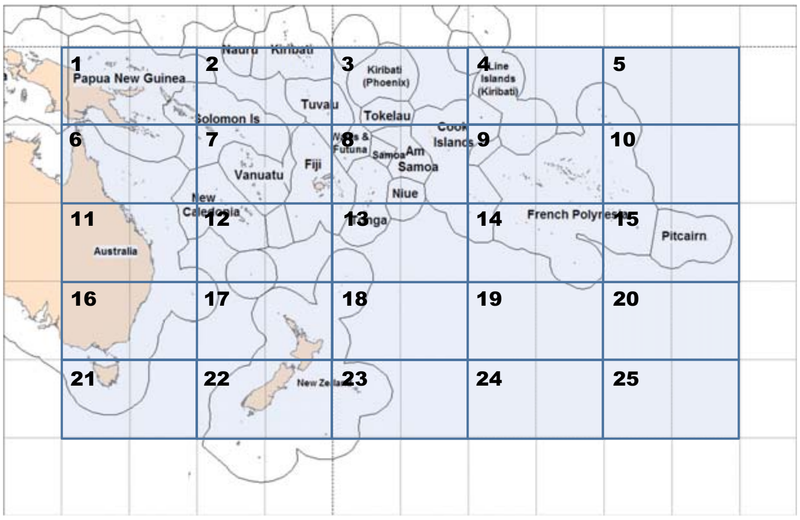

Figure 5. Locations where South Pacific albacore gonads and otoliths are sampled.

ging was completed in 2009 off the west coast of the south island of New Zealand where 2,766 albacore were tagged and released; 1,457 of these fish also received an injection of oxytetracycline (OTC) as part of an experiment to validate age estimates for albacore. To date, only one recapture has been reported from these tagged fish. This fish was recaptured 11 months after release, approximately 200 km from the release site.

The second phase of albacore tagging will be completed by the end of 2010 and will include tagging in New Caledonia, New Zealand and Tonga. A focus for the tagging in 2010 will be the deployment of 30 miniature pop-up satellite archival tags (miniPATs) on large (~ 20 kg) albacore. The miniPATs can provide detailed information on the vertical and horizontal movement of fish, and are particularly suited for albacore, which typically suffer from low recapture rates, such that standard archival tags are not a viable option.

Tagging in New Zealand has been completed for 2010 with 92 albacore tagged with conventional tags and injected with OTC. Five albacore were also released with miniPATs. Since their deployment, 3 miniPATs have released prematurely after 9, 11 and 30 days. The data from these tags have been received from the satellites revealing detailed information in the vertical movements of albacore (Fig. 6). An interesting observation from these individuals is the predominance of occupying habitats in the 17.5–19.5°C range. On the east coast of New Zealand this has typically been in the 50–100 m depth range with regular bounce dives to deeper and colder habitats. Further analysis will provide information on the horizontal movements of these individuals.

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1. Epipelagic layer: From the surface to around 200 m depth, in the illuminated surface zone where there is enough light for photosynthesis.
2. Mesopelagic layer: From 200 m down to around 400 m, in a zone where some light penetrates but is insufficient for photosynthesis.

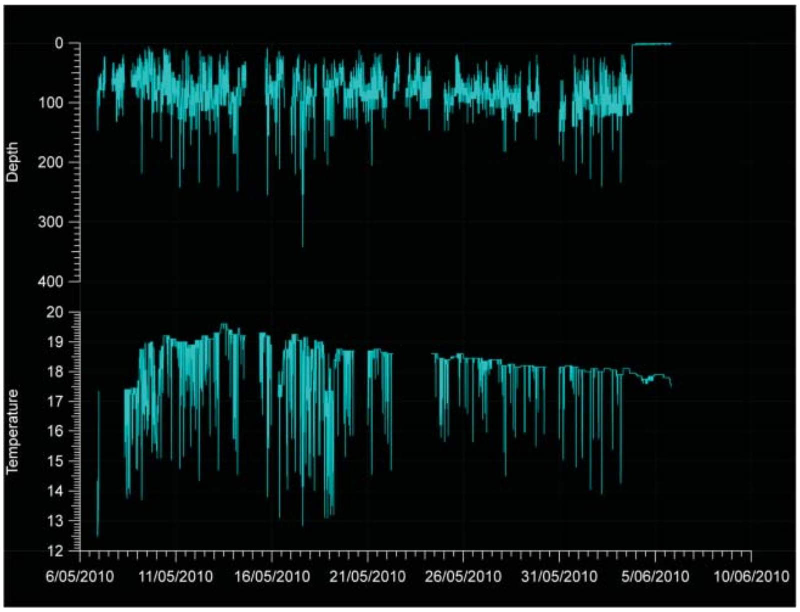

Figure 6. Vertical movement and temperature profile of one PSAT-tagged South Pacific albacore tagged of the east coast of New Zealand in May 2010.

AQUACULTURE SECTION

White teatfish aquaculture project in Kiribati

The Australian Centre for International Agricultural Research (ACIAR) has agreed to fund a project to assess growth and survival of hatchery-produced white teatfish (*Holothuria fuscogilva*) juveniles in the wild, in the atolls of Kiribati. This is a mini-project scheme that will be implemented by Kiribati's Ministry of Fisheries and Marine Resource Development (MFMRD) with technical assistance from SPC's Aquaculture Section.

The Kiribati Beche-de-mer Project was initiated in the mid-1990s as a result of concern over the overfishing of the commercial sea cucumber species, white teatfish (*Holothuria fuscogilva*). Hatchery production of white teatfish was initiated by the Kiribati government with assistance from the Japanese Overseas Fisheries Cooperative Foundation (OFCF). From 1997 to 1998, several hatchery runs produced approximately 8,000 juveniles but the joint project ended in 1999. Since then, the Kiribati government, through the Fisheries Division, has been maintaining small-scale production at the beche-de-mer hatchery and have released approximately 20,000 white teatfish juveniles into the lagoon. However, monitoring the releases has not yet provided good estimates of post-release survival rates of white teatfish juveniles. Juveniles are highly cryptic and rarely seen. Most of the released juveniles are never found during the monitoring period. Moreover, individuals found in surveys cannot be equivocally distinguished from wild stock. The economic and practical feasibility of restocking, in terms of the number of surviving adults versus the cost of hatchery production, is questionable unless effective release and monitoring strategies are developed.

An earlier ACIAR-funded mini-project conducted in 2005–2006 used knowledge gained from another ACIAR project, "Optimal release strategies for restocking and stock enhancement of the tropical sea cucumber". The WorldFish Center in New Caledonia has developed optimum release methods for juvenile sandfish (*Holothuria scabra*), which could be applied to the related white teatfish, and the previous mini-project aimed to test the methods and develop suitable protocols for white teatfish. Although there were some good outcomes from the project, it did not present any data on survival and growth of hatchery-produced white teatfish released in the wild.

In early 2010, Kiribati's Fisheries Division had 500 juveniles (~4 cm length) ready for release at the Tarawa hatchery (Fig. 1). Knowledge gained from the previous study indicates that dark-coloured surfaces such as hard reef substrata with epilithic algae, and certain seagrasses, may allow the juvenile white teatfish phase to be camouflaged and thus provide protection from predation. This mini-project will provide important insights into release strategies for a valuable sea cucumber species that is not cultured elsewhere in the Pacific, and enhance a priority research commitment of the Kiribati government over the last decade. The project does not involve any introduction or transshipment of new species, potential legal disputes or controversial issues.

Description of experiments

The specific objectives of the mini-project are to: 1) investigate survival and growth of hatchery-produced white teatfish juveniles in inshore marine habitats, and 2) build capacity of Kiribati aquaculture officers in release strategies and monitoring of released hatchery-produced white teatfish juveniles.

In January 2010, SPC's Aquaculture Officer went to Kiribati to develop small-scale release experiments to obtain baseline data on habitat preferences of ju-

Figure 1. Hatchery-raised juvenile white teatfish (*Holothuria fuscogilva*).

veniles. Because there were only small numbers of juveniles for the experiments, and because keeping track of those released in the past (one as recently as this year) has been unsuccessful, the juveniles were caged so that they could not escape from the release area (Figs. 2 and 3).

For this experiment, it was decided that several habitats had to be tested in order to identify where the juvenile white teatfish would grow best and survive. The common habitats within the lagoons of Kiribati are varied, but some characteristic habitats that were selected include seagrass beds (Abaiang), hard substrates on lagoon pinnacles (Abaiang) and silty areas near mangroves (North Tarawa). Two cages were deployed at each site and each cage received between 30 and 35 young sea cucumbers that had been transported in plastic bags with oxygen. The sea cucumbers were carefully released and placed in their new habitats.

Figure 2. Cages are built in the lagoon with steel rod, rope, chicken wire and small mesh netting.

Figure 3. The small size of the cages facilitates the monitoring of the released juvenile white teatfish.

Initial observations and issues to overcome

The sea cucumbers were observed during the following days of their release in the sea pens. They seem to have adapted to all three new environments because they were observed excreting sand only a few hours after being placed in cages. On the next day, the sea cucumbers placed in the hard substrata environment had already covered themselves with pieces of coarse sand and small rubble. A few days later the sea cucumbers in the silty area had travelled around the cage, staying mainly in the corners or in areas where they felt protected.

Unfortunately, some particularly bad weather conditions destroyed the set up several days later. This experiment, besides the initial observations, will therefore not achieve the goal of the project. The Fisheries Department has been working on organising further spawning of white teatfish in order to resume experiments later in 2010. The major problem faced by Kiribati Fisheries Division is that the white teat fish has been so heavily exploited thorough the atolls that even acquiring a dozen of fresh broodstock has become problematic.

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Collaborative project to develop post-larval capture and culture methods in Pohnpei, Federated States of Micronesia: A sustainable way of supplying the ornamental fish market

Post-larval capture and culture trials in Pohnpei

Following an agreement between the Coral Reef Initiatives for the Pacific (CRISP) programme in Noumea, New Caledonia, the Marine and Environmental Research Institute of Pohnpei (MERIP), Federated States of Micronesia, and Hawaiian SeaLife in Honolulu, project funds were granted to develop post-larval capture and culture (PCC) techniques to supply Hawaii's marine aquarium trade.

When the project started in early 2010, Simon Ellis and his staff from MERIP had already been fishing for several weeks. Two light traps had been used, and there were some encouraging results, despite poor weather conditions that prevented fishermen from deploying the traps outside the lagoon where fish recruitment is likely to be higher and where species diversity is greater. Various types of fish had been collected on a regular basis, such as damselfish (*Pomacentrus pavo, Chrisiptera leucopoma*) surgeonfish (*Acanthurus triostegus, Ctenochetus striatus, Naso brevirostris*) and butterflyfish (*Chaetodon lunulatus, C. ephippiuma, C. vagabundus*). Some of these species have interesting commercial value from a PCC point of view (i.e. non-traditional wild-caught fish market).

Now, some fishermen are paid by MERIP to fish at night, set the traps and retrieve them in the morning with the catch. The fishermen prefer to monitor the equipment overnight to avoid any risk of theft and be able to retrieve the catch at first light. Fishermen receive USD 30 per night to fish. In the future, they would need to make a minimum of USD 20–30 worth of commercially desirable post-larvae per night to sustain this activity. As part of this project, the economics of PCC must be understood in Pohnpei in order to ensure the long-term viability of this activity.

