Fisheries Newsletter

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In this issue

Editorial

Sea cucumbers, or beche-de-mer as we call their dried and marketable form, are today's special in this issue. Few people know that these strange looking creatures lying lazily in shallow areas of tropical waters are the targets of the second-most valuable capture-based, export fishery in the South Pacific, second only to tuna. Unfortunately, these targets have been hit so hard in recent years that several Pacific Island countries, which are among the main producers, have banned their fishing for up to 10 years, in the hope that stocks will recover.

In the first feature article (p. 24), Carleton and co-authors explain why "the key priority [for sea cucumber management] is to break or moderate the boom-and-bust cycle typical of this industry." They also demonstrate how using more precautionary production levels (which would allow the production of a higher-value species mix and larger sea cucumbers) and better processing techniques would provide far greater economic returns (almost the double of what the fishery actually does), and would eliminate the need for moratoria. In other words, year after year, national economies, particularly cash-starved rural coastal communities, would benefit from increased revenues.

In the second feature article (p. 43), Léopold and co-authors confirm Carleton's conclusions. They describe how, in New Caledonia, a sandfish sea cucumber fishery is co-monitored and co-managed, using an original total allowable catch (TAC) system, by a coastal community and local authorities, under the scientific guidance of the French Institute of Research for Development (IRD). Between 2008 and 2012, the sandfish biomass in the study area nearly tripled, while the average income per fisher nearly doubled, even though the number of fishers increased during the period... a success story, for sure!

Transposing the TAC management system used at the New Caledonia site to another social context and a wider geographic scale will certainly be a challenge. But, among the many lessons learned while reading these two articles, I will certainly remember one: limiting captures can provide far greater economic returns.

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Fishing for milkfish fry using a bulldozer net, Arnavon Islands, Solomon Islands (image: Tim Pickering).

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

SPC participates in purse-seine bycatch mitigation cruise

David Itano, ©ISSF 2012

A key ecological concern about purse-seine fishing around fish aggregation devices (FADs) is the wasteful catch of unwanted species. In the search for better fishing practices to avoid these wastes, the International Seafood Sustainability Foundation (ISSF) has, since 2011, implemented a global research programme — the ISSF Purse-Seine Bycatch Mitigation Project — to develop and test technical options to reduce bycatch resulting from large-scale purse-seine fishing on FADs. At the core of the project is the chartering of purse-seine vessels to serve as experimental platforms to conduct these tests under different oceanographic and fishery-specific conditions.

The first cruise to the western and central Pacific Ocean (WCPO) left Pago Pago, American Samoa in May 2012. The Pelagic Fisheries Program (PFP) of the University of Hawaii was the lead institute responsible for conducting experiments during the cruise, and was represented by David Itano, cruise leader, and Jeff Muir. As a key partner and science provider to the Western and Central Pacific Fisheries Commission, the Secretariat of the Pacific Community (SPC) was invited by ISSF to send scientific staff to participate in the cruise. Ferral Lasi and Bruno Leroy from SPC's Oceanic Fisheries Programme joined the cruise. The Hawaii Institute of Marine Biology (HIMB), represented by Melanie Hutchinson, was also part of the scientific investigation. Finally, two senior Fisheries Observers from the Pacific Islands region — Kevin Kisekup from the Papua New Guinea National Fisheries Authority and Elton Clodumar from the Marshall Islands Marine Resources Authority — were invited to join the cruise as part of a capacity building programme.

Key tasks undertaken by SPC staff during the cruise included: 1) monitoring and logging monitoring, control and surveillance (MCS)-related data produced by the Archipelago Electronic Monitoring System; 2) conducting paired spill-and-grab sampling on catches; and 3) testing the viability of GoPro cameras for their potential for supporting the electronic monitoring of tuna catch and size estimates. The two senior Fisheries Observers assisted SPC staff with spill sampling, and provided technical support to the PFP and HIMB scientists.

The cruise

The cruise took place on the *Cape Finisterre,* a US-flagged, 72.6 m purse-seine vessel powered by a 1,000 hp Caterpillar engine. The vessel has 18 storage wells that can hold 1,242 t of fish when full. The vessel is skippered by John Crisci (an American), and has a crew of 21 made up of a wide range of nationalities including

Americans, Ecuadorian, Panamanians, Philippinos, Solomon Islanders, Samoans, Tongans, Tuvaluans, Mexicans, Croatians, Chinese and Indonesians.

The cruise was divided into two parts. The first leg began on 22 May when the vessel departed Pago Pago, and ended on 10 June, when it returned. The second leg departed Pago Pago on 14 June and returned on 1 July. The cruise path ran through the exclusive economic zones of Tuvalu, Tokelau and "pockets" of international waters between them. During the cruise, fishing was mostly done around FADs but, when transiting between FADs, free schools that were encountered were also targeted.

Summary of cruise research activities

The research activities undertaken by the three organisations taking part in the cruise are summarised in the tables below.

What is the Archipelago Electronic Monitoring System?

The system, which uses video-based electronic monitoring, has been developed by the Canadian company Archipelago Marine Research Ltd. to "augment observer programmes, increase the accuracy of data collected by observers, and provide monitoring on the unobservable component of the fleet ".*

For the ISSF Purse-Seine Bycatch Mitigation Cruise, the system comprised an array of cameras mounted in strategic locations on the vessel, which are connected to the main winch hydraulic system, a central computer and a monitor that is located on the vessel's bridge. The system switches on as soon as the main winch hydraulic system is used, as it is a signal that fishing is occurring, even in the middle of the night. The system attempts to automatically log vessel fishing activities and store data in a computer for later perusal by law enforcement officers to ensure that fishing regulations are not violated. If the system works well, there should be no need for Fisheries Observers to collect MCS information.

* Use of a video electronic monitoring system to estimate catch on groundfish fixed gear vessels in California: A pilot study. By Maria Jose Pria et al. [http://www.edf.org/sites/default/files/California Fixed Gear EM Study 2008.pdf]

Table 1. Summary of activities undertaken by the SPC team, and their outcomes.

Experiments or activities	Outcomes
Trial of the Archipelago Electronic Monitoring System	· System works fine and is suitable as additional support for MCS reporting but cannot replace observers. · Cannot replace Fisheries Observer work because scientific data still needs to be collected by observers.
Paired spill and grab sampling	· Large sample size of data obtained from FAD fishing in the central Pacific Ocean region, and can be used for comparison with other regions in WCPO. · Data from average lengths of tunas to fill sampling bins are used to determine optimal bin size for spill sampling.
Trial of GoPro cameras	· GoPro cameras can be used to monitor performance of grab and spill observers on board. · GoPro cameras are not suitable for capturing species composition during brailing or loading of wells at the wet deck. · Ice slurry mixed with fish blood obscures fish sliding down the chute into wells. GoPro cameras are of little use in such situation.

Table 2. Summary of activities undertaken by the PFP team[1]

Experiments or activities
Underwater visual census at FADs
Natural behaviour of tuna and bycatch in the net
Initial release of fish from the net by towing FADs
Pre-set estimation of catch and bycatch
Vertical and horizontal behaviour of tuna and bycatch species on FAD aggregations
Targeting skipjack after dawn while avoiding bigeye and bycatch
Shark escape panel experiment
Bigeye tuna tagging (sonic/conventional)

[1] The outcomes of the work carried out by the Pelagic Fisheries Program and Hawaii Institute of Marine Biology teams will be released later as internal documents of the International Seafood Sustainability Foundation.

Table 3. Summary of activities undertaken by the HIMB team.

Experiments or activities
Condition and post-release survival of sharks
Best practice for the live release and handling of whale sharks and manta rays
Shark tagging

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What are spill and grab samplings?

Grab sampling is a standard method used by SPC for determining tuna species composition of purse-seine activities in the WCPO, and involves the Fisheries Observer selecting five fish at random from each brail as fish are poured on deck from the net. Each of the five fish is then identified and its fork length measurement taken. However, it has been found through statistical analyses that the use of this sampling method for estimating species composition was biased because five fish are too few a sample size to represent less common species, such as bigeye tuna, and because five fish are taken at the top of the brail, where the bigger fish tend to be.

Spill sampling is a new method being recommended to all Fisheries Observers, and consists of "spilling" part of the fish contained in a brail, as it is winched in, into a bin. All of the fish spilled into the bin are then identified and measured. A spill sample is taken for every tenth brail during a fishing trip. Overall, the number of fish sampled using the spill sampling method is greater (±200–300 fish/10 brails) than with grab sampling (50 fish/10 brails), and takes into account the stratification (bigger fish at the top) or layering (weaker fish — usually smaller specimens and bigeye — dying first and dropping to the bottom of the net) of the fish that may occur during brailing. It therefore enables better estimates than grab sampling.

David Itano, ©ISSF 2012

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My career in fisheries observing: A story for aspiring observers

Manoi Rex Kutan, *Observer ID code:* **MAK**

Profile

2001–2007: Joined the Papua New Guinea National Fisheries Authority (NFA) Observer Programme

2008: Selected as a Pacific Islands Regional Fisheries Observer Trainer

2009: Selected as the Papua New Guinea Observer Training Coordinator

2011: Selected as the Secretariat of the Pacific Community Regional Observer Debriefing Training and Support Officer

Becoming a Fisheries Observer

After flunking two courses at the Papua New Guinea (PNG) University of Technology, I returned to my home island of M'Buke, in Manus Province, for six years before joining the PNG Observer Programme in 2001. I was very, very fortunate to be selected to attend this observer training because there were about 400 applicants and only 17 of us were selected. Nowadays, the PNG National Fisheries Authority (NFA) receives almost a thousand applications for observer training each year.