Assembling and deploying crest netting equipment

A crest net was designed and made in New Caledonia, and then brought to Pohnpei to carry out experimental crest netting trials. A 320-mm pipe was imported from the Marshall Islands Mariculture Farm and assembled as a cod end for the crest net (Fig. 1). This matched the end of the net perfectly and overall, the net was strong and suitable for being deployed on the reef crest.

The crest net was deployed in two different areas. The first location was a reef top where a strong current flushes the water from the windward side of the island towards the lagoon. The net was securely tied to the reef top and between mangrove trees because the reef structure was too dense to allow any rebar pegs to be driven through it (Fig. 2). Unfortunately, there was too little water flowing during low tide in this area at night and the fisherman assigned to monitor the net came back with only a few dead specimens.

The second site sampled was a channel that was excavated from a lagoon reef. It had many advantages: 1) the pegs could easily be planted into the substrate, 2) the net remained well underwater all night, and 3) with the current weather pattern, the windblown water would be pushing the current through the net continuously. However, yields in this area were not high, probably because most fish in the area had already recruited in the lagoon and because the flow was sometimes too slow, allowing larvae to swim out of the net.

Further sites were surveyed on the barrier reef around MERIP. One site had good potential but the reef top was too hard, making it difficult to anchor the net. Another site with good potential was a narrow reef top with good incoming flow and areas to keep the cod end constantly underwater. MERIP staff will keep conducting net sets at dif-

Figure 1. The crest net with a 320-mm PVC pipe fitted as a cod end.

Figure 2. The crest net set on the reef top between mangrove trees.

ferent areas until an optimal location is found for the crest net.

Post-larval husbandry

MERIP has an indoor wetlab with four flow-through 100-L glass tanks. It was recommended that these aquaria be used for a one-week weaning period before fish were transferred to an outdoor system. Indoors, fish are sorted by species and fed with live *Artemia nauplii* until formulated diets are introduced. A small system to feed fish with *Artemia nauplii* continuously was demonstrated.

Once the fish fully accept the commercial diets, they are transferred to an outdoor system made of four raceways (2,000 L each), which are divided with *hapa* nets where fish can be separated by size and species.

It takes only a few weeks for the fish to reach commercial sizes when they are fed on formulated diets. They will then be graded and packed for export.

Future plans for post-larvae exports

MERIP, as part of this project, intends to start trial shipments of post-larvae by the end of 2010. Initial stocks will be shipped to Hawaiian Sealife Inc. in Honolulu. Hawaiian Sealife is currently expanding its scope of operations in many different directions. PCC has gone in several directions, including a push to market juvenile fish into the marine aquarium trade, and a school programme where students can observe their fish growing and changing over the course of a semester. Overall, Hawaiian Sealife will work on promoting PCC techniques and the location, on the aquarium market. They will use their newly built facilities, located near Honolulu International Airport. China is also coming up as a new and vast market for this type of aquarium product.

The biggest ornamental aquaculture facility in the world — Oceans, Reefs and Aquariums — is also interested in developing a line of PCC products. They are well aware that closed cycle technology for many species is still years away and in their "all cultured" policy they could buy and sell many PCC products. This is a path that MERIP will want to further explore in the future.

Other activities at MERIP

MERIP has been promoting other types of activities in the past few years, including sponge and coral farming. Both activities have been increasing and there are now over 20 sponge and coral farmers on Pohnpei Island (Fig. 3).

Sponge seems to grow very well in open areas near lagoon passes where there is considerable current flow. An individual small-scale farm can hold from 1,000 to 2,000 pieces of sponge, which takes two years to grow. They are then washed in a washing machine and cleaned prior to export. They are sold in New Zealand and have had successful market response. The trend here is on the increase.

Figure 3. A sponge farm in Pohnpei.

Corals are also being grown by a small-scale private farmer who sells them to MERIP, which oversees the export. All corals are exported to the Marshall Islands where they are grouped with Marshall Islands Mariculture Farm shipments to Oceans, Reefs and Aquariums in Florida, USA. Corals that have been cultured thus far are soft corals (leather corals, *Zooanthus* spp.), small polyps from hard corals such as *Acropora* spp., and large polyp from hard corals such as bubble corals or torch corals (Fig. 4).

Figure 4. Soft corals farmed in Pohnpei.

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COASTAL FISHERIES SCIENCE AND MANAGEMENT SECTION

Bonefish catch-and-release sportfishing picks up in the Pacific

Bonefish sportfishing supports one of the most important recreational fisheries in subtropical and tropical regions worldwide. Flyfishing for bonefish is one of the most esteemed forms of sportfishing in the world. The fish are stealthy, fast swimming fighters that are challenging to catch. The silver-bodied fish spend much of their time swimming along very shallow banks searching for food. The sport is well established in many places, mostly in tropical areas of the Caribbean, Indian Ocean, Africa, South America, USA (Florida), and now the Pacific Islands region, and attracts sport anglers from all over the world who are looking for new fishing sites and challenges.

A beautiful bonefish caught on a fly (Image: Being Yeeting).

In countries such as Cuba, Seychelles, Mexico and the Bahamas, tourism has developed around flyfishing for bonefish, bringing in foreign currency and creating income opportunities for coastal communities, including direct employment for local fishing guides and side benefits for the catering and hotel industries. In the Pacific Islands, flyfishing for bonefish is practiced commercially in New Caledonia and on Christmas Island (Kiribati) where weekly charter flights from Hawaii bring in flyfishing enthusiasts. On Christmas Island, with only about 1,000 visiting flyfishers a year, this tourism-based fishery is valued at a minimum of USD 2.5 million annually, excluding any side benefits to the community. The bonefish resource on Christmas Island suffered from a lack of any management control, especially from considerable gillnetting activities, until 2008 when a bonefish regulation was drafted (with assistance from SPC) and put in place. Recent reports from bonefish fishers and local fishing guides on Christmas Island claim that bonefish stocks are becoming abundant again, which means the management plan has been a success.

Specialist bonefish enthusiasts are seeking new destinations that offer them a guarantee that they will catch many good-sized bonefish. An "exotic" natural environment and a high-quality tourism infrastructure are also important. Aitutaki in Cook Islands is seen as an ideal destination that meets these criteria. The local government, municipal council, hoteliers and the Ministry of Marine Resources see the potential for this fishery and have committed to developing sport fishing and tourism around Aitutaki's bonefish resource, and have asked SPC to assist them in this endeavour.

In January 2010, SPC's Senior Fisheries Scientist (Live Reef Fisheries) visited Aitutaki to hold a public meeting with the local community of Aitutaki, and to develop an appropriate management plan for the proposed bonefish fishery. This visit was a follow-up to previous trips by staff of SPC's Nearshore Development Fisheries Section (see article in Fisheries Newsletter #128) who have taken the lead in assisting the Aitutaki Island Council in developing this tourism-based bonefish fishery.

SPC's Senior Fisheries Scientist spent five days working with Aitutaki Fisheries staff conducting interviews with fishers and village community members, as well as conducting a quick field assessment of bonefish fishing areas and known spawning aggregation sites. On the last day, a draft framework of the proposed management plan for the new fishery was presented to the community. Community members were very interested in and supportive of the new fishery and wanted to see the management plan completed and endorsed before the fishery was officially opened.

Following the trip, a draft management plan was developed and sent to the Cook Islands Ministry of Marine Resources and the Aitutaki Island Council for comments.

Conducting interviews with experienced Nonouti bonefish fishermen (Image: Being Yeeting).

Gillnetting for bonefish – A big threat to the fishery (Image: Being Yeeting).

Franck Taunga Smith, flyfishing guide, releases a bonefish (Image: Éric Clua).

The Aitutaki bonefish management plan is currently being finalised.

In early February 2010, SPC received another request, this time from the Kiribati Ministry of Fisheries and Marine Resources Development (MFMRD), to assist with developing a tourism-based bonefish fishery in Nonouti, one of the outer islands in the southern Gilbert Islands. The island has abundant bonefish resources, and a trial visit by an Australian bonefish fishing group proved to be a success. The main objective for the request was to assess whether Nonouti's bonefish resources could support a tourism-based bonefish fishery, and if so, develop a management plan and regulations for the new sport fishery there. With the success of the Christmas Island Bonefish Fishery, MFMRD viewed this as a great and worthwhile outer island income generating opportunity and willingly covered all of the SPC Senior Fisheries Scientist's travel costs (airfare from Noumea to Nonouti and back).

The SPC Senior Fisheries Scientist was in Nonouti from 24 February to 3 March 2010, and during that time held meetings and conducted interviews with fishers and members of local communities. In total, 19 very experienced fishers (who have been fishing for bonefish in Nonouti for more than 10 years) were interviewed (fishermen ranged in age from 38 to 79 years). Field visits by boat were also made to look at spawning aggregations sites and sand flats in Nonouti's lagoon. On the last day of the visit, the fieldwork findings were presented in a public meeting. There was very strong support for developing the bonefish fishery into a tourism-based catch-and-release fishery. There was also general agreement to ban gillnetting for bonefish and to ban all forms of fishing at bonefish spawning aggregation sites during spawning periods. These findings were used to develop a draft framework for the Nonouti Bonefish Management Plan.

A draft Nonouti Bonefish Management Plan has been completed and sent to MFMRD and the Nonouti Island Council for comments and refining. The management plan emphasises the importance of maximising benefits and distributing these benefits equally among the island community. Once the management plan is finalised, it will be translated into the local I-Kiribati language so that Nonouti community members can fully understand it and its implications on their livelihoods.

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Developing a sustainable marine aquarium trade industry on Kiritimati Island

The marine aquarium industry in Kiritimati Island (also called Christmas Island) began in the late 1970s. Today it is now the biggest income earning activity and source of livelihood for the local people, providing much needed cash to pay for school fees, church contributions, and staple food items such as rice, sugar and flour. The industry is currently valued at a minimum of USD 1.5 million annually.

When it started, there was only one exporter of marine aquarium fish from Kiritimati to Hawaii. The operation was small and used a land-based, closed-system holding facility. The collection and handling of fish was very well controlled and, therefore, fish that were exported were of very high quality. The company quickly established a very good reputation, and specialised in the flame angelfish (*Centropyge loriculus*), which fetched a price of USD 25.00 a piece on average. The flame angel became the signature fish for Kiritimati in the 1980s, known for its striking colours compared with the same species from elsewhere in the Pacific. The demand for the flame angelfish from Kiritimati grew steadily but the company controlled the supply and was, therefore, able to maintain the high price. In addition to the flame angelfish, other rare deepwater fish species were found in Kiritimati, including the declivis butterflyfish (*Chaetodon declivis wilderi*), tinker's butterflyfish (*Chaetodon tinkeri*), griffis angelfish (*Apolemichthys griffis*), hogfish or candycane (trade name) (*Bodianus opercularis*), and longnose black tang (*Zebrasoma rostratum*). These highly sought-after fish boosted their demand from Kiritimati, and with the very high price they commanded, the marine aquarium fish trade in Kiritimati became a highly successful and profitable industry.

In the 1990s, more local Kiritimati people became interested in the industry and the number of marine aquarium operators increased dramatically from 2 to 10 companies. Several of these new companies had no idea or any experience in the marine aquarium fish industry and thus failed, so that by the early 2000s only 6 companies remained. With the increased number of operators and no controls or regulations, there was strong competition among operators to surpass each other in exporting large quantities of fish. This was the beginning of poor management practices and the decline in the overall quality of marine aquarium fish from Kiritimati. This in turn caused a drop in fish export prices, especially of the flame angelfish, which dropped significantly from USD 25.00 to USD 1.00 a piece. In recent times, the price of the flame angelfish has gone up slightly to USD 5.00 a piece.