Training was delivered by SPC and the Pacific Islands Forum Fisheries Agency (FFA), and our trainers were Peter Sharples (SPC's Port Sampling and Observer Coordinator at the time) and Karl Staisch (FFA's Observer Manager at that time). Peter is now my supervisor here at SPC. At end of the observer training I graduated among the top five.

Working as a Fisheries Observer

Working as a Fisheries Observer has its challenges. Although the basic training tries as much as possible to reflect the actual working environment, once actually out there, physically putting into practice what has been taught, is quite different. You are on your own with no one to guide or assist you in any decision you make.

At times, I really did not like the working conditions but I liked my job overall so never complained — that was all part of it. Although never directed at me, I have witnessed different types of treatment dished out to Fisheries Observers by others on board the vessel. It is, however, always at the back of my mind when I go on board a fishing vessel that this will be my home for a month or two. I endeavour to see everyone onboard as being of "one community", and that we should at all times try to respect one another. All of the vessel masters I have worked with have been very friendly but I always try to remember my limits. I respect them and they respect me. Knowing when to speak and what to say is a very important skill in this job. But I also soon realised that not saying too much is better.

You also get to travel to a lot of places and meet and work with different people from different cultures and nationalities. This has been all very exciting.

As an observer collecting information for various agencies, I try to focus on the end result of the information I am asked to collect. Understanding the purpose for the main data fields has made it easier to make decisions on the best information to record, although this is usually fairly clearly laid out. In the early days, I sometimes found I made mistakes that needed to be corrected at the end of the trip (during debriefings), but because I was conscious of why I recorded something the way I had, I was able to explain this to the debriefer who was then able to see where I was coming from and help to correct those errors, making it easier for him to teach me the correct method or approach.

The motivating argument

It was in 2004 during one of NFA's consultative meetings with experienced observers to meet and discuss observer issues. Peter Sharples from SPC, and a well-known regional fisheries consultant and character, Mike McCoy (teaching turtle tagging) were also present. We were all discussing a datafield that we understood differently from Peter's explanation. I was the most vocal about this and so we argued. Later, during our closing ceremony, I apologised to Peter. What he told me has never left my mind. He said: "It was good to voice your thoughts because only after such discussion can we be sure whether our thoughts are right or wrong." After that, he said, "I am really looking forward to working with you," a comment I will always remember. I know he does not recall this conversation, but to me, it was a huge motivating factor.

Becoming an Observer Trainer

In 2008, on a day that I was about to board a carrier vessel to meet my assigned host vessel out at sea, I received a phone call from my Observer Manager telling me that I will not board the vessel but will instead attend the basic observer training at the PNG National Fisheries College (NFC) as one of the newly appointed national trainee trainers.

The Pacific Islands Regional Fisheries Observer (PIRFO) training standards were still being developed and we were asked to contribute to this development. Six PNG senior Fisheries Observers were selected to attend the training, working alongside Peter, SPC Trainer, Siosifa Fukofuka and FFA Observer Manager, Tim Park. I do not really know how I was selected. During the training Peter told me that I had performed exceptionally and recommended my attendance in the Solomon Islands to assist in the next observer training. My PIRFO trainer development programme had been launched. In April, I went to Honiara and then in October, to Vanuatu for further observer training in the capacity of a PIRFO Trainee Trainer.

Observer Training Coordinator

In 2009, as a result of PNG being a founding cooperating partner in the development of the new PIRFO training standards, the NFC was in a position to run their own PIRFO observer training. They began looking for someone to coordinate the training, and despite having no formal certification or qualification as a trainer or coordinator, I was chosen for the job. I was the first PNG Observer Training Coordinator, coordinating and undertaking PIRFO training. I was joined by fellow observer trainer, Glen English, as a full-time PIRFO Trainer, and assisted from course to course by selected senior observers (Glen is now working out of Fiji, as SPC's southern regional PIRFO Training and Support Officer).

In 2010, I suggested holding a PNG national debriefing training workshop. With Glen's assistance we facilitated and delivered this workshop, a first for a national observer programme.

Observer Debriefer Training and Support Officer

In 2011, the new position of Observer Debriefer Training and Support Officer was advertised by SPC, and I applied. Low and behold, here I am now, sitting next to my 2001 trainers at the SPC headquarters, writing this article. Actually, there is not much sitting involved, as my job is to provide PIRFO debriefing training to all SPC member countries.

From left to right: SPC's Debriefing Trainer, Manoi Kutan, and FFA's Observer Manager, Tim Park awarding certificate of successful completion of the Introduction to Debriefing course to Solomon Islands Senior Observer (and ex-Solomon Islands football international) Jeffrey Aruhe

Never in my wildest dreams in my early days as an Observer did I see myself being here, let alone in any one of those positions along the way. I saw myself as simply a Fisheries Observer, but I realise now that, like the data that are collected, the Observer's performance is constantly being monitored.

And I achieved all this with just an Observer Certificate. I know for sure that if it were not for my observer experience, someone with an academic degree would be sitting here in my place.

A tip: I believe that one of my strengths as a Fisheries Observer was to take my work seriously and to try to understand at least the fundamental reasons for carrying out my observer duties, then doing my best to carry out the work properly.

Thank you.

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Comment from Peter Sharples, SPC's Observer Support and Development Coordinator:

From the start, Manoi demonstrated communication skills and initiative beyond his quiet exterior. Accurate observations were also a natural tendency. This, combined with a willingness to share his view and the initiative to help and lead others, put him where he is today. It was we who were lucky to be in the right place at the right time to recognise Manoi's skills and later secure his services for our region. It is not incredible luck that got Manoi to where he is. Fisheries observing is a valued profession these days and there are many opportunities to move on once the long days, weeks and months at sea start to wear thin. Listed below are just some of the many Fisheries Observers that have gone on to do other things that they have been able to do, or been able to do better, because of their training and/or experiences as a Pacific Islands Fisheries Observer:

Karl Staisch (Australia) – WCPFC Regional Observer Programme Manager

Siosifa Fukofuka (Tonga) – SPC Oceanic Fisheries Programme (OFP) Regional Training Coordinator

Peter Sharples (New Zealand) – SPC, OFP Regional Observer Support and Development Officer

Deirdre Brogan (Ireland) – SPC, OFP Fisheries Monitoring Officer

Manasseh Avicks (Solomon Islands) – SPC OFP Observer Training and Support Officer (northern region)

Philip Lens (PNG) – PNG NFA Observer Manager

Glen English (PNG) – SPC OFP Observer Training and Support Officer (southern region)

Ambrose Orianihaa (Solomon Islands) – South Pacific FFA Observer Placement Officer

Fredrick Austin (Solomon Islands) – FFA Observer Support Officer

Bernard Fiubala (Solomon Islands) – Marshall Islands Marine Resources Authority (MIMRA) Observer Advisor

Dike Poznanski (Marshall Islands) – MIMRA Observer Coordinator

Steve Peter (Federated States of Micronesia) – Pacific Islands Regional Fisheries Observer (PIRFO) and FSM National Oceanographic Resource Management Authority (NORMA) Trainer

John Still Villi (Solomon Islands) – PIRFO Trainer

Kevin Kisekup (PNG) – PIRFO Trainer

Adrian Nanguromo (PNG) – PNG National Fisheries Authority (NFA) Observer Coordinator

Iamo Airi (PNG) – Papua New Guinea (PNG) NFA Observer Trainer at the National Fisheries College

John Mahit (Vanuatu) – Vanuatu Observer Coordinator

Elton Clodumar (Nauru) – PIRFO and Nauru National Trainer

Ian Tervet (Palau) - Palau Observer Coordinator

Benaia Bauru (Kiribati) – PIRFO Trainer

Toetu Pasaleli (Samoa) – Samoa Observer Coordinator

Jacob Keju (Marshall Islands) – MIMRA Full time Debriefing Officer

Jimmy Belade (Solomon Islands) – Solomon Islands Assistant observer Coordinator

Ricky Narruhn (Federated States of Micronesia) – Trainee PIRFO Trainer and NORMA Assistant Trainer

Lucas Tarapik (PNG) – PNG NFA National Debriefing Coordinator

Linus Yakwa (PNG) – PNG NFA Observer Administration Coordinator

Henry Mabai (PNG) – NFA Madang Observer Port Coordinator

Herman Kisokau (PNG) – Parties to the Nauru Agreement (PNA) VMS Officer

Vitolos Tomidi (PNG) – PNG NFA Observer Operations Coordinator

Juan Jose Areso (Spain) – Indian Ocean Spanish Fleet Liaison Officer

Filipe Viala (Fiji) – Fisherman / Engineer

Dennis Yehilomo (PNG) – PNG NFA Fisheries Enforcement Officer, then recruited as the FFA Surveillance Operations Officer

Glen Joseph (Marshall Islands) – Director of Marshall Islands Marine Resources Authority (MIMRA)

Lamiller Pawut (PNG) – PNG NFA Monitoring Control and Surveillance (MSC) Executive Manager, then recruited as the FFA Fisheries Enforcement Advisor

A new approach to monitoring FAD programmes

Nearshore anchored fish aggregating device (FAD) programmes are being implemented widely throughout the Pacific. Numerous agencies are involved and FADs are deployed with a wide array of overarching objectives, including climate change adaptation, reef conservation, securing food and livelihoods for Pacific Islanders. The primary objective of FAD deployment, however, is universal: to improve the efficiency of small-scale fishers in targeting tuna and other pelagic fish.