Flame angels in a Kiritimati land-based facility (Image: Éric Clua).

In spite of the growth and changes in the industry, there has never been any attempt to manage it. As a result of the unmeasured fishing effort, there has been increasing concerns about the current status of the resource and the sustainability of the industry over the long term. This and the reputation of poor quality fish coming out from Kiritimati caused the Kiribati Fisheries Department to seek technical assistance and advice from SPC. In response to the request, a two-week mission led by SPC's Senior Fisheries Scientist for the Live Reef Fish Initiative was planned and made to Kiritimati from 20 April to 5 May. The team consisted of six others, including two local fisheries officers from the Kiribati Ministry of Fisheries and Marine Resources Development (MFMRD) headquarters in Tarawa, a hired consultant from the industry, the manager of the Coral Reef Initiatives for the Pacific (CRISP) Programme, and a videographer and sound engineer from the local French Television channel RFO in New Caledonia. The mission was funded collaboratively by a grant to the Live Reef Fish Initiative from the MacArthur Foundation and CRISP, and received local logistical support from the Kiribati government through MFMRD. The RFO crew came along at their own expense with an interest in making a TV documentary about the marine aquarium trade in Kiritimati, but also with an agreement that the video footage they took would also be used as part of an SPC educational awareness video on the marine aquarium trade in the Pacific. The main aims of the mission were to:

- make the necessary improvements to the general marine aquarium industry practices of Kiritimati, with the hope of improving the quality of fish exports;
- train local Kiribati fisheries staff on using and conducting underwater visual census methods so that they could assess and monitor their marine aquarium trade fish resources;
- conduct a fisheries resource survey to assess the status of the marine aquarium trade fish resources in Kiritimati; and
- investigate and assess the opportunities and the interest in Kiritimati for maricultured commodities for the marine aquarium trade, especially the use of postlarval capture and culture methods.

To achieve these objectives, a three-day training workshop for industry people was conducted on collecting and handling practices, from catching the fish to shipping them overseas. In total, 36 local participants attended the workshop, including divers and fish collectors, fish packers and fish exporters. Training consisted of both classroom lectures and practical sessions. In order to get a better idea of the problems and the local situation, participants were asked about local industry practices such as the types of gear used, methods of catching fish, how fish are handled and kept, and how the fish are packed for shipping. Samples of good practice collection gear were brought to the workshop and shown to participants. Differences between various locally used gear types were highlighted and their use was demonstrated. During field sessions, it was possible to observe first hand how the fish collectors actually caught fish. Best practice collection methods, including gear, were demonstrated so that the fish collectors could see the difference. Hands-on training and advice was also provided on how to decompress fish properly and on the ocean-based system of storing fish on mooring lines.

Fish are stored offshore in perforated fish buckets hung from mooring lines (Image: Tekinaiti Kaiteie).

Two other topics relating to industry practices that were covered during the training included fish holding facilities for storing fish before export, and fish packing methods. The lecture on holding facilities described the technical side of holding fish, and the

Trainees practiced the proper way of bleeding air (“needling”) from the fish bladder through the side (Image: Éric Clua).

holding systems and design of a small and simple closed system holding facility that would be appropriate for the average-size operation in Kiritimati. The practical part of this session included a visit to existing facilities to assess their setup and make recommendations on how they could either be improved or how they should set up a new system if none existed. For the fish packing training, several companies demonstrated their methods of packing fish followed by discussions to highlight areas that need improvement to ensure better survival rates and better quality fish exports.

Being Yeeting, SPC Senior Fisheries Scientist (Live Reef Fisheries), shows some "good practice collection gear" to the workshop participants.

Additional issues covered during the workshop included dive safety (which was becoming a problem) and other potential mariculture opportunities for the marine aquarium trade, especially post-larval capture and culture technology, which was presented by the CRISP Progamme Manager.

The Kiribati Fisheries Department was interested in knowing what accounted for the high number of fish reported to be "dead on arrival" (DOA). Based on an actual assessment of current practices, the following observations of "bad practices" were noted. Solutions to address these practices are provided in the table below.

Fish collection

Bad practices	*Solutions*
The mesh size of nets was too big so many fish were being gilled.	Use smaller mesh size nets of 0.5 in. Samples of smaller mesh size nets were distributed to all operators.
The material used for the current nets used was too hard.	Use 0.18 mm twine for nets and knotless mesh. Samples of this light net were distributed to all operators.
Fish collectors used very short nets that were 1 m long x 0.5 m high, which meant that the handling of fish was very quick and rough in order to avoid them escaping.	Use 10 m x 2 m nets with rubber bands to pull the net back to make pockets. Use of these nets was demonstrated.
Most collectors did not use a probe but used their hands instead to chase the fish into the net. They therefore tend to move many rocks to get to the fish. For those collectors who used probes, the probes were usually short and made of metal, which tended to break the coral when used to get fish out from among the corals.	Use long fibreglass probes that are flexible and which allow the collector to herd fish from a fair distance away without scaring the fish. This will also prevent breakage of corals. Using these probes was demonstrated and samples were distributed to some collectors.
A lot of fish collectors were putting too many fish in their fish collection baskets.	Do not overstock fish; 10 fish per fish collection basket is recommended.
Many divers/fish collectors do not have their dive cards, so it was difficult to confirm if they had actually ever received proper dive training.	A proper dive certification course should be organised to re-certify these divers. A regulation on dive certification as a requirement for fish collectors should be imposed.
A number of divers/fish collectors actually admitted that they are diving without proper dive training and certification but were taught by diver friends.	A proper dive certification course should be organised to certify these divers.
Only a few divers that came out in the field practical sessions had good underwater skills.	A dive certification course would improve this.

Fish decompression method

Bad practices	*Solutions*
The current method pokes the fish from the underside next to the anal pore and up to the air bladder.	The method of poking the fish from the side was introduced and shown to collectors. Some collectors were able to try the method out.
The needles used are not cleaned after every use.	Remind collectors to wash and flush the needle out with seawater between applying it to different fish.
The handling of fish is generally rough.	Change the mentality of collectors to treat fish with respect and as living things.

Fish transport and storage

Bad practices	*Solutions*
All operators use the offshore fish storage system where captured fish are stored in individual cups with holes and are hung in a perforated holding bag hung on mooring lines.	The design and best practices for this system needs to be looked at to make it efficient. Land-based holding facilities have many more advantages and are therefore recommended.
When transferring fish from or into the storage bags on the mooring lines, the lines are brought up to the surface and several storage bags with fish are often left out of the water for up to half an hour.	This handling practices should be incorporated in a best practice guideline for the offshore holding system
Handling of fish is also rough at this point with new fish transferred into individual plastic cups that are often thrown several meters from the boat into storage bags.	Change the mentality of collectors to treat fish with respect and as living things.
Many fish are stored on the mooring lines for 2 weeks to 1 month before they are pack and shipped.	The offshore holding system is only good for holding fish for 3–4 days maximum, otherwise fish are starved and could develop diseases.
During transport, after collection and also while sorting decompressing fish, the fish are kept in large plastic bins on board the boat. This water is not changed often enough to get rid of fouled water and ensure good quality water.	The importance of frequently changing the water in the bins (i.e. at least every 10–15 minutes) was explained.

Land-based holding facilities

Bad practices	*Solutions*
Only 1 operator has an almost complete land-based holding facility but still lacks some vital equipment such as a protein skimmer and UV light.	The setup of a full complete system with the minimum equipment required was described. The function of each vital piece of equipment was explained.
All operators have always wanted to build land-based, closed-system holding facilities but lack the technical know-how to set them up.	Each operator's facility was looked at and a design of a possible setup for their holding facility with a list of equipment they will need to acquire was provided.

Fish packing

Bad practices	*Solutions*
General method of packing and packing materials is standard.	This was good.
The general handling of fish is rough in order to save on time,	Change the mentality of packers to treat fish with respect and as living things.
Efficiency of packing team performance and effective use of packing space needs improving.	A design of a packing table and the organisation of different workers for the various packing stages were presented.
Air stones for aeration are sometimes excessively used.	Packers were cautioned on the possibility of injury to fish eyes, which can result from excessive air bubbles.
Sometimes packing water is collected from the lagoon rather than from the ocean. Lagoon water is not very clean.	All companies were asked to always get packing water from the ocean and not from the lagoon.

Training in underwater visual census (UVC) for assessing marine aquarium fish resources in Kiritimati was provided to four local fisheries officers. The UVC method developed by SPC's Reef Fisheries Observatory was used. Once they gained confidence in using this method (i.e able to recognise and identify common important marine aquarium fish species and estimating their size to within a 10% error margin), the trained fisheries officers were allowed to assist in conducting a proper resource survey of marine aquarium trade fish resources of Kiritimati.

The survey was conducted in the second week of the mission, and 24 survey stations were selected with 6 stations each on the different sides of the island (i.e. north, south, east and west). Data are being entered and processed by one of the trained fisheries officers under a three-week attachment training at SPC headquarters in June. A survey report and management plan for the marine aquarium trade in Kiritimati are expected to be one of the results of this attachment.

A follow-up mission will be organised towards the end of the year to look at the potential of PCC and for further refining industry practices and the management plan if required.

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The "dollar-fish" island

The mission implemented in April 2010 in Kiritimati was the opportunity for a French TV team to join the SPC team. Several hours of footage were taken on the mission itself but also about the island, its people and the local way of life. A 26-minute documentary is in preparation, entitled "The dollar-fish island", to be displayed on French TV channel RFO later this year. This movie will be translated into English by SPC and dispatched throughout the Pacific. The main theme of the movie will be the dependence of Kiritimati Island on its fish resources, both pelagic (tuna), and coastal (marine aquarium industry). The focus will be on the flame angelfish, due to its enormous potential in Kiritimati and because of the ongoing ecological and financial wastage due to the local industry's lack of organisation. The footage will also be used for an SPC technical movie technical movie that depicts how capture and handling techniques can be improved in the Pacific aquarium trade.

Original text: English

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NEW PUBLICATIONS FROM SPC'S DIVISION OF FISHERIES, AQUACULTURE AND MARINE ECOSYSTEMS[1]

The future of Pacific Island fisheries

By Robert E. Gillett and Ian Cartwright

Fisheries are the most significant renewable resource that Pacific Island countries and territories (PICTs) have for food security, livelihoods and economic growth. As Pacific Island populations grow, the future benefits that these resources can provide will depend on how well we are able to balance the increasing demands on fisheries with the capacity of oceanic, coastal and freshwater fish stocks to sustain those harvests. Aquaculture's role in supplementing wild fisheries production is also a consideration.

This report considers the future of fisheries over a 25-year timeframe (2010–2035). It is intended to provide the basis for long-term strategic approaches to developing and managing fisheries at national and regional levels. The first part of the report provides a brief overview of the status of and trends in the region's fisheries, the major issues and challenges, and gaps that need to be addressed. The second part examines ways in which the contribution of national and regional institutions can be enhanced, and regional cooperation strengthened, to provide countries with the capacity and adaptability they need to address emerging needs and priorities.