The effectiveness of FADs in achieving this objective is confirmed when talking with fishers; however few data are available in support of this. The collection of data surrounding small-scale, diversified and geographically dispersed fisheries is generally problematic, so SPC and development partners are trialling a new approach to monitor FAD programmes.

The FAD sampling design is currently being trialled in Yap State in the Federated States of Micronesia, and there are plans to replicate this in other locations in 2013. The data collection methodology involves communities and fishers who are beneficiaries of FADs, and selects data collectors from each site to champion the monitoring process.

The sampling framework collects fisheries-dependent and independent data to understand the effectiveness of FADs in improving the efficiency of fishers' fishing activities and learn whether FADs change the fishing location, and consumption and sales patterns of households that have access to FADs or FAD-caught fish. The sampling design consists of the following components:

1) **FAD deployment registry** – records details (location, FAD type, rigging components, cost and maintenance) of every FAD that is deployed. These data, when linked to catch data, can facilitate optimisation of FAD programme design, including best locations, depths and rigging.

2) **Fishing vessel identification** – identifies and collects information on all active fishing vessels (name, owner, type, general catch and effort information, and safety equipment ownership) mainly to establish indices of fishing effort.

3) **Fishing activity log** – counts the number of fishing trips, by vessel type, returning to a pre-selected landing site over a series of random periods. These data form the basis for estimating total fishing trips from a landing site — indices of effort — which, in combination with trip-level catch data, allows for an estimation of total catch.

4) **Catch and effort log sheet** – general trip-level data are collected, including financial data, while fishing effort and catch data are collected by fishing event (i.e. location and fishing method), which allows disaggregation of catch and effort data by location (i.e. at and away from FADs). These data allow us to understand the effect that FADs have on the efficiency of fishers' fishing activities (i.e. catch rate and fuel consumption).

5) **Household fishing, consumption and sales calendar** – a daily household survey that is implemented before and after FAD deployment for at least two periods of four weeks. The survey, which is completed by households in beneficiary sites, collects data daily on household fishing activity by location (e.g. reef and lagoon, FAD, open water), fish consumption by fish category (reef and pelagic), and fish sales by category (reef and pelagic). The calendar helps indicate how effective the FADs are in achieving secondary objectives, such as transferring fishing effort from the reef to pelagic fisheries and increasing income generated from the sale of tuna.

The FAD sampling design is based on the regional artisanal tuna fisheries monitoring programme that is being implemented in a number of countries, and the data collected will help inform the management of small-scale fisheries.

Yap State FAD monitoring programme

Six nearshore, subsurface FADs were deployed in Yap State in the Federated States of Micronesia in February and March 2013. The FADs were deployed as a component of the project "Coping with Climate Change in the Pacific Islands Region", which is funded by the German government and implemented by SPC and the German Agency for International Cooperation. Local partners in this project include Yap's Marine Resources Management Division of the Department of Resources and Development, and the non-governmental organisation Yap Community Action Program.

Four landing sites have been selected for implementing the FAD monitoring framework and five data collectors have been hired to facilitate data collection. The results of this exciting inter-agency project will be reported on once sufficient data become available.

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Survey for milkfish fry collection in the Arnavon Islands, Solomon Islands

Milkfish fry fishing along the beach with a bulldozer net (image: Tim Pickering).

Whenever milkfish are mentioned in the Solomon Islands, it is not long before the Arnavon Islands (between Santa Isabel and Choisel islands) are also mentioned because this area is famous for an abundance of milkfish of all sizes. The Arnavon Islands are protected and managed by rangers in a three-way conservation co-management arrangement among the communities of Choisel, Isabel and Wagina islands. Shallow lagoons within these islands attract milkfish fry, and act as nursery areas for milkfish right up to juvenile sizes (1 kg or more).

In March 2013, a research survey to collect milkfish fry and fingerlings from the Arnavon Islands was conducted. The four-person survey team consisted of two master's students from the School of Marine Studies at the University of the South Pacific (USP), Simon Vuto and Joshua Lavisi, who were accompanied by Solomon Islands Ministry of Fisheries and Marine Resources (MFMR) Inland Aquaculture Officer, James Ngwaerobo, and SPC Inland Aquaculture Specialist, Tim Pickering. The survey was part of an Australian Centre for International Agricultural Research project[1] implemented by the WorldFish Center, Solomon Islands MFMR, and SPC's Aquaculture Section.

The two main target species of the survey were the introduced freshwater fish Mozambique tilapia (*Oreochromis mossambicus*), which was introduced in the islands in the 1960s, and the indigenous milkfish *Chanos chanos*. These two species were selected because they are low in the food chain (i.e. are mainly herbivorous) and are inexpensive to feed and grow in aquaculture ponds.

The main objectives of the survey were to: 1) monitor seasonal fry abundance, and study its relationship with weather, tides and moon phases; 2) find out whether the reputation of the Arnavon Islands as a place with an abundance of milkfish extends to sizes of interest for capture-based aquaculture; and 3) determine whether the type of coral sand coast and marine environment found in these islands is better suited for fry capture than the fairly restricted collection sites along the steeply sloped gravel beaches of major high islands such as Guadalcanal.

The two USP students conducted the one-off survey in the Arnavon Islands for milkfish fry and fingerlings to help determine whether capture-based milkfish aquaculture is worth doing in the Solomon Islands. Accompanied by Ngwaerobo and Pickering, the students also tested the logistics of transferring fry from outer islands of the Solomons, such as the Arnavons, to Honiara for nursery and pond grow-out.

Tilapia are easy to breed in ponds or in tanks on land. Milkfish can be easily grown in freshwater ponds too, but their breeding takes place in the open sea. Operating a milkfish hatchery is technically demanding, and requires big breeders because the fish do not reach maturity until they are around five years old.

[1] ACIAR-funded project FIS 2010/057, "Developing inland aquaculture in Solomon Islands".

It took two days to go by inter-island vessel from Honiara to the village of Kia on Isabel Island, and from there by 40-hp fiberglass boat to the Arnavon Islands. The survey team was hosted and guided by three rangers — Rabo, Moses and Rudi — of the Arnavon Association, which administers the wildlife reserve there. Permits and permissions to conduct research in the reserve were obtained by the WorldFish Center beforehand.

A visual survey of the two major islands in the Arnavons (Sikopo Island and Kerehikapa Island) showed that the area is rich in milkfish habitat for small to medium juvenile stages, with the lagoons being high in primary productivity (e.g. rich, golden phytoplankton blooms, abundant cynanobacteria/algal floc) and having narrow openings to the open sea. Many milkfish schools, from fingerling size (6 cm) up to large juvenile (40 cm), were seen swimming in these lagoons, which are well known as a milkfish resource by fishers from Wagina, Choisel and Isabel islands.

The sampling plan followed the recommendations of Philippine milkfish experts and previously written reports, and involved using a bulldozer net along beaches with an onshore breeze and rising tide. In the Arnavon Islands, this proved impractical because the sea on the weather side of all the islands was choppy, making it too difficult to operate the bulldozer net. Furthermore, because the beaches are turtle nesting sites there are many sharks around, and any activity in these windward waters rapidly attracted small sharks into shallow water areas, even in broad daylight. Stingrays are also a major hazard to surveyors and we sighted several, some at very close range.

The trend that emerged from the survey was that the sheltered bay inside the "horseshoe" of each island had better catches of milkfish larvae than elsewhere. Dense shoals of baitfish aggregated there to feed on zooplankton within metres of the beach. The number of fry caught by the bulldozer net was greater at night than during the day at the same place, but was not startlingly high. After four days and nights of systematic fishing, only 149 glassy fry were caught. In the Philippines, the minimum number of glassy fry considered to be "interesting" enough for a middleman to come and buy them is 2,000 fry.

Schools of small fingerlings swimming in the tidal lagoons of the Arnavon Islands (in depths of 10–20 cm) were observed, and the survey team caught some for experimental transport to Honiara. The only means of catching these fish was a mosquito bed-net as a seine, but even so, 27 fingerlings ranging in size from about 5–8 cm were caught.

A knotless-mesh seine net about 10 m long would be the most promising way to capture milkfish fingerlings from this type of environment for transport to grow-out ponds. The high primary productivity of these lagoons and their connections to the ocean mean that replenishment by new recruits will be quite rapid. Targeting larger milkfish for direct consumption should be avoided, however, for conservation reasons, and taking milkfish for home consumption from the Arnavon lagoons is restricted under the joint management plan for these islands.

The second objective of the survey was to conduct a trial of live shipment of fry from the Arnavons back to Honiara for nursery grow-out, to determine the logistics that were involved, and to further boost the number of fish available for stocking into the John Bosco Farm pond for an expanded grow-out trial during 2013. The survey team packed the 149 fry and 27 fingerlings into two eskies, using 6 L of transport water in each. The survey team departed the Arnavons at 0700 (bound for Isabel's Suavanao Airport via Kia), and arrived at Henderson Field at 1530. The fish successfully acclimated to the MFMR milkfish nursery at Kukum with 100% survival.

Our conclusion is that transporting both fry and fingerling stages of milkfish within the Solomon Islands by air in modest, yet useful, quantities is a practical proposition, and does not require any special equipment apart from battery-powered aerators and eskie-style fish boxes. So far, fingerling stages are easier to find and catch for aquaculture than glassy fry. But, if it were possible to locate the right spot for glassy fry collection, that conclusion could easily change.

Details of the bulldozer net and the targeted milkfish fry (insert). Images: Tim Pickering

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Practical training on seaweed culture in Indonesia

A practical training for technical staff involved in* Kappaphycus alvarezii *seaweed aquaculture was held from 8–15 October 2012, at the National Seaweed Centre on Lombok in Indonesia. Two main lessons were learned in Indonesia that are useful for Pacific Island countries to help adapt aquaculture industries to climate change: 1) improved seaweed varieties that can tolerate warmer and more brackish water conditions are now available; and 2) floating rope rafts deployed in deeper water provide greater protection during rough weather, and more choice in seaweed farm site selection. The training was supported by SPC through its Fisheries, Aquaculture and Marine Ecosystems Division and the European Union-funded "Increasing Agriculture Commodity Trade" project. Eight extension officers and technical staff from Fiji, Kiribati, Papua New Guinea (PNG) and Solomon Islands attended the practical training.

Seaweed culture

The seaweed *Kappaphycus alvarezii*, traditionally known as "cottonii", has been identified by SPC and several governments of Pacific Island countries and territories (PICTs) as a priority for low-tech, household-scale aquaculture in rural areas.

The benefits of seaweed farming is that it: 1) is environmentally friendly; 2) requires low-level technology, low investment, and minimal post-harvest processing; 3) can be conducted at the household level; and 4) the seaweed itself can be stored for up to six months All of these factors make seaweed farming an attractive livelihood activity in remote locations where there are few alternative income-earning possibilities. The need for alternative livelihoods in isolated coastal communities, and the increased demand for seaweed-based products globally have accelerated the intentional introduction of *Kappaphycus* seaweed to over 20 countries, including 11 in the Pacific.

Cottonii seaweed, however, like coral, bleaches when seawater is too warm or too brackish. Increased rough sea conditions that uproot staked lines can cause setbacks for cottonii seaweed aquaculture.

Two improved varieties of cottonii seaweed cultivated at the National Seaweed Centre on Lombok in Indonesia (image: Ruth Garcia Gomez).

Why a training in Indonesia?

Although cottonii aquaculture is well established in Southeast Asia, it has produced mixed results in the Pacific Islands region. In Indonesia, the National Seaweed Centre has focused on developing higher-performing strains of *K. alvarezii* that are faster growing and more tolerant to environmental stresses such as increased water temperature and salinity fluctuations. Learning about these new strains and being trained on the techniques used for their aquaculture was a real opportunity.

Compared with Asian countries, the Pacific Islands face constraints such as remoteness from markets, small volume of production, and a relative lack of seaweed culture expertise. Nonetheless, seaweed farming continues in Fiji, Kiribati, PNG and Solomon Islands, and there are plans to increase production.

Practical training

In order to improve cottonii seaweed production in PICTs, and to discover how to use the new strains developed in Southeast Asia, theoretical and hands-on skills focusing on production, harvesting and processing need to be acquired by extension officers and project staff from producer countries.

Increased production and competitiveness can be achieved through capacity-building in technical skills for:

- site selection to avoid fish-grazing and environmental stresses leading to disease;

- farm layout and construction;
- supply of quality propagules for planting;
- post-harvest techniques to maintain quality; and
- adaptation to the effects of climate change.

Project extension officers and field personnel need a good grounding in these production issues so that they can impart them to seaweed farmers. Our Indonesian hosts demonstrated that floating rope rafts in deeper water are now the preferred system for large-scale seaweed culture, replacing the previous system of rope lines held by wooden stakes on sandy substrate in shallow water. Participants learned how to construct and deploy these rope grids, which give farmers a wider choice of suitable planting sites. They also ride the waves much better, compared with the wooden-stakes method of planting seaweed.

The hands-on training was conducted at the Gerupuk Seaweed Station in Gerupuk village, which is one of the main seaweed production areas in Indonesia. A one-day theoretical session, focused on seaweed cultivation, strain selection for growth enhancement, production of seedlings by using tissue culture techniques, management strategies and seaweed culture methods. This session was followed by a five-day hands-on training, where different improved farming, harvest and processing strategies were presented in a very practical way.

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Building the bamboo frame that will then be used as a floating raft to hang cottonii lines over deep waters (images: Ruth Garcia Gomez).

The latest information on fisheries, aquaculture and climate change in the Pacific

In late 2011, SPC published a comprehensive assessment of the vulnerability of tropical Pacific fisheries and aquaculture to climate change,[1] and a summary of the main findings for each Pacific Island country and territory.[2] These two publications were written to assist countries and territories in understanding why and how climate change is likely to affect the plans they have to maximise sustainable socioeconomic benefits from fisheries and aquaculture. These publications conclude with the implications of climate change for the contributions that fisheries and aquaculture make to economic development, government revenue, food security and livelihoods, and the adaptations and policies needed to minimise the risks of climate change to these contributions, and to maximise the opportunities expected to arise.

To assist national managers, policy-makers and other key stakeholders in fisheries and aquaculture to integrate the recommended adaptations and suggested policies into strategic plans for the sector, SPC and the lead authors of the vulnerability assessment have produced a range of other summary documents.

A series of four-page Policy Briefs[3] are now available, which summarise the main expected impacts and list the key adaptations and suggested supporting policies. There are separate Policy Briefs for oceanic fisheries, coastal fisheries, freshwater fisheries and aquaculture.

The main outcomes of the workshop organised by SPC and the United Nations Food and Agriculture Organization (FAO) in Noumea in 2012 — which were to transfer the results of the vulnerability assessment to the Heads of Fisheries Departments from the region — were published as part of the FAO Fisheries and Aquaculture Proceedings entitled "Priority adaptations to climate change for Pacific fisheries and aquaculture: Reducing risks and capitalising on opportunities".[4] The workshop report contains a summary paper,[5] which organises the information from the vulnerability assessment in a new way to link the projected effects of climate change on fish habitats to the future production of fish and invertebrates.

A short article synthesising the main findings has also been published in the journal *Nature Climate Change*.[6] This article is based on the latest modelling for the projected changes to rainfall and major ocean currents across the region. It also includes the latest modelling of projected changes to the biomass of skipjack tuna under a high CO_2 emissions scenario. The article describes the resources and countries that are likely to be adversely affected by climate change, and those that are expected to be favoured. It also summarises key adaptations and supporting policies, and lists important questions that remain to be answered to reduce any uncertainty about the effects of climate change on fisheries and aquaculture in the region.

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1 Bell J.D., Johnson J.E .and Hobday A.J. (eds). 2011. Vulnerability of tropical Pacific fisheries and aquaculture to climate change. Secretariat of the Pacific Community, Noumea, New Caledonia. 925 p.

2 Bell J.D., Johnson J.E., Ganachaud A.S., Gehrke P.C., Hobday A.J., Hoegh-Guldberg O., Le Borgne R., Lehodey P., Lough J.M., Pickering T.D., Pratchett M.S. and Waycott M. 2011. Vulnerability of tropical Pacific fisheries and aquaculture to climate change: Summary for countries and territories. Secretariat of the Pacific Community, Noumea, New Caledonia. 372 p.

3 Downloadable from: http://www.spc.int/DigitalLibrary/FAME/Collection/Brochures

4 Johnson J., Bell J. and DeYoung C. (eds). 2013. Priority adaptations to climate change for Pacific fisheries and aquaculture: Reducing risks and capitalising on opportunities. FAO Fisheries and Aquaculture Proceedings 28, Food and Agriculture Organization of the United Nations, Rome, Italy. 109 p. [available from: http://www.spc.int/DigitalLibrary/Doc/FAME/Meetings/13_SPC_FAO_climate_workshop_Proceedings.pdf]

5 Bell J., Johnson J., Ganachaud A., Gehrke P., Hobday A., Hoegh-Guldberg O., Le Borgne R., Lehodey P., Lough J., Pickering T., Pratchett M., Sikivou M. and Waycott M. 2013. Vulnerability of fisheries and aquaculture to climate change in Pacific Island countries and territories. p. 25–109. In: Johnson J., Bell J. and DeYoung C. (eds). Priority adaptations to climate change for Pacific fisheries and aquaculture: Reducing risks and capitalising on opportunities. FAO Fisheries and Aquaculture Proceedings 28.

6 Bell J.D., Ganachaud A., Gehrke P.C., Griffiths S.P., Hobday A.J., Hoegh-Guldberg O., Johnson J.E., Le Borgne R., Lehodey P., Lough J.M., Matear R.J., Pickering T., Pratchett M., Sen Gupta A., Senina I. and Waycott M. 2013. Mixed responses of tropical Pacific fisheries and aquaculture to climate change. Nature Climate Change doi: 10.1038/NCLIMATE1838

"Fish and People": An innovative fisheries science learning tool for the Pacific

Simon Foale

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***Most people know that if you leave a fish stock unharvested for a while, it increases, and that after you start fishing it again, it declines. But history has shown repeatedly that people all over the world have been reluctant to believe that fisheries can be overharvested to the point where they do not recover, such that when stock collapses do happen, we are surprised. The Pacific is no exception. While there is an abundance of traditional institutions to regulate harvests (e.g. customary tenure and taboos), the reason for implementing them has usually had more to do with stockpiling resources for social rituals (e.g. funeral feasts) than with a conscious, collective desire to prevent stock collapse and guarantee food security. Consequently, traditional management institutions have mostly not been able to prevent the collapse of vulnerable and/or high-value export commodity species such as sandfish** (Holothuria scabra)**, green snail** (Turbo marmoratus) **and giant clam** (Tridacna gigas).*

In recent decades fisheries research has provided a wealth of detailed knowledge about key aspects of the life cycle of fish and marine invertebrate species, including many that are economically important. This knowledge, if communicated effectively to fishers and community leaders in the Pacific, could potentially help them to see the importance of the connection between overharvesting adults in a fish stock, and the consequent decline in the production of fertilised eggs, and recruitment of juveniles to the fishery. In a region where language remains an important barrier to the effective communication of scientific ideas, a logical strategy is to make as much use of imagery as possible. Video is an accessible and powerful medium, and there is now a video-based fisheries science education tool specifically made for Pacific Island audiences: "Fish and People".