While it is impossible to accurately predict what Pacific Island fisheries will be like in 2035, this study identifies and briefly describes the most likely significant factors driving change in fisheries, and their possible impacts. These factors were identified through discussions with Pacific Island fishery stakeholders and global specialists, and a review of the fisheries literature.

Access to the online version:
http://www.spc.int/fame/en/component/content/article/59-future-of-fisheries-study

Management plan for the sea cucumber fishery of Yap State

By Magele Etuati Ropeti, Kim Friedman, Kalo Pakoa and Andy Tafileichig

The management plan for the sea cucumber fishery in Yap was developed in response to a request from the Yap State Marine Resources Management Division (MRMD) for technical assistance from the Secretariat of the Pacific Community's (SPC) Coastal Fisheries Programme. The SPC Coastal Fisheries Programme facilitated the process of developing the plan through wide consultation with resource custodians and industry stakeholders. Data from fieldwork in Yap were also incorporated. Scientific advice and relevant information on the fishery were provided on site to enable all parties to make informed management decisions.

Like most other small island states, Yap has limited land for agriculture development. However, it possesses a vast ocean area rich in marine life and fisheries resources, including sea cucumbers. Although sea cucumber species are not traditionally used as a protein source by Yap communities, the fishery has been increasingly harvested due to the high value of dried sea cucumber (bêche-de-mer) on the Asian market. Easy access and quick cash returns have seen the sea cucumber fishery become one of the most important sources of income for some coastal communities. Given the potential benefits for all communities and the likelihood that the fishery will collapse if present harvest rates continue without a management framework, a more fair and precautionary approach has become necessary to prevent unsustainable exploitation.

This plan provides a management framework that will enable the State Authority to guide the exploitation and harvesting of the sea cucumber fishery in Yap. The recommended management actions require close collaboration between government, resource owners, communities and agents to ensure sustainable utilisation and to optimise economic benefits for everyone.

Access to the online version: http://www.spc.int/coastfish/

Guidelines for a community-based ecosystem approach to fisheries management

SPC's Coastal Fisheries Science and Management Section, in collaboration with the UN Food and Agriculture Organization and The Nature Conservancy, has produced a new publication entitled "A community-based ecosystem approach to fisheries management: guidelines for Pacific Island countries". These guidelines have been produced to describe how an ecosystem approach to fisheries management

(EAF) can be merged with community-based fisheries management (CBFM) in Pacific Island countries and territories (PICTs). This merger of approaches is referred to in these guidelines as the community-based ecosystem approach to fisheries management (CEAFM), and represents a combination of three different perspectives; namely, fisheries management, ecosystem management and community-based management. CEAFM is the management of fisheries, within an ecosystem context, by local communities working with government and other partners.

The main requirement for such a merger is the involvement of a broader range of stakeholders and access to the expertise and experience of several government agencies in addition to a fisheries agency. CEAFM is not seen as a replacement for current fisheries management but an extension that combines a high degree of community and other stakeholder participation to minimise the impacts of fishing and other activities on ecosystems. In addition to fishing activities, coastal ecosystems in many PICTs are affected by excessive shoreline development and by coastal waters that contain high levels of nutrients and silt.

CEAFM aims to involve the participation of community stakeholders to ensure that future generations of Pacific Island people will continue to have access to the benefits associated with sustainable fisheries and healthy ecosystems.

Access to the online version: http://www.spc.int/coastfish/

Solomon Islands Tilapia Aquaculture Action Plan 2010–2015

Small-pond aquaculture of tilapia fish is identified as one of four top priorities in the Solomon Islands Aquaculture Development Plan 2009–2014, so now more detailed work is needed on this sector. The Solomon Islands Tilapia Aquaculture Action Plan 2010–2015 has been prepared to 1) set out a logical and structured pathway for sustainable tilapia aquaculture development in Solomon Islands, and 2) identify potential roles for partner agencies in supporting tilapia aquaculture and helping meet national needs for food security and sustainable livelihoods. The publication details what Solomon Islands needs in order to achieve their vision for a responsible and sustainable tilapia aquaculture industry for food security and income generation!

Access to the online version: http://www.spc.int/aquaculture/

Proceedings of the Regional Workshop on the Management of Sustainable Fisheries for Giant Clams

These are the proceedings of a four-day workshop that involved technical consultation between a wide range of stakeholders, including government, private and public sectors, and specialists who are active in the production of giant clams for the global marine aquarium trade in the Pacific region. Attendance included representatives from American Samoa, Australia, Cook Islands, Federated States of Micronesia, French Polynesia, Fiji, Kiribati, New Caledonia, Palau, Papua New Guinea, Republic of the Marshall Islands, Samoa, Solomon Islands, Tonga and Vanuatu.

Access to the online version: http://www.spc.int/aquaculture/

A review of aquaculture in the Pacific Islands 1998–2007

A provisional desktop review of aquaculture in the Pacific was carried out by the Secretariat of the Pacific Community (SPC) on behalf of its 22 Pacific Island member countries and territories in order to bridge an information gap. During the period 1998 to 2007 a peak value of USD 222 million was recorded in 1999 and in 2005, associated with high levels of pearl and shrimp, respectively. The maximum volume was 6,900 metric tonnes (t) in 2005. In 2007 the region's production was worth USD 211 million and volume was 5,300 t. Aquaculture has an important role in diversifying trade, increasing capacity for fisheries production, and contributing to rural development. One of the immediate challenges to overcome is to provide a suitable investment climate for private enterprises.

Access to the online version: http://www.spc.int/aquaculture/

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1. Documents produced by SPC's Coastal Fisheries Programme can be downloaded free of charge (in PDF format) from: http://www.spc.int/coastfish/.
To obtain paper copies, please contact the Fisheries Information Unit (cfpinfo@spc.int). Please note that paper copies are only sent for free to SPC member countries and territories.

Freshwater prawn research breakthrough at USP

By Monal Lal, Johnson Seeto and Tim Pickering

A milestone in aquaculture research has been achieved at the Seawater Laboratory of the Division of Marine Studies at the University of the South Pacific (USP). In post-graduate research co-supervised by SPC's Aquaculture Section, the Monkey River prawn *Macrobrachium lar* has been successfully reared in captivity for the first time ever — from eggs through the planktonic larval phase of their lifecycle to the post-larval stage.

An historical first. One of the *Macrobrachium lar* post-larvae reared in captivity at the Seawater Laboratory of the University of the South Pacific.

This prawn, known locally as *ura dina*, is indigenous to Fiji and a number of other Pacific Island countries, including the Solomon Islands, New Caledonia and Vanuatu. The largest river prawn in these places, *M. lar* is the basis of valuable inland fisheries for sale in local markets and restaurants.

M. lar has been a subject of research to assess its potential for aquaculture since the early 1970s in places such as Hawaii, with the hope that it can be farmed much like its cousin the Malaysian giant freshwater prawn, *Macrobrachium rosenbergii*, whose annual production value in Asia alone is estimated at around one billion US dollars.

The Monkey River prawn has a number of favourable characteristics for aquaculture, which include its large size, widespread acceptance among local communities as a delicacy, and the fact that it is a tough, hardy species that can survive out of water for short periods of time.

Another important characteristic of the species is that it is indigenous to many Pacific Island countries where there is interest in developing freshwater prawn farms. If research on *M. lar* culture techniques could make breeding and rearing more practical, then the introduction of an exotic prawn to establish freshwater prawn aquaculture in the Pacific Islands could be avoided.

A major drawback to further research into the suitability of *M. lar* for culture has been — until now — the inability to grow young prawns (known as post-larvae) in captivity after hatching from the egg. Past researchers could reach about Stage 6 or 7 out of an estimated 11–13 larval stages, but then the larvae would die for unknown reasons.

This has meant that post-larvae for any culture work had to be caught by hand from the wild, which is time consuming and tedious. This is a barrier for larger-scale farming operations involving this species, because the easiest and most sustainable way to obtain large numbers of post-larvae required for commercial farming is in a hatchery.

The earliest published attempts at growing *M. lar* larvae in the laboratory all the way through to the post-larval stage was by Wilbert Kubota in 1972 at the University of Hawaii, followed by John Atkinson in 1977 at the same institution. Satya Nandlal recently completed his PhD thesis on the aquaculture of *M. lar* at the University of the South Pacific (USP). His research included extensive field trials and attempts to rear the species to the post-larval stage in the hatchery. Unfortunately, in all these studies the larvae could only be reared up to a certain stage, and then all larvae died.

The success of the present study in reaching the post-larval stage can be attributed for the most part to the development of a suitable feed that appears to better meet the nutritional requirements of the larvae, in addition to culturing it at its preferred salinity level in an appropriate rearing environment.

Another finding of this study is that *M. lar* larvae develop through approximately 13 stages in the ocean before they change into post-larvae (compared with 11 stages for *M. rosenbergii*). After they become post-larvae, the animals migrate landward and eventually settle in high-elevation freshwater streams far inland.

So far, five post-larvae have been produced in the USP laboratory. They metamorphosed into post-larvae after 77, 78, 85, 101 and 110 days of culture, respectively. It is a major achievement, because what previously appeared to be impossible has now been proven possible. For the future, however, this species still compares very poorly with *M. rosenbergii*, which can routinely reach post-larval stage in only 20–30 days and with 20–50% survival of big batches. There is scope for much more research into *M. lar*, and the work done here is an important step towards further developing and refining techniques for its culture.

Post-graduate student Monal Lal holds one of the freshwater prawn broodstock used for his research, flanked by his supervisors Tim Pickering of SPC (left) and Johnson Seeto of Marine Studies at USP (right).

This study at USP was initiated as part of an SPC-coordinated regional strategy for domesticating *M. lar* — through linked studies in Fiji, Vanuatu and New Caledonia — and funded by the Australian Centre for International Agricultural Research in collaboration with SPC. The study was undertaken by Master of Science student Monal Lal and supervised by Johnson Seeto and Dr Timothy Pickering of SPC.

Apart from larval culture research, investigations are also continuing on capture-based culture of *M. lar* for grow-out in small ponds by rural householders as a cash crop. A new technique for rearing prawn larvae — developed by Japan International Cooperation Agency Senior Volunteer Tomohiro Imamura while at USP — was instrumental in achieving this outcome.

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Mountains of pelagic biodiversity[1]

By Alistair Dove

Source: Deep Type Flow – Conversations about marine science and society. http://deeptypeflow.blogspot.com/2010/05/mountains-of-pelagic-diversity.html

If you ever saw the dramatic seamount scene in Blue Planet (and if you haven't, where ya been?), then you are probably familiar with the idea that submarine mountains can attract lots of animals; as Attenborough puts it, they "create oases where life can flourish in the comparatively empty expanses of the open ocean". In that spectacular BBC sequence, jacks and tuna swarm an Eastern Pacific seamount peppered with colourful schools of barberfish, *Anthias* and goatfish. Then the sharks cruise in, including silkys and hammerheads, there for a clean from the faithful barberfish.

There's a paper in the latest issue of PNAS that quantifies the richness of seamounts, so beautifully depicted by those geniuses at the BBC Documentary department. The authors, led by Telmo Morato from the Secretariat of the Pacific Community in New Caledonia, analysed data gathered by longline fisheries in the western and central Pacific, close to and remote from seamounts. In a sense, a longline is a standardized sort of sampling unit like a quadrat, so they can be analysed across locations to measure differences in diversity. They accounted for differences between total catch per longline using the statistical process called rarefaction, which is a practical application of one of my favourite fundamental biological patterns — the species accumulation curve —, which I've discussed before.[2] It looks like a great dataset with great spatial resolution and pretty good coverage in the tropics, though the equatorial zones are less well represented.