The Fish and People DVD explains, in five 12-minute modules, the basics of fishery biology, with particular emphasis on life cycles and scales of larval dispersal of common and economically important Indo-Pacific species. It also explains other aspects of their biology, such as growth rate and longevity, which, along with larval connectivity, are central to understanding how populations of each species respond to fishing, and protection from fishing, and at what scales in space and time. The video is targeted at high-school students, but has already proved to be popular with a wide range of audiences in many countries.

Opening frame of the Fish and People DVD.

The product articulates around a series of compelling interviews with Solomon Islanders (fishers, scientists, non-governmental organisation workers, government officials and teachers), who each deliver a key part of the message, in language and context that clearly has salience and immediacy.

The rationale for approaching the impending fisheries management crisis in the Pacific with a high-school level learning tool like Fish and People is straightforward. The assumption is that if a critical mass of young adults acquire a detailed understanding of how overfishing destroys fisheries and food security, they will not only innovate their own, "bottom-up" fisheries management strategies as they assume positions of influence within the community, but they will also be more likely to understand the need for, and therefore comply with, "top-down" management approaches such as size limits, gear restrictions, quotas and moratoria. While many Pacific Islanders can readily describe noticeable declines in the size and abundance of fish and marine invertebrates during their own lifetime, the aim of Fish and People is to help people to incorporate their own, often richly detailed empirical observations into a model of fishery dynamics that will engender a stronger sense of agency in managing fisheries for future food security and livelihoods.

The key feature of this particular learning tool is its rich use of imagery to communicate the science. In addition to a series of powerful interviews with Solomon Islanders, Fish and People also features superlative underwater

The DVD includes animations about underwater surveys and other monitoring techniques

cinematography, and many high quality animations, which clearly explain the scientific concepts. The narration is in English, and where interviewees speak Solomon Pijin, an English translation is presented on screen. All key scientific terms, such as *gamete*, *zygote*, *larva*, and *plankton*, are printed in large font on screen as they occur in the narration. The DVD disk also includes a detailed Lesson Plan and Teachers Guide, along with various supporting materials, including still photographs of marine organisms spawning, and microscope photos of larvae, plus animated computer models demonstrating dispersal of larvae in reef and coastal environments. Fish and People was scripted by myself and Russell Kelley, and assembled and edited by multi-award-winning media professionals at Digital Dimensions and Eco Media Production Group (http://www.ecomedia.com.au/). The production was funded by the Australian Research Council, James Cook University and Solomon Telekom Television Ltd.

My collaborators and I plan to redesign and re-edit Fish and People for different audiences, including Solomon Islands villages, along with school and rural village audiences in the Philippines, Indonesia, and other Pacific Island countries. This process will entail keeping most of the animations, shooting new interviews, and creating new, locally voiced, voice-overs. We are also currently testing the impact of the show on the scientific knowledge of Solomon Islands high school students.

The Fish and People DVD modules can be streamed or downloaded from:

http://www.ecomedia.com.au/fishandpeople.html

or here:

https://vimeo.com/channels/fishandpeople

The Lesson Plan and Teacher's Guide can be downloaded here:

https://www.dropbox.com/s/l3p65gre6i4mce0/Lesson-Plan and Teachers Guide small.pdf

We welcome feedback and suggestions.

The DVD also includes compelling interviews with Solomon Islanders who each deliver a key part of the message

Sea cucumber identification cards help sustainable reef management in Fiji

Helen Sykes

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Waitabu Marine Park in the Vanua Bouma of Taveuni Island, is one of the original community-based marine managed areas in Fiji. Started in 1998, Waitabu's no-take, or "tabu vakdua" area, was one of the first of the Fiji Locally Managed Marine Areas (FLMMA) network in 2001. Protected for 15 years, the tabu vakadua area is now rich in fish, coral and invertebrate life, and the community has recently started a new project; a temporary closure known as a tabu tara.

The concept of the tabu tara is to close an area of reef neighbouring the long-term tabu vakadua, allow marine life to increase in the newly closed area, and then to open it for short-term specific harvests. In this way, it is hoped that a form of sustainable "farming" of marine resources, with regular harvesting will occur.

Sea cucumbers have been a trade item in Fiji for 200 years. Unfortunately, in recent times, advancing technology such as scuba and hookah (underwater breathing equipment) has allowed fishers to go deeper and collect for longer periods than in the past, resulting in many reefs being completely stripped of these important reef cleaners. Without sea cucumbers, the seabed may become covered in anoxic sediments and detritus, and corals may eventually become unhealthy and die. When corals are in poor health, all life on the reef suffers.

In Waitabu's tabu tara, the community has begun counting and studying their sea cucumber populations, so that a sustainable harvest can be decided upon, which will eventually allow them to regularly take a certain number of cucumbers, while enough are left to breed and re-stock the reef.

If this is to succeed, it is important for community member to understand sea cucumber biology and lifecycles, so that they can make informed decisions about harvesting frequency and size. During the recent annual tabu area surveys (11–16 February 2013), a training session on sea cucumbers was held.

Sea cucumber identification cards and information sheets in use during training.

Identification cards in use during the survey. Note the rope strap attached to the ID card set to facilitate its underwater use.

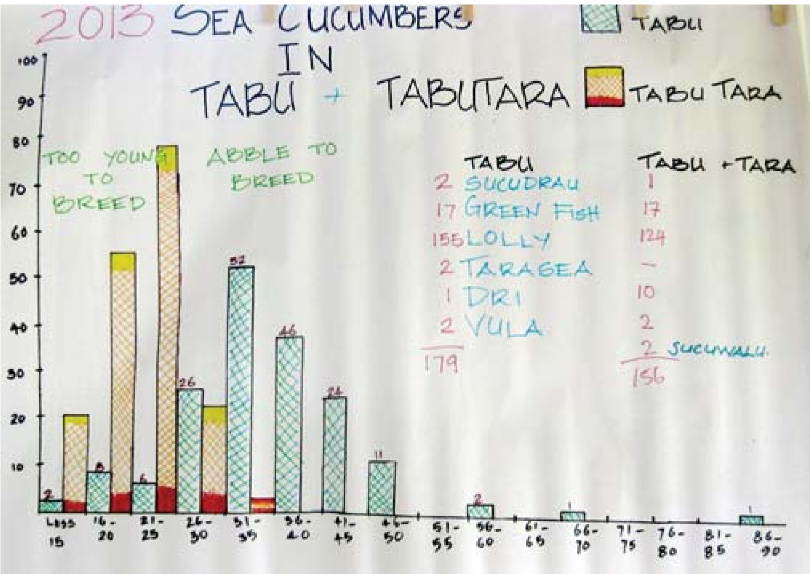
Participants from four of the Vanua Bouma communities — Waitabu, Wai, Korovou and Lavena — learned about the lifecycle of sea cucumbers in general from information sheets compiled by the LMMA network and the Secretariat of the Pacific Community (SPC), and to identify specific species using a set of waterproof cards provided by SPC.

A survey of sea cucumber numbers, species, and sizes was then carried out over both the long-term tabu vakadua and the new temporary tabu tara areas.

While many sea cucumbers were found in both areas, they were noticeably larger in the long-term tavu vakadua than in the tabu tara.

The community was advised that many of the sea cucumbers in the tabu tara were as yet below optimal breeding size, and that surveys should continue until they equalled the size of those found in the Tabu Vakadua, at which time a controlled harvest could be organised as part of the sustainable management of their marine resources.

A set of sea cucumber identification cards was given to each of the four communities involved in order to aid them in future surveys.



A graph of sea cucumber survey results was presented to and discussed with the community.

Community-based resource management pre-awareness training for communities in the Solomon Islands

In November 2012, the Foundation of the Peoples of the South Pacific International (FSPI) under its Communities and Coasts Program launched its "Strengthening Marine and Coastal Community Based Adaptive Resource Management Initiatives in Central Island Province, Solomon Islands" project. The project was designed to integrate existing provincial government activities in the delivery of community-based resource management (CBRM) information to as many communities as possible in the Central Province. The project is funded by the Australian Agency for International Development (AusAID) under the Coral Triangle Initiative, with FSPI as a coordinating body. The Central Province government, through the Division of Fishery, is the key stakeholder in this project.

The project team consisted of one Project Officer (FSPI), two Fishery Officers (Central Province) and one Planning Officer (Central Province), covering twelve communities on small Gela Island over five days. It should be noted that of the twelve communities visited, only three were aware of CBRM.

Before the project was launched, the Central Province Planning Officer had already conducted an assessment of an additional two communities for other types of projects — the Dede community for a clinic and the Toa community for water supply — with funding from the Provincial Capacity Development Fund (PCDF). He had used the opportunity to distribute the documents related to fisheries management.