I don't think anyone would be surprised by their result that, yes, seamounts are diverse places. When they broke it down by species, about 2/5 (15 species) showed positive association with seamounts; this group included both sharks and fish. Interestingly, three species (pelagic stingrays, albacore and shortbilled spearfish) showed negative associations with seamounts, while 19 showed no measurable association. So, the net effect is positive, but there's clearly some structure in the data, depending on what species you look at. Nor, I think, would most people be surprised by the distance effect they found, wherein sample diversity decreased with distance moved away from the peak of a seamount, and most sharply in the first 10 or so kilometers. What was surprising, to me at least, was that both the absolute diversity and the distance effect they found were greater on seamounts (Fig. 1, left) than they were for coastal zones (Fig. 1, center).

I would have thought that coastal zones, with their larger area, more complex topography and currents, coastal upwelling and inputs from the land, should have had higher diversity. Indeed, it kind of goes against the island biogeography ideas, that as we go away from the largest habitat towards smaller more distant patches, diversity drops; if you think of seamounts as underwater islands and continental shelves as underwater mainlands, perhaps you'll see what I mean.

There are a couple of reasons I can think of to explain the observed difference. Perhaps there is something intrinsic to seamounts, some feature of topography or productivity that makes them real magnets for diversity. Under this scenario, they are true biodiversity hotspots. Alternatively, perhaps coastal zones once were more diverse than seamounts but have been denuded by our actions, so that only the remote and submarine mountains remain as examples of what once was. Perhaps it's a bit of both, or some other concept (that you should propose in the comments). Either way, Morato et al. show us that we may be successful at protecting widely roaming pelagic species by strategically preserving relatively tiny specks of submarine oases. Since reading their paper, I have enjoyed thinking of schools of pelagics, hopping from mountaintop to mountaintop, skipping across vast plains of abyssal ocean, and as usual dreaming about diversity and all the fantastic forms of life in the 3D wonderland of the open ocean. It just makes you want to down tools and grab the next slow boat bound for Cocos, doesn't it?

Morato T., Hoyle S., Allain V. and Nicol S. 2010. Seamounts are hotspots of pelagic biodiversity in the open ocean. Proceedings of the National Academy of Sciences. DOI: 10.1073/pnas.0910290107

1. Note from Editor: We published another article on seamount-related work by Morato et al. in this newsletter (see issue #129). Alistair Dove provides here a lively report about their work.
2. See: http://deeptypeflow.blogspot.com/2010/03/when-can-we-stop-sampling-and-have-beer.html and http://deeptypeflow.blogspot.com/2010/04/sacs-revisited.html

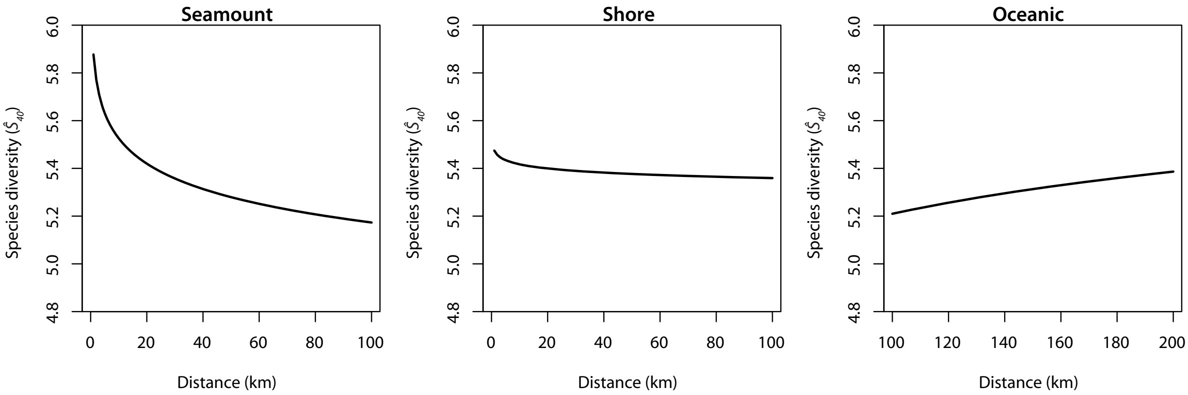

Figure 1. Mean species diversity rarefied from 40 ($\hat{S}_{40}$) individuals as a function of distance to seamount summit or shore.

CIRCLE HOOKS IN THE PACIFIC

Steve Beverly

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Circle hooks were probably first used by Polynesian and Amerindian fishermen in the Pacific hundreds or even thousands of years ago.[1] Now they are widely used not only because they are good at catching fish, but also because they are "friendlier" to bycatch species in commercial fisheries and catch-and-release species in recreational fisheries. In ancient times circle hooks were very well adapted to catching small bottomfish from shore and from canoes using simple handlines. In more recent times, circle hooks are used as the hook of choice in commercial and recreational fisheries. They can be found almost anywhere there are hook-and-line fisheries, and their popularity among fishermen, fisheries researchers, fisheries managers, and conservationists is growing. Recent research has shown that the use of circle hooks in pelagic longline fishing can mitigate bycatch and reduce mortality of non-target discarded species (Watson et al. 2005). More recent research is showing that circle hooks are able to maintain the same catch rates of target species so fisheries that use circle hooks can remain viable.

No one knows who invented the circle hook but it was probably developed by fishermen from Oceania centuries ago. Circle hooks have been excavated from archaeological sites in French Polynesia, Hawaii (Fig. 1), and in the Channel Islands off the California coast where the Chumash Indians lived and fished. These ancient circle hooks were made from pearl and abalone shell, bone (including human bone), and sometimes wood.[1] Replicas of these ancient Oceanic hooks have become very popular as fashion accessories, usually as hand-carved shell or bone pendants on necklaces.

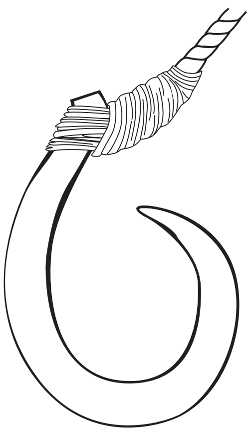

Figure 1. Bone circle hook from the Hawaiian Islands.

A circle hook is defined as any round-shaped hook with a point that is perpendicular, or at a 90° angle, to the shank of the hook (Fig. 2). Figure 3 shows the parts of a basic fish hook, including the point and the shank. It can be seen by comparison to a circle hook, that the hook in the diagram — which is actually a J hook — has the point parallel to the shank. Circle hooks are sometimes called C hooks or G hooks because of their rounded shape resembling those letters of the alphabet. They are also often referred to as rotating, or self-setting hooks. Circle hooks rotate in the direction of the point when a fish takes the bait and pulls on the line (Fig. 4). Because of this rotating action, a circle hook will set itself with no action from the fisherman. The more the fish pulls, the deeper the hook is set, even if the line is untended. No jigging is required when using circle hooks.

Circle hooks were probably originally designed by fishermen to catch small bottomfish. In fact, circle hooks are preferred today by fishermen targeting deep-water bottom snappers. They are also used though for commercial tuna and swordfish fishing and for recreational catch-and-release fishing. Aside from their self-setting characteristic, circle hooks are less likely than J hooks to catch or injure bycatch species in commercial fisheries, and are less likely to injure either bycatch species or tag-and-release fish caught in recreational fisheries.

Pelagic longline fishing targets tuna and billfish species such as bigeye tuna, yellowfin tuna, albacore tuna and broadbill swordfish, but also catches non-target species. Some non-target

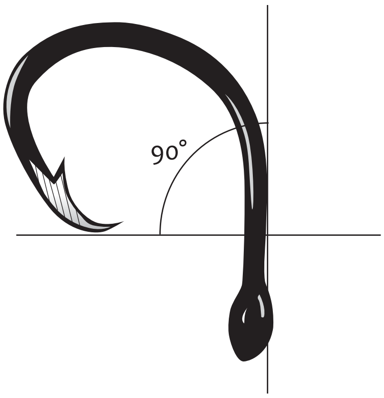

Figure 2. Circle hook showing the point at a 90° angle to the shank.

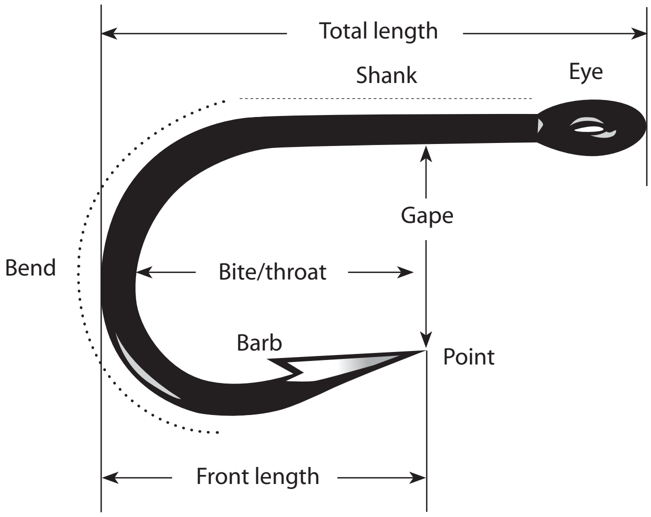

Figure 3. Hook anatomy (From Mustad website: www.mustad.no/abouthooks/index.php).

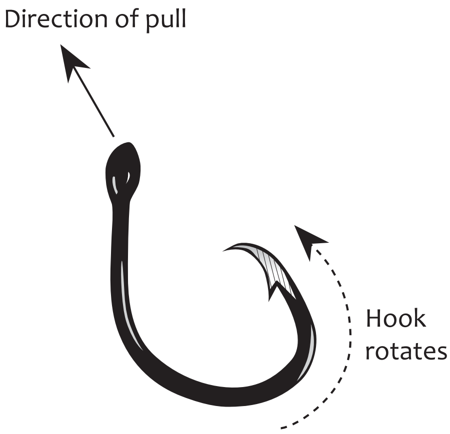

Figure 4. Circle hook showing direction of rotation when the line is pulled.

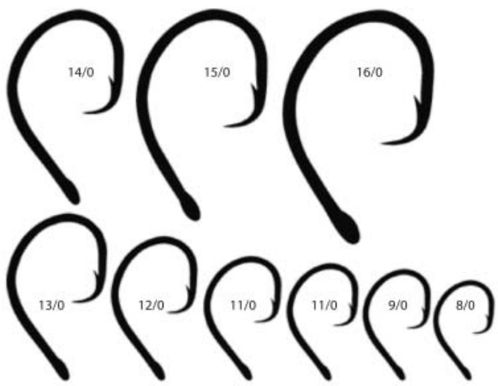

Figure 5. Different size circle hooks used in commercial and recreational fisheries (not to scale — from Mustad website: www.mustad.no/abouthooks/index.php).

species are retained but others are discarded. These discarded species are called bycatch and include fish that have no commercial value and other species that are endangered and are protected by law, including sea turtles, seabirds, marine mammals and sharks. Sea turtles that are caught as bycatch are of particular concern in pelagic longline fisheries because some turtle species are considered vulnerable to local and even global extinction because of their declining numbers. The two species caught most frequently on pelagic longlines are loggerheads and leatherbacks, although olive ridley and green turtles are caught as well. Turtles can be lightly hooked in the mouth, deeply hooked (hook is swallowed), or externally hooked on the neck or flipper. Large tuna circle hooks have been shown to be useful in mitigating the catch of sea turtles in longline fisheries. Circle hooks used in commercial and recreational fisheries are made from high carbon galvanised steel or stainless steel, and range in size from 8/0 to 16/0 (Fig. 5) and sometimes even 18/0.