Local focal points were community chiefs, elders, leaders and teachers. It is anticipated that the information given to chiefs and community leaders will be delivered to community members in their own time. Where possible, the project or joint staff may conduct fuller awareness trainings in these communities if needed, and if resources allow.

The communities visited by the project team have experienced overfishing, dynamite fishing and night diving from nearby villages and islands, but enforcement is a challenge for the legal authorities. However, with the introduction of the Fishery Ordinance for Central Province (currently in draft form) by the Fishery Officer, community chiefs and leaders are keen to work together in managing their marine resources with provincial and national authorities, supported by the legal document that is awaiting national endorsement.

Chief Cecil Maneou of Belaga village reported: "Our communities have rich marine resources, and for the past decade our communities have been involved in fishery

According to Hugh Govan, Project Adviser, the major innovations of this approach include the:

- move away from investing all resources in facilitating CBRM in one or a few sites towards attempting to provide all 200+ communities of the Central Province with key fisheries information;
- leadership provided by the provincial fisheries and planning officer in making maximum use of scarce logistical resources to increase service delivery to communities;
- formation of cross-sectoral or integrated teams that allow for joint implementation;
- inventory by the project team of all available information resources to narrow down the essential information to be carried to communities; and
- provision of SPC Information Sheets, produced in collaboration with the Locally Managed Marine Area Network, which were the core materials used with communities as the essential topics were covered. These Information Sheets are a good guide to discussions and constitute rich reference materials when left with the community.

development; for instance, with the Fishery Center at Salisapa (ice machine). However, we have noted that there has been a decline in marine resources in the past year, hence it is time for us to consider managing our marine resource for the benefit of future generations".

According to the project team, the trip was a success because local communities perceived the benefits of this initial activity and had limited knowledge of fisheries management or the scientific aspect of it. However, it was found that a few local communities already practice forms of marine resource management. For instance, the community of Toa has been imposing a ban (tabu) on their coral reefs for more than a year.

The Central Province government is fully supportive of this project and the approach it is taking, and will continue to share its resources to help mobilise the project team so that they can achieve the project's objectives over the remaining year.

The SPC/LMMA Information Sheets for Fishing Communities were used as a guide to discussions.

A member of the Limanak community holding hatchery-raised juvenile sandfish (image: Cathy Hair)

The Nago Island Marine Research Facility in Papua New Guinea is up and running!

The Nago Island Mariculture Research Facility (NIMRF) began operating as a fully functioning marine hatchery and research facility several months ago. NIMRF is located on Nago Island, just off of Kavieng, the capital of New Ireland Province. The facility is being managed by Papua New Guinea's National Fisheries Authority.

Thanks to the outstanding effort and time spent by the manager, technicians and employees of the facility, and through technical and financial support provided by James Cook University (Townsville, Australia) through a project funded by the Australian Centre for International Agricultural Research (ACIAR) (project: FIS/2010/054), the NIMRF is fully operational. SPC has been part of the technical committee, providing technical and financial support for certain activities.

The ACIAR project's main objective is to promote the production of marine species that are technically feasible and socially acceptable to local communities within the region. The species that the project will focus on include sea cucumbers (sandfish), edible oysters and marine ornamentals, including hard and soft corals.

There have been substantial improvements to the facility, including a microalgae laboratory, wet laboratory, and increased optimisation of water distribution and filtration systems. Also, tanks and raceways have been distributed inside the facility in separate sections, in order to make NIMRF more efficient and easily manageable.

As initial activities, a number of sandfish spawning trials have been carried out with encouraging results: more than 500 juveniles have been produced and are currently being reared in sea pens. Some local communities in the vicinity of the facility have been involved in the project from the beginning. For example, the community at Limanak has provided the sandfish broodstock for the initial spawning trials. This same community has been selected to carry out initial grow-out trials by using different farming strategies, such as floating *hapas*[1], submerged cages and sea pens.

The fact that the moratorium on sandfish harvesting will remain in effect, most likely, for another three years, makes the development and optimisation of sandfish production techniques extremely relevant for the future of many local communities within the area.

Sea pen for sandfish grow-out, Limanak village (image: Cathy Hair).

To conclude, the facility will continue improving its operating systems over 2013, with a view to initiating certain activities on a larger scale in 2014.

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[1] The *hapa* is made by placing two open cloth sacks, one inside the other. The dimensions are usually 2 × 1 × 1 m and the interior sack is half that size. The outside *hapa* is of smaller mesh. As the eggs hatch, the larvae swim through the mesh in the first sack, but are retained in the second. [source: http://www.fao.org/docrep/field/003/ac182e/AC182E01.htm]

New policy brief on mangroves

Image: Mark Spalding

An unprecedented partnership of organisations — from forestry and conservation sectors and across the United Nations — has released a policy brief to provide managers with lessons learned in past mangrove conservation and management efforts, and with policy recommendations.

Found mostly in the tropics straddling the land and sea, mangroves make up less than 0.4% of forests of all kinds worldwide. Taken together, some 70 species of mangroves are found in 123 tropical and subtropical nations and territories but occupy just 152,000 km^2 in total — an area slightly larger than Nepal.

Yet these tidal forests harbour rich biodiversity and are highly effective carbon stores and sinks; alongside to the living biomass of the trees, mangrove soils are carbon-rich and sequester carbon over millennial timescales. In addition, they provide enormous benefits including:

- important habitat and nursery areas for many exploited coastal fish and crustacean species;
- breeding grounds for some offshore species, such as the shrimp species that are the target of many large-scale fisheries;
- sources of rot-resistant, high-value timber and excellent fuelwood that has been harvested in sustainable silviculture programmes in some countries for over 120 years; and
- natural coastal defence systems, reducing erosion, attenuating waves and even reducing the height of storm surges.

Since 1980, the world has lost about one-fifth of its mangrove forests and many of those that remain are degraded, states the new policy brief, entitled "Securing the Future of Mangroves".

According to the policy brief, the conversion of mangroves for coastal aquaculture is the foremost driver of mangrove loss. An estimated 38% of global mangrove loss can be attributed to the clearing of mangroves for shrimp culture, while another 14% can be blamed on other forms of aquaculture.

"Such large-scale conversion has had major negative environmental impacts, including collapses in wild fisheries, reports Ms Van Lavieren, Coastal Zones Programme Officer at the United Nations University's Canadian-based Institute for Water, Environment and Health (UNU-INWEH).

"There is now a growing awareness of the importance of mangroves, and government and community-led efforts are underway to restore or replant mangroves, and to improve legal systems to regulate future use."

Losses are being driven by other human threats as well, including overharvesting and deforestation; agricultural, urban and industrial runoff; oil spills; and poorly managed dredging and coastal development.

"Despite declining rates of loss, rare and critically important mangrove forests continue to be lost at a rate three to five times higher than that for global forests. Set against this is a growing realisation of the social and economic value of mangroves and a remarkable array of restoration efforts in many countries around the world," says Dr Mark Spalding, Senior Marine Scientist at The Nature Conservancy, and co-author of the policy brief.

The most pronounced losses (over 20%) have occurred in the Asia-Pacific region, followed by Central America. Limited losses have occurred in East Africa, with only an 8% decline between 1980 and 2005.

Economic valuations of mangrove ecosystem goods and services provide some of the most powerful arguments for effective mangrove management. "When the full suite of ecosystem services from mangroves can be assessed, the arguments for maintaining healthy mangrove forests are usually compelling," says Ms Van Lavieren.

Specific examples of the economic value of healthy mangroves include prawns harvested in Australia across the wide, shallow coastal shelf areas off both the Northern Territory and Queensland. Prawns are one of the Australia's most valuable export fisheries, earning more than USD 70 million annually.

One study cited in the policy brief shows that planting and protecting nearly 12,000 hectares of mangroves in Vietnam cost just over USD 1 million but saved annual expenditures on dyke maintenance of more than USD 7 million.

The Matang Mangrove Forest Reserve in Malaysia is arguably the world's best example of a sustainably managed mangrove ecosystem. Established in 1902, the reserve covers an area of about 500 km^2, approximately 73% of which is considered productive forest. Harvesting mangrove timber for poles, firewood, and charcoal production occurs on a 30-year rotation cycle. The annual value of the forest products between 2000 and 2009 was estimated to be USD 12.3 million, with cockle aquaculture adding an estimated annual value USD 10.7 million.

The policy brief describes instruments and measures readily available to help conserve and manage mangrove ecosystems, and highlights lessons from around the world on successful measures for protecting mangroves. It also makes recommendations to improve legal and policy frameworks, mangrove management tools, data and information collection, economic incentives to promote more environmentally-responsible behaviour and local livelihoods, recognition of the full value of mangrove ecosystem goods and services, and coordinated global action under agreements related to biodiversity, wetlands and sustainable development.

Among the recommendations are several relating to climate change, including the need to:

- integrate the role of mangroves in climate change adaptation and disaster risk reduction into local and national adaptation plans;
- recognise the role that mangroves play as carbon stores and sinks, and to include these functions in national and international strategies that address climate change; and
- increase protection and restoration of mangrove ecosystems to enhance existing carbon stocks and help mitigate CO_2 emissions, and build mangroves into emissions trading and climate change mitigation planning.

The policy brief concludes that there is now a clear understanding of the management interventions required to secure the future of mangroves; interventions that are underpinned by many successful examples of mangrove management from around the world and by solid and convincing economic arguments. It also concludes that reversing the trends of mangrove loss and of the growing vulnerability of coastal peoples will require a real commitment by governments to develop and implement robust high-level policies for mangrove ecosystems.