Recent experimental work in the Atlantic Ocean has shown that the use of 18/0 circle hooks (compared to J hooks) greatly reduces sea turtle catch and, in some cases, increases target catch (Watson et al. 2005). Furthermore, when turtles are caught on circle hooks, injury is reduced and turtles are more likely to survive being caught and released. Turtles caught on circle hooks are less likely to be seriously injured because these hooks are wide and are less likely to be swallowed. A recent study using captive loggerhead turtles showed that the overall narrowest width of the hook is the most important measurement because that is what determines whether or not a turtle can swallow the baited hook (Watson et al. 2003). Mouth injuries compared with gut injuries are usually not fatal. The study concluded that using hooks larger than 51 mm in width has the potential to significantly reduce mortality of loggerhead turtles incidentally captured on longlines. A 16/0 circle hook, for example, has a width of 51 mm while a 9/0 J hook (which is similar in size to a 16/0 circle hook) has a width of only 41 mm. Another recent study, this time of recreational catch of bluefin tuna in the Atlantic Ocean, found that most of the fish caught on circle hooks were hooked in the jaw while J hooks were more often swallowed by the fish (Skomal et al. 2002). The estimated mortality for J hooks in the study was seven times greater than for circle hooks. The study concluded that circle hooks cause less damage than J hooks and can be a valuable conservation tool in recreational tag-and-release fisheries.

Circle hooks have now become mandatory in commercial longline fisheries in the United States that target swordfish, and may soon become mandatory for tuna longline fisheries as well. The US government also promotes the use of circle hooks by fisheries in other countries and may soon adopt rules that prohibit the entry of longline-caught fish using hooks other than circle hooks, into US markets. Research has already shown that circle hooks work to mitigate bycatch. Much of the research being carried out now on circle hooks is being directed towards quantifying the effects of circle hooks on target catches. To be successful, any bycatch mitigation technique or gear modification must not affect the commercial viability of the fishery or else fishermen will not be inclined to use them. Experiments are being carried out in the Atlantic Ocean, the Mediterranean Sea, the Indian Ocean, and the Pacific Ocean, including Hawaii and many small Pacific Island countries and territories (PICTs), to show whether or not the use of large circle hooks will affect the commercial viability of pelagic longline fisheries.

The Secretariat of the Pacific Community (SPC) and Hawaii's Pacific Island Fisheries Science Center (PIFSC) are currently carrying out a series of experiments using large circle hooks. The studies are taking place in American Samoa, Cook Islands and New Caledonia. The purpose of the experiments is to compare the effectiveness of large (16/0) circle hooks with hooks normally used in Pacific Island domestic longline fisheries that target albacore tuna, bigeye tuna and broadbill swordfish. The experiments are very simple, with only one independent variable, 16/0 circle hooks. The studies have been designed to compare catch rates of the main target species using hooks normally used in the fishery (control hooks) with catch rates using 16/0 circle hooks (experimental hooks). No other changes are made to the fishing gear and no changes are made to the normal fishing strategies employed by cooperating fishermen. The fishing trials are being conducted on one or more vessels licensed to fish in the domestic longline fishery in three PICTs.

An investigator from either SPC or PIFSC is on every fishing trip during the experiments. The vessels involved are allowed to fish as they normally do with no input from the investigators. Setting and hauling times, branchline length and material, number of hooks between floats, setting depth, location and bait type are all determined by the vessel operators. The investigators monitor all sets to ensure that control and experimental hooks are deployed evenly throughout each set and to record all data. Data, including fork length, are recorded using the SPC/Pacific Islands Forum Fisheries Agency Regional Longline Observer Catch Monitoring Form LL-4. Catch rates, or catch per unit of effort (CPUE), are expressed as the number of fish caught per 1,000 hooks, or kilograms per 100 hooks. Robust data sets are being accumulated by monitoring at least 65,000 experimental hooks in approximately 45–50 longline sets in each of the three fisheries where the experiments are taking place. A statistical comparison will be used to test the null hypothesis of no difference in CPUE for control hooks and experimental hooks at the conclusion of the field trials, and separate reports will be submitted. The reports will assist regional fisheries management organisations in deciding whether or not to mandate the use of large circle hooks in their fisheries, and they will help to convince fishermen of the efficacy of using circle hooks. There is a concern among some longline fishermen that 16/0 circle hooks are too large to catch albacore tuna. These experiments may end up putting that notion to rest.

The experimental hooks are stainless steel round shank 5° offset 16/0 circle hooks. The experimental hooks are alternated one-to-one with the control hooks at the onset of each experiment, but are allowed to be distributed randomly as the experiments progress. Investigators check to be sure that there are equal numbers of control and experimental hooks deployed on every set. In order to ensure that hooks are sequenced properly and that data are recorded from the correct hook type, the snaps on all branchlines with experimental hooks are marked with small plastic cable ties. Control snaps are not marked.

So far, the investigators have compiled preliminary results from the experiments in Cook Islands and New Caledonia. Both experiments are ongoing as the experimental vessels conduct short trips of one-week duration and only set limited numbers of hooks. Therefore, it will take up to one year to collect all data from these two experiments. Vessels from American Samoa set more hooks and stay at sea longer so data from there will not take as long to collect. Preliminary results from New Caledonia are of special interest because the fishery there targets albacore tuna, as do most domestic longline fisheries in PICTs, including the American Samoa fleet. The domestic fleet in Cook Islands targets broadbill swordfish and bigeye tuna. The first fishing trip in New Caledonia in March 2010 consisted of only five sets with 9,130 hooks (4,430 control hooks and 4,700 experimental hooks). The control hooks (O) were smaller circle hooks, and the experimental hooks (X) were 16/0 circle hooks. Figure 6 shows the catch results. Although this is a small effort and results are not conclusive, it can be seen that the 16/0 hooks caught about 1.4 times more albacore tuna than the 15/0 hooks.

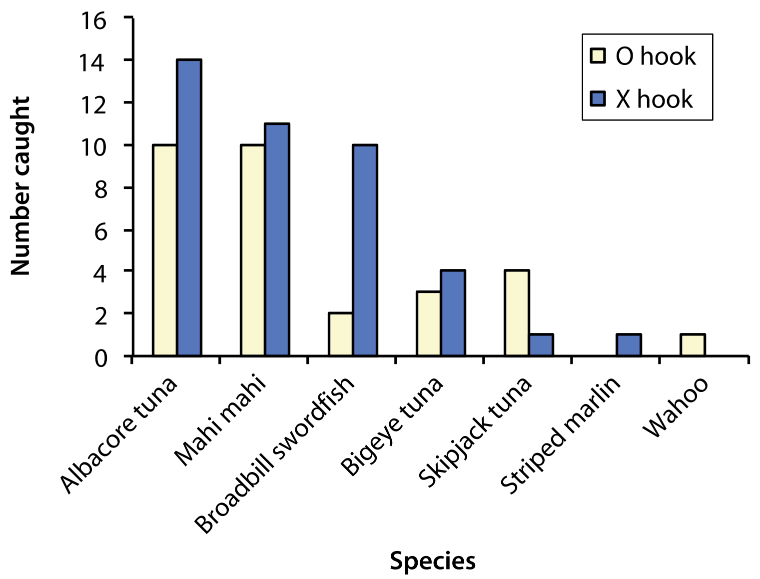

Figure 6. Comparison of number of fish caught by experimental and control hooks in the New Caledonia experiment.

The experiment in American Samoa will compare the boat's normal hooks, which are 14/0 circle hooks, with experimental 16/0 circle hooks. In total, 65,000 hooks will be set during a normal fishing trip that will last from 45–50 days. The boat in American Samoa targets albacore tuna and delivers all of the catch frozen to the cannery in Pago Pago or to a mothership in Pago Pago Harbour. Since a good proportion of the catch from the American Samoa fleet is shipped to the US, and because the fishery is under the management of the Western Pacific Fishery Management Council in Hawaii), the boats there may be subject to future regulations that require the use of 16/0 circle hooks. The results of this large circle hook experiment, and the others being carried out in Cook Islands and New Caledonia, will have a profound effect on the future of domestic fisheries in the Pacific Islands region.

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1. See: http://fishingfiles.com/forum/showthread.php?p=2934 (last accessed, June 2010)

OVERVIEW OF DEEPWATER BOTTOMFISH FISHERIES AND CURRENT MANAGEMENT ACTIVITIES IN PACIFIC ISLAND COUNTRIES AND TERRITORIES

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Introduction

During the 1970s, the South Pacific Commission (now Secretariat of the Pacific Community – SPC) became involved in assessing and promoting what was termed "deep reef slope fisheries" as an alternative to fishing on or within shallow reefs. SPC's efforts coincided with other activities sponsored by the UN Food and Agriculture Organization, and overseas donors in Samoa and elsewhere, that encouraged the expansion of fisheries beyond shallow reef areas. Many deep reef slope fish, such as *Etelis* and *Pristipomoides*, were known or found to be free of ciguatera and thus held export potential.

From 1974 to 1988, SPC masterfishermen undertook survey fishing in 19 of the 22 member SPC Pacific Island countries and territories (PICTs), with Guam, Nauru and Pitcairn being the only locations not included.

Commercial fisheries for deep reef slope species eventually became established at various times in Samoa, Tonga, Fiji, Vanuatu, Papua New Guinea and American Samoa (Dalzell and Adams 1994). It is worth noting that in many PICTs, deepwater bottomfish often comprised a catch component of deep reef slope fisheries, but were not always the sole target. In fact, in an exhaustive review of SPC's bottomfish activities, it was reported that over 200 species of fish belonging to 93 genera were caught by SPC masterfishermen by dropline fishing throughout the Pacific Islands (Dalzell and Preston 1992).

More recently, changes to resource availability and the economic viability of the tuna longline fishery in some PICTs have raised the potential for renewal or increases in activity in deepwater bottomfish fisheries. Several PICTs have requested SPC's assistance in undertaking investigations that could lead to renewed stock assessments and management interventions.

As a result, SPC commissioned a study during the latter half of 2009 to provide an overview of the current management framework for commercial deepwater bottomfish fisheries[1] in several PICTs. The work, undertaken by the author of this article, also included a short review of the deepwater bottomfish market in Hawaii, as that location has been an important one in the past for several PICTs, and fish prices there are often used as a reference point for deepwater bottomfish fisheries in PICTs.