The policy brief was based on the World Atlas of Mangroves (2010), published by Earthscan as an output of a joint project primarily funded by the International Tropical Timber Organization through the Japanese government, and implemented by the International Society for Mangrove Ecosystems in collaboration with the Food and Agriculture Organization of the United Nations, United Nations Environment Programme–World Conservation Monitoring Centre, United Nations Environmental, Scientific and Cultural Organization–Man and Biosphere Programme (UNESCO-MAB), UNU-INWEH, and The Nature Conservancy.

The policy brief was written by Hanneke Van Lavieren, Mark Spalding, Dan Alongi, Mami Kainuma, Miguel Clüsener-Godt, and Zafar Adeel, and funded by UNU-INWEH, UNESCO-MAB and the Spanish Government.[1]

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[1] The full policy brief is available from: http://inweh.unu.edu/wp-content/uploads/2013/05/Securing-the-future-of-mangroves-high-res.pdf

Effective management of sea cucumber fisheries and the beche-de-mer trade in Melanesia

Crick Carleton,[1] John Hambrey,[2] Hugh Govan,[3] Paul Medley[4] and Jeff Kinch[5]

Introduction

Sea cucumber fisheries are the second-most valuable capture-based, export fishery in the South Pacific, but sustainably managing these fisheries has proven to be very difficult over the years. In years of peak exploitation, production has been valued at over USD 50 million, but in poor years the value has been only a fraction of this. Better management, combined with (current) higher prices could increase the value of the fishery, but potential income is being lost as a result of persistent overfishing and wild swings in productivity resulting from overexploitation.

Market demand currently exceeds global supply, and prices are rising, particularly for more sought-after species of sea cucumber. Rather than strengthening the position of sea cucumber fishers, however, the lure of easy money and market forces are encouraging poor practices and mis-management. Overexploitation often results in fisheries being closed (for periods of up to 10 years or more) to allow stocks to recover.

It could be argued that this is simply "business as usual" — a valuable renewable resource is rising in value, and a range of people are seeking to profit from this unfolding opportunity — but five aspects of the current circumstances surrounding this fishery and trade are particularly disturbing.

1. The stocks are so depleted that each boom-and-bust cycle yields less than half the volume of product as it did formerly.
2. Sea cucumbers play an important role in maintaining the health of many marine habitats; where they are absent or present in low numbers, ecosystem structure and function are altered.
3. The high value of prime sea cucumber product is encouraging households to focus on sea cucumber fishing and processing at the expense of subsistence and other revenue-generating activities, and encouraging greater dependence on imported products, requiring that households earn more from sea cucumbers.
4. Market makers are struggling to find new sources of supply, and the market is entering a period with a declining rate of increase in the volume of global supplies.
5. Those involved in sea cucumber trading can make substantial short-term profit in return for limited investment and at low risk. This, in combination with lax or non-existent control on exploitation and trade, and the absence of transparency, supports corrupt and illegal activity.

Bringing the sea cucumber industry under responsible and sustainable management is of utmost importance. The key elements of management are well known, but the practicalities of putting these in place are problematic. A key priority is to break or moderate the boom-and-bust cycle typical of this industry. A more considered, strategic and coordinated approach to managing supplies could greatly strengthen the position of the industry, to the distinct benefit of national economies and rural coastal and island communities. These issues form the focus of this study.

The study

A recent study by Nautilus Consultants[6] focused on the sea cucumber fishery and its associated trade in five countries: Papua New Guinea (PNG), Solomon Islands, Vanuatu, Fiji and Tonga. The study formed part of an initiative by the Australian Centre for International Agricultural Research (ACIAR) that was implemented by SPC, and responds to concerns raised by Melanesian country leaders and more broadly by the Heads of Fisheries of Pacific Island countries and territories (PICTs).

The intention of the study was to raise the profile of sea cucumber fisheries by highlighting the potential economic returns from a sustainable fishery, and the wealth lost through inadequate management, and identify effective approaches to the management of sea cucumber fisheries in the Pacific, with an initial focus on Melanesia.

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[6] Full report available at: http://www.spc.int/DigitalLibrary/Doc/FAME/Reports/Carleton_13_BDM_Management.pdf

The scoping study sought to:

- profile the current and historic structure, operation and scale of sea cucumber harvesting and export in the five countries;
- estimate the scale of revenues being foregone as a result of persistent overexploitation and the boom-and-bust nature of the fisheries;
- identify fiscal and trade tools that could be used to better control production and trade;
- identify how management regimes could be strengthened to encourage sustainable exploitation and to boost income to peripheral coastal and island communities; and
- identify potential for regional cooperation — with a particular focus on member countries of the Melanesian Spearhead Group — in strengthening management and increasing trade revenue.

This article presents the results of the study in two parts:

Part A.
Provides a general introduction to sea cucumber fisheries and the beche-de-mer trade in the study countries; presents production estimates for each of the five countries; and presents estimates of the economic loss resulting from mis-management, which ultimately results in fishery closure.

Part B.
Discusses potential solutions to better manage these fisheries, with an emphasis on economic and trade management tools.

The commentary and data presented in this article are summaries of the report by Nautilus Consultants titled: "Effective management of sea cucumber fisheries and the beche-de-mer trade in Melanesia: Bringing the industry under rational control".

Part A: The sea cucumber industry and the beche-de-mer trade in Melanesia, and economic loss from overexploitation

An introduction to the sea cucumber industry

Beche-de-mer is the trade name for dried sea cucumber, which generally refers to the cooked and dried form of some 60 commercially traded species. The product is considered a food delicacy, especially in Asian markets, and is also used in powdered form in Chinese medicines.

Sea cucumbers inhabit a wide range of habitats across coastal shallows and reef ecosystems and play an important ecological role.

While 35 sea cucumber species are traded across Melanesia, examination of production and export records suggests that 21 species make up more than 90% of production volume, and just 8 species make up over three-quarters of production value.

Some of the most valuable sea cucumber species can be found (in healthy populations) at densities of 10–30 per hectare, whereas lower-value species can be found at densities of several hundred or several thousand per hectare. The higher-value species are typically harvested by free divers, whereas the lower-value species are more commonly harvested with less discrimination through shallow water gleaning. Specimens found in deeper water are sometimes harvested using a weighted impaling device, and some fishers use an underwater breathing apparatus (UBA), which is discouraged and illegal in Melanesian countries.[7] Not only is the use of UBA dangerous, but it results in the harvesting of larger numbers of mature adults, which adversely impacts spawning and stock recovery.

Sea cucumber harvesting most typically follows a boom-and-bust pattern of exploitation. More heavily fished stocks take longer to recover; recovery can take several decades, and some stocks may never recover. If a stock is fished before it has fully recovered, both harvest volume and average individual size will decrease. Underpinning this relationship is the fact that most sea cucumbers are broadcast spawners with a pelagic larval stage, during which larvae are carried by sea currents for up to 20 days. Therefore, stock recovery depends on having a sufficient concentration of spawning adults, the larvae finding suitable substrate on which to settle, and a sufficient proportion of young surviving long enough to recruit to the commercially exploitable population. Populations are particularly susceptible to local extinction as a result of overfishing because recruitment across large stretches of ocean is problematic.

The range of species that make up the beche-de-mer trade from the countries under study is shown in Table 1 and listed according to the estimated 2012 in-country purchase value (producer and/or processor selling to buyer and/or exporter) for A-grade dried beche-de-mer.

[7] In recent years, however, Fiji has issued a limited number of licenses for harvesting sea cucumbers using UBA gear.

Table 1. The main sea cucumber species traded in the western and central Pacific.

Code	Common name	Scientific name	Purchase price USD kg^{-1} (dried)[a]	Value group[b]	Av. weight t yr^{-1} (beche-de-mer)[c]
SF	sandfish	*Holothuria scabra*	90	H	70
WTF	white teatfish	*Holothuria fuscogilva*	84	H	159
GSF	golden sandfish	*Holothuria lessoni* [+]	60	M	-
BTF	black teatfish	*Holothuria whitmaei*	53	M	29
GF	greenfish	*Stichopus chloronotus*	50	M	19
PRF	prickly redfish / pineapple fish	*Thelenota ananas*	45	M	30
BF	deepwater blackfish / Panning's blackfish	*Actinopyga palauensis*	45	M	1
DRF	deep water redfish	*Actinopyga echinites*	45	M	8
SRF	surf redfish	*Actinopyga mauritiana*	39	M	45
BF	blackfish / hairy blackfish	*Actinopyga miliaris*	20	L	26
CF	curryfish	*Stichopus herrmanni*	20	L	53
STF	stonefish	*Actinopyga lecanora*	20	L	18
TF	tigerfish / leopardfish	*Bohadschia argus*	20	L	74
SNF	snakefish	*Holothuria coluber*	16	L	86
PNF	peanutfish / dragonfish / warty	*Stichopus horrens*	14	L	7
CHF	chalkfish / brownspotted sandfish	*Bohadschia similis* [*]	14	L	48
BSF	brown sandfish	*Bohadschia vitiensis* [*]	14	L	3
FF	flowerfish / orangefish / ripple fish	*Pearsonothuria graeffei*	14	L	97
AMF	amberfish	*Thelenota anax*	14	L	48
LF	lollyfish / reef lollyfish	*Holothuria atra*	11	VL	182
ETF	elephant trunkfish	*Holothuria fuscopunctata*	11	VL	42
PKF	pinkfish	*Holothuria edulis*	6	VL	18

Notes
[a] The estimated price at which A-grade dried product was bought from producers.
[b] Product grouped by price bracket: H = high; M = medium; L = low; VL = very low.
[c] The average amount of dried product of each species exported each year from the countries under study, based on production over 15 years (incorporating periods when fisheries closed), 1996–2012.
[+] Golden sandfish has previously been classified as *H. scabra* var. *versicolor* but has recently been re-classified as *H. lessoni*, a separate species (Kinch et al. 2008).
[*] Species with taxonomy due to be reviewed (Kinch et al 2008) – *B. similis* now renamed *B. marmorata* (Uthicke et al. 2010).