Background

Past analyses of deepwater bottomfish data — from primarily SPC Fisheries Programme activities — have produced some conclusions that help to explain the parameters of the fishery on a region-wide basis:

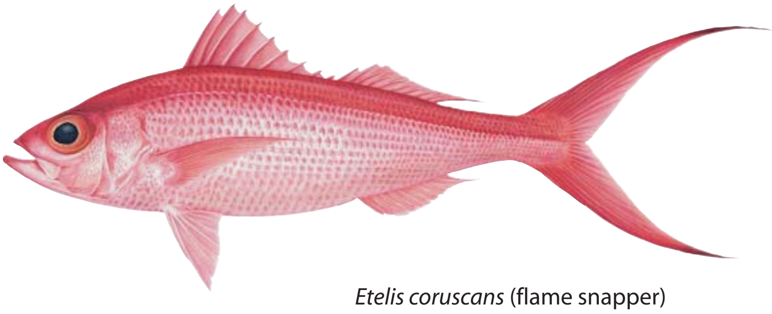
- Catch composition was markedly different between low-lying atolls and high islands, with atoll catches containing proportionately fewer eteline (including *Etelis* and *Pristipomoides*) and other snapper species than high island catches.
- Mean catch rates by weight increased with sea depth to about 250 m but declined significantly below that depth.
- There was a distinct decline in the number of species captured by dropline fishing at each location from the western limit of fishing around Palau to the eastern limit of French Polynesia. This decline in species number is consistent with biogeographic trends in other fishes and invertebrate groups within the region.

The implications of slow growth and longevity for catch rates in virgin and developed fisheries targeting deepwater bottomfish have been clearly demonstrated by results from several such fisheries in the region. New fisheries or locations for deepwater bottomfish initially experience high catch rates and tend to capture larger individual fish; but this characteristic disappears in a relatively short time depending on the unexploited biomass.

Current deepwater bottomfish fishing activity

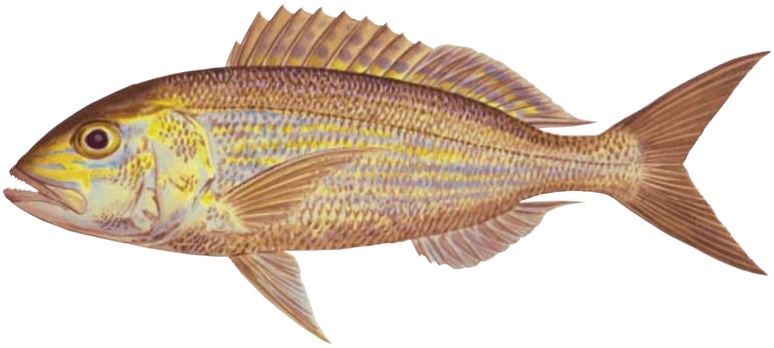
The paucity of available data from many PICTs on both catch and effort makes it difficult to quantitatively support contentions of any significant trends on a regional basis. On a country-by-country basis, available information points towards some increases in commercial deepwater bottomfish landings in American Samoa and the Commonwealth of the Northern Mariana Islands.[2] Decreases in either fishing activity and/or landings are apparent in five countries: Fiji, Guam, Papua New Guinea, Samoa and Tonga. In five other countries — Federated States of Micronesia, Marshall Islands, Nauru, Niue and Tuvalu — fisheries officials indicated that no commercial deepwater bottomfish activity took place in 2008. Insufficient or no information is available to determine trends in deepwater bottomfish activity from the remaining PICTs.

In Samoa, a country that in some respects pioneered deepwater bottomfishing on its outer reef slopes during the 1970s, the reduced effort in the fishery is ascribed to a combination of factors. Perhaps the one factor with the most impact has been the resurgence of the tuna longline fishery in recent years. Vessel owners among the local alia fleet are reportedly more likely to invest in tuna longlining because returns from that fishery are perceived as being much higher than with bottomfishing. Some alias, probably five to ten at most in the entire country, still practice bottomfishing; but fishermen are more likely to target emperors (lethrinids) present at shallower depths than the deepwater *Etelis* or *Pristipomoides* species. The major reasons given are the lack of an export market due to poor flight connections, the ability to continue to catch sufficient quantities of the more shallow-water species, and the absence of a premium paid for deepwater species on the local



Etelis coruscans (flame snapper)
Artwork Les Hata, ©Hawaii DAR

Etelis carbunculus (ruby snapper)
Artwork Les Hata, ©SPC



Pristipomoides multidens (goldbanded jobfish)
Artwork Les Hata, ©SPC

Pristipomoides filamentosus (crimson jobfish)
Artwork Les Hata, ©Hawaii DAR

Figure 1. Four major species of deep bottom snappers in the Pacific Islands.

market to justify the added effort required.

In Tonga, the 2000 decade started with vessels being "reasonably profitable" according to the one major buyer and exporter. Total production in 2008 suffered because one entire company fleet was idle. Those vessels were back in operation in 2009 and production is reportedly increasing. One vessel operator who recently departed the fishery expressed the opinion that the present Tongan fleet is quite old and requires renewal if production is to be maintained. The present low profitability of the fishery and poor business conditions in Tonga are preventing this renewal from occurring. Present low profitability suggests that a rapid increase will not occur in the near future.

In two of the five PICTs where a decreasing trend is apparent, Fiji and Tonga, one identified contributing factor has been the reduced or stagnant prices overseas for deepwater bottomfish exports in the face of rising operating costs. In the case of Tonga, the negative impact of low prices has been compounded by a drop in catch rates and an apparent reduction in the average size of fish caught (Adams 2007).

The perception that high export prices could be achieved for deepwater bottomfish has been a driving force for the development of these fisheries in several countries. In some cases failure of export activities has been due to insufficient examination of market conditions, including:

- seasonal market demand;
- freight costs and the logistical problems of getting fish to market;
- species preferences by specific markets; and
- competition from other sources of supply with the same or similar species.

In other cases the export market was developed but its performance did not keep pace with increasing fishing and air freight costs. Contributing to the problems have been falling catch rates as resources either became depleted or the fishery matured, and catch rates subsequently stabilized at levels below those required for profitability.

The market for fresh deepwater snapper and grouper in Hawaii

Hawaii has been a major destination for much of the exports of deepwater bottomfish from several PICTs. Imports into Hawaii from the South and Western Pacific (including Indonesia) during 2002–2006 averaged 341 metric tonnes (t) per annum, representing over half of the total supply of bottomfish in Hawaii's fresh seafood market. It is known that some importers have forwarded quantities of bottomfish imports on to the US west coast, but the amounts are thought to be small.

The primary sources of the bottomfish supply in Hawaii in recent years have been Tonga, Indonesia and New Zealand. In the past, Fiji and, to a lesser extent, Samoa exported bottomfish to Hawaii. A nuance of the market sometimes not fully appreciated by operators desiring to export is that market demand is seasonal and the highest demand and prices occur in just a few months, December and January being the highest. For example, in 2007, the last

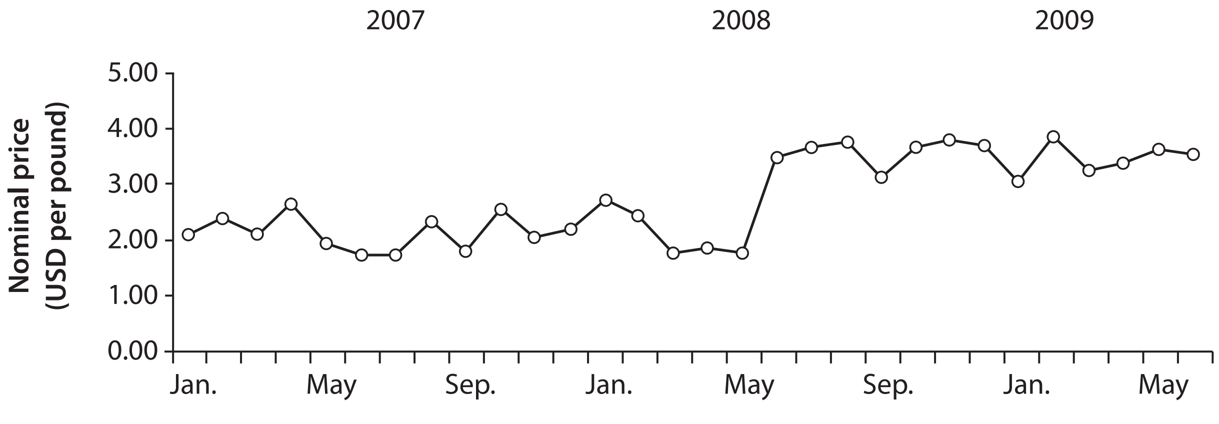


Figure 2. Nominal prices for fresh snapper and grouper imports to Honolulu, January 2007–June 2009. Source: Division of Aquatic Resources, Hawaii Department of Land and Natural Resources.

year for which comprehensive price data are available, prices varied for *E. coruscans* caught in Hawaii, from a high of USD 8.12 per pound (USD 17.90 per kg) in December, to a low of USD 4.45 per pound (USD 9.81 per kg) in June. Other factors such as the number of tourists and overall health of Hawaii's economy play important roles in demand and prices for deepwater bottomfish during this and other periods during the year.

This demand in Hawaii does not necessarily translate into higher prices for imports, however. It must be remembered that the market there is highly sensitive to fish quality, and in spite of the reputation of deepwater bottomfish maintaining their quality over time, it is very difficult for imports to command the prices paid for domestic supplies. This is assumed to be because of the distances and transit times involved, but biases towards local supply cannot be ruled out.

Information published by the State of Hawaii's Division of Aquatic Resources shows that import prices averaged around USD 2.00–4.00 per pound (USD 4.41–8.82 per kg) during 2007–2009 with little seasonal variation (Fig. 2). Prices for Hawaii-caught deepwater bottomfish averaged USD 5.81 per pound (USD 12.81 per kg) for *P. filamentosus* and USD 7.16 per pound (USD 15.78 per kg) for *E. coruscans* during the same period.

Due to concerns over the state of the resource, Hawaii has instituted a management system that closes the fishery once a total allowable catch (TAC) for seven deepwater species is reached. The TAC is adjusted on the basis of ongoing research for each "fishing year", which begins on 1 September. The 2009–2010 TAC for the main Hawaiian Islands was set at 254,050 pounds, or about 115 t, resulting in the closure of the fishery beginning 20 April 2010 lasting until 31 August 2010 when a new TAC will be implemented.

The impacts of such closures on import levels have been mixed. The first closure, from May–September 2007, resulted in an historical high for bottomfish imports into Hawaii, with 62% of the market supply during 2007 coming from imports. A second closure occurred in May 2008 but the volume of imports was greatly reduced from the previous year (Fig. 3). Overall, TAC levels have increased 30% in the three periods since they were introduced. Recent economics research has shown that increases in TAC levels will decrease prices and this may result in fishery revenues declining (Hospital and Pan 2009).

Why some deepwater bottomfish fisheries have ceased

As early as 1992, reasons were identified for the demise and/or lack of interest in continuing deepwater bottomfish fisheries in those countries where they had been established (Dalzell and Preston 1992). That analysis

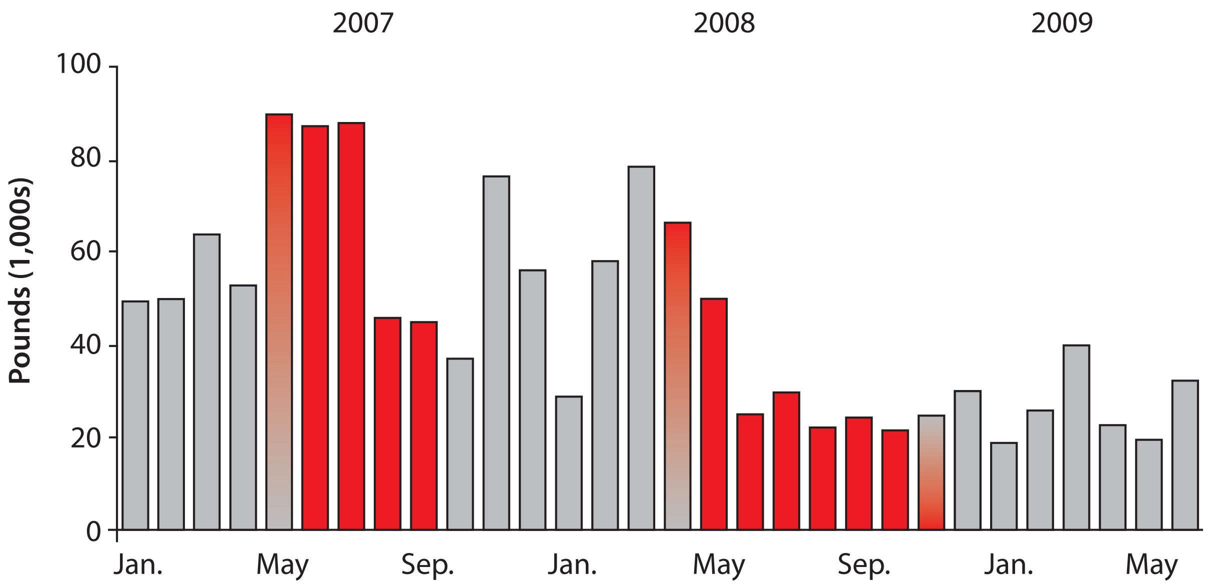


Figure 3. Deep bottomfish imports to Honolulu market. Red denotes closure periods for main Hawaiian Islands deepwater bottomfishing.
Source: Division of Aquatic Resources, Hawaii Department of Land and Natural Resources.

rings true 18 years later as one views the current situation in many PICTs. In general, the major causes identified were:

- limited productivity linked to habitat;
- decline of catch rates once virgin stocks were depleted;
- overcapitalisation through government subsidies;
- need for direct airline connections to high value export markets;
- problems with delays in payments even when airline connections existed; and
- interest in developing tuna longlining because of its greater economic potential.

Three additions to the above list that have become evident during efforts at developing deepwater bottomfish fisheries (even when the foregoing were or should have been known) are:

- lack of a significant price premium to encourage fishers to target deepwater bottomfish and expend the extra effort and costs involved;
- attempts at development schemes that were overly optimistic in production estimates, lacked current information on export markets, and/or did not take into account major bottlenecks of transportation and other logistics considerations; and
- removal of subsidies or financial support from donors.

Why some deepwater bottomfish fisheries have continued

A primary reason for those fisheries still in operation (Tonga and Fiji being two of the more significant locations) is the existence of sufficient habitat to support considerable deepwater bottomfish stocks. It is no coincidence that both countries possess seamount fisheries and do not rely solely on deep outer slope habitats. This has enabled a dispersal of fishing effort and opportunities for alternative fishing areas. Other reasons that have contributed to the ability to maintain production in these fisheries, if at reduced levels, are primarily economic in nature:

- reasonable airline connections to export markets;
- emergence of local buyers and exporters that reduce marketing risk;
- lack of alternative fishery opportunities;
- existence of a large domestic market, including tourism (Fiji); and
- diversification by some companies that has allowed them to remain economically viable during periods of poor economic performance of the deepwater bottomfish fishery.

Management of sustainable deepwater bottomfish fisheries in PICTs

Responses to a questionnaire circulated to PICTs as part of the study indicate that four PICTs have specific management arrangements in place that pertain to deepwater bottomfish, with three of those being US-affiliated territories and the fourth being Tonga. An additional three PICTs have existing coastal fishery management arrangements that, in general, cover or could cover deepwater bottomfish. Ten PICTs reported having neither specific deepwater bottomfish management arrangements in place nor other management arrangements that would apply specifically to the resource. The situation has not changed all that much from what was reported in 2004, when SPC's Marine Resources Division presented a paper to the Heads of Fisheries meeting that provided a short overview of deepwater snapper fisheries in the SPC region (Adams and Chapman 2004). Progress has been made in Tonga, however, with the completion of its deepwater snapper and grouper management plan, and at least two provinces in Papua New Guinea have produced draft plans.

Data collection on deepwater bottomfish fisheries in PICTs seems to work well when the activities are part of an overall fisheries monitoring scheme. The nature of the resources and bottomfishing in general (not just that targeted at deepwater species) make it practical to integrate data collection on deepwater species along with collection of data from other bottomfishing activities.

The objective of collecting data for stock assessment purposes is to determine sustainable yields. Catch monitoring is the obvious means by which this can be accomplished, but other activities such as tagging or otolith sampling (from both adults and juvenile specimens) can contribute to overall knowledge of the resource. Such activities other than catch monitoring would be most appropriate where resource use justifies the effort and the activities are within the capacity of fisheries departments to undertake.

As a basis, data collection for deepwater bottomfish stock assessment purposes should be part of a well-designed program that is within the available human and financial resources of the agency concerned to undertake and sustain. At a minimum, the data collected should reflect:

1. Estimates of total catch broken down by species, in number and/or weight.
2. Estimates of effort, such as vessel-day fishing, trips, or other consistent measure.

3. Fishing location as specifically described as possible (e.g. fine-scale global positioning system readings such as those that might be entered into a logbook or inferred from a vessel monitoring system and keyed to a map of fishing areas).
4. Size sampling data by species, accompanied by fine-scale location if possible. Where possible, both length and weight measures should be collected through sampling to develop length–weight relationships.

The data collected from the use of deepwater bottomfish resources on seamounts are essentially the same, but with even greater emphasis on the need for the data to be location-specific and not aggregated. Catches from individual seamounts can be used as a tool to detect patterns, and length frequency data by species are important. There still remains the unanswered ecological question of deepwater bottomfish population connectivity between seamounts, and this calls for careful collection of the data linked to specific seamount locations.

For those PICTs where data have been generated from past collection programs or assessments, it is useful to have those data available as well as the results from the assessments themselves. This is not always an easy task, as past data may not be easily located or be in electronic formats no longer used. This argues for even more care when designing and executing new data collection programs aimed at stock assessment that may be useful in future or related work.

Acknowledgements

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1. Deepwater bottom fishing is considered here to be fishing for bottom dwelling species using a multi-hook terminal rig in depths greater than about 100–120 m (Preston et al. 1999). Vertical droplines or handlines are the most common gear types employed, although it is acknowledged that there may be or have been some activities using longlines set on or just above the bottom.
2. Available commercial landings data for the Commonwealth of the Northern Mariana Islands and American Samoa apply to 2004 and 2007.

SOME COMMON FISHERY TERMS

Source: The Pew Environment Group, Ocean Science Fact Sheet. March 2010. http://www.pewtrusts.org/uploadedFiles/wwwpewtrustsorg/Fact_Sheets/Protecting_ocean_life/PewCommonFisheryTerms.pdf

Benthic zone - Ecological area that includes the seafloor and the region directly above it. It commonly consists of nutrient-rich sand, silt or dead organisms and is typically home to seaweeds, bacteria, fungi, sponges, sea anemones, worms, sea stars, fishes and other creatures.

Biomass (B) - The quantity of a group of living organisms, measured by weight.

B_0 - The historical baseline or unfished virgin biomass (B) against which decline **should** be measured.

Bycatch - The part of a fishery catch that is not a legal target of the fishery. Bycatch may be retained and landed but is usually discarded (released or returned to the sea, dead or alive). Examples: sea turtles caught in a longline fishery, sharks caught while fishing for swordfish, small or undersize red snapper caught when fishing for larger red snapper, and target species caught after a quota or limit has been reached.

Catch - The total number or weight of fish taken out of their environment, dead or alive, through fishing. Catch includes fish that are discarded or released and not landed.

Ecosystem-based management (EBM) - An integrated approach to oversight that considers the entire ecosystem, including interactions and interdependencies among species and their habitats.

Exclusive economic zone (EEZ) - The area of sea and seabed extending from the shore of a country claiming exclusive rights to it. Under the United Nations Convention on the Law of the Sea, coastal countries have sovereign rights within a 200 nautical-mile EEZ with respect to natural resources and certain economic activities. Nations also exercise jurisdiction over marine science research and environmental protection. Freedom of navigation and overflight, as well as other uses permitted on the high seas (waters beyond national jurisdiction) are still allowed.

Fishing mortality (F) - The rate at which fish are removed from a population through fishing or the portion of the total mortality rate that is attributed to fishing.

Highly migratory species (HMS) - Species whose life cycle includes lengthy migrations, usually through multiple exclusive economic zones (EEZ) or the high seas. Examples: yellowfin tuna and great white shark.

Landings - The number or weight of fish unloaded at a dock or brought to shore.

Maximum sustainable yield (MSY) - The largest average catch that can be taken continuously (sustained) under prevailing environmental conditions without affecting the reproductive health of a stock. B_{Msy} is the long-term average biomass (B) level needed to achieve MSY. F_{Msy} is the fishing mortality rate (F) that results in B_{Msy} for a fish population.

Overfished - Refers to a stock whose biomass (B) has been exploited below the minimum level recommended by scientists and set by management. The minimum threshold is often the biomass associated with maximum sustainable yield (B_{Msy}) or a percentage of B_{Msy}. A stock below the minimum threshold requires a rebuilding plan to return it to a state equal to or greater than B_{Msy}.

Overfishing - Refers to fishing at a mortality rate (F) above a maximum recommended by scientists and set by management. The maximum rate is often a percentage of the fishing mortality rate associated with maximum sustainable yield (F_{MSY}). Overfishing typically results in declines in fish numbers or biomass (B) and requires a reduction in fishing effort.

Pelagic zone - The ecological area consisting of the open sea away from the coast and the ocean bottom. The pelagic zone contains organisms such as surface seaweeds, many species of fish and sharks and some mammals, such as whales and dolphins. Pelagic animals may remain solely in the pelagic zone or may move among zones.

Recruitment - A measure of the number of fish entering the fishable population by surviving to a certain age or size or by migrating into a fishing area. Recruitment can also refer to the number of fish reaching sexual maturity or spawning age within a species.

Size limit - A minimum or maximum on the size of fish that may legally be caught.

Spawning stock biomass (SSB) - The total amount of male and female fish in a stock, measured by weight, that are sexually mature (old enough to spawn).

Stock - A grouping of fish used as the basic unit for fisheries management. A stock includes one species of fish in a particular area that shares similar growth and migration patterns. Example: the northern stock of Pacific Ocean albacore tuna.

Straddling stock - A stock that moves within the exclusive economic zones (EEZs) of two or more coastal countries or between an EEZ and an area adjacent to it. Example: skipjack.

Total allowable catch (TAC) - The total catch permitted to be caught from a stock for a given time period determined by fisheries managers. A management agency allocates the TAC among stakeholders.

Total mortality (Z) - The rate of fish dying during a year or season due to both fishing and natural causes. This rate varies among species.

Transboundary fish stocks - A stock or population of fish that moves across political or management boundaries. Example: bigeye tuna (many countries).

Weight-at-age - The average individual weight of the fish in each age class of a particular stock.

Year/age class - The fish spawned or hatched in a given year, a "generation" of fish. The age composition of a given stock or catch refers to the proportion of fish of different ages or generations.