Productivity is commonly shown in terms of peak exports; however, data indicate that heavy harvesting in one year impairs productivity in future years. In four of the five countries under study, sustained high fishing pressure on stocks has resulted in fisheries closures to allow stocks to recover. To better reflect potential productivity, the average production over a period that includes at least two boom-and-bust cycles is presented. Accordingly, average exports over 15 years, including low or zero harvests when fisheries have been closed, are shown in the final column of Table 1.

At current purchase prices, 15-year average production for the 5 countries under study is valued at some USD 20 million per year, rather than upwards of USD 50 million, which has been ascribed to one-off peak production from all PICTs.

The broad scale of harvests and exports is shown in Figure 1, where the 15-year average annual value of exports of beche-de-mer by species is shown, together with the equivalent volume of sea cucumbers harvested (live weight estimates). Interestingly, the largest biomass harvested is of the low value lollyfish sea cucumber and the second-largest is of the very high-value white teatfish.

Regional beche-de-mer production

The beche-de-mer industry is a complex multi-species, multi-layered industry that requires analysis at multiple levels (from global to local). Good datasets on the total volume of exports by each country under study are available (early figures for Tonga are absent) and the species composition of exports is available, but inconsistent

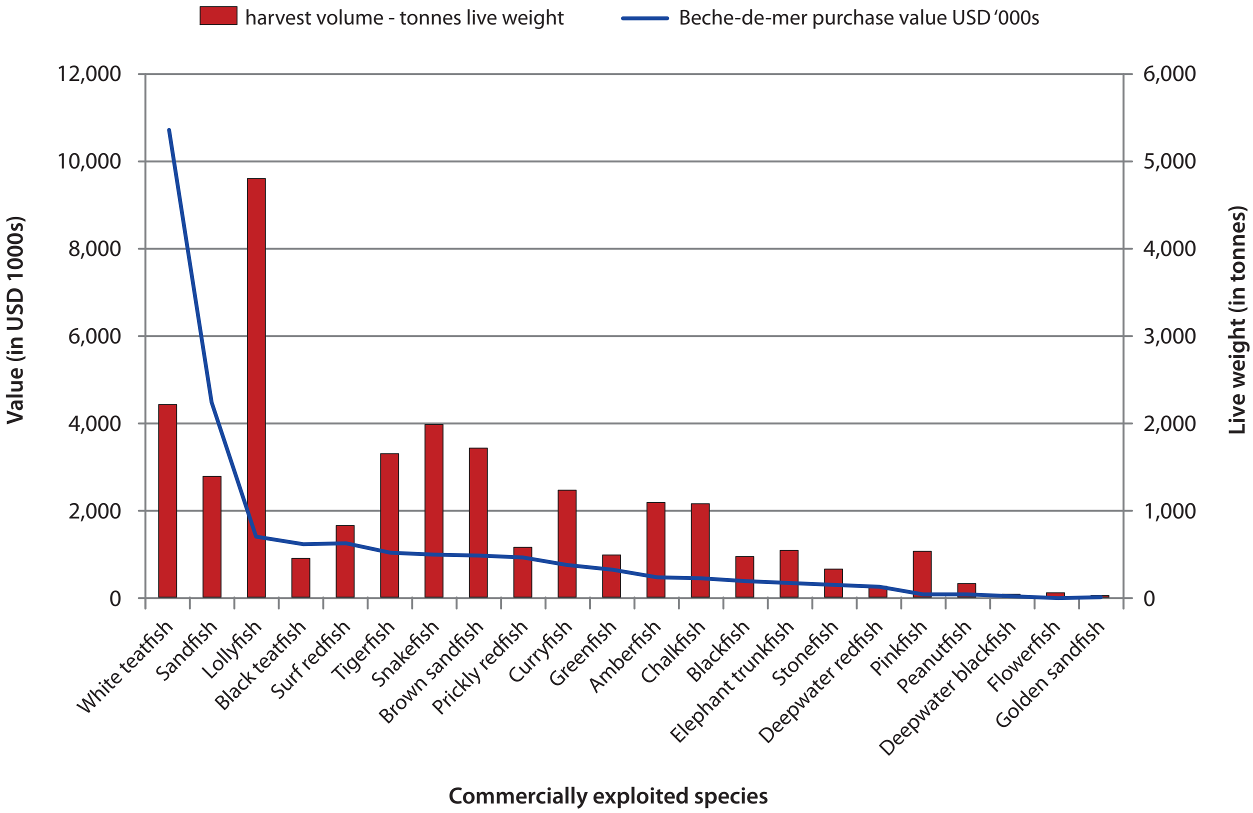


Figure 1. Sea cucumber species ordered by value of average harvests, also showing the equivalent harvest volume (tonnes live weight for five countries under study). Notes: Not all beche-de-mer purchased by traders is A-grade; purchases comprise a range of sizes of animals and are processed to different standards. Accordingly, the prices used in calculating value have been discounted from those shown in Table 1, discounted by 20% for white and black teatfish, and 30% for all other species.

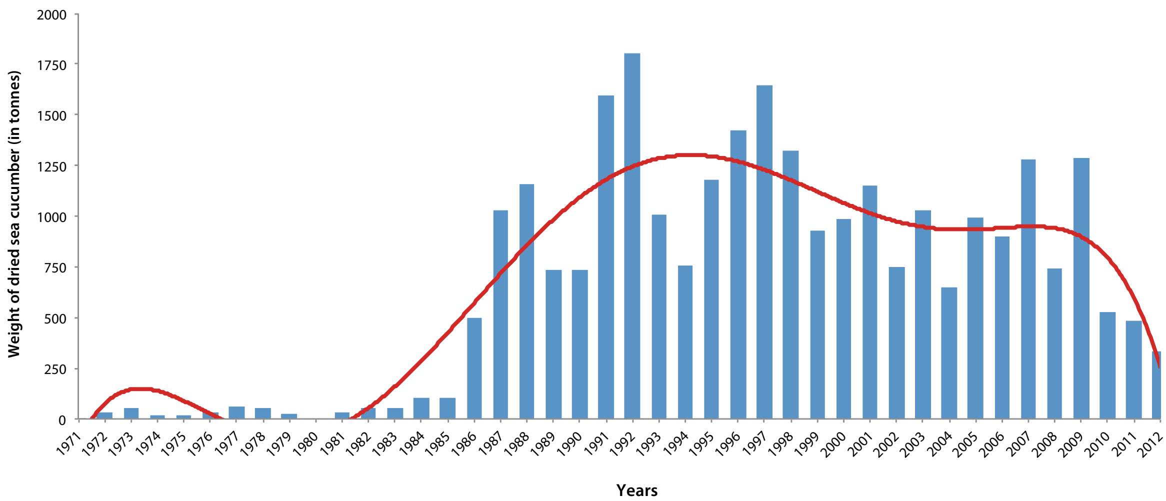


Figure 2. Exports of beche-de-mer from the five countries under study, 1986–2012, tonnes of product (dried weight). Source: Fisheries Department statistics from Fiji, Papua New Guinea, Solomon Islands, Tonga and Vanuatu.

across the data series (species-discriminated data for Vanuatu are poor).

When looking at the management of sea cucumber fisheries, national-level statistics are too general and greater disaggregation is required. To better inform such analysis, the study consolidated production and harvest statistics, by species, at the provincial level (see Fig. 5).

Figure 2 shows the combined exports of beche-de-mer for the five countries over the period 1971–2012. The graphic has been overlain with a polynomial trendline, reflecting the broad changes in export across this time series. In broad terms, the evolution of the fisheries has been low-level exploitation through the 1970s, with steady growth of exploitation in the 1980s that reached a peak in the early 1990s. Harvests dropped off after this but a secondary, lower-level peak was reached in the late 1990s. Concerns about widespread overfishing of stocks resulted in the closure of fisheries in the Solomon Islands (2006), Vanuatu (2008) and PNG (2009); the Tongan fishery was closed from 1997 for 10 years. In the late 2000s, with most fisheries subject to a moratorium, regional production was being provided by Fiji and Tonga only[8] stocks in both of these countries are now thought to be overexploited, and fishing pressure will have to be reduced to allow for stock recovery.[9]

The increasing demand for beche-de-mer can be largely ascribed to the increased demand from China, resulting from economic growth and rising incomes. As beche-de-mer supplies from traditional sources are reduced, the trade has sought new sources, but these in turn have also been overexploited (Purcell et al. 2012; To and Shea 2012). The result has been substantial upward pressure on market prices: pries for lower-value species have typically increased by two to three-fold over the last seven years, while higher-value species have increased four or five-fold. Given this, buyers and exporters encourage fishers to focus on exploiting high-value species — attractive because these are low-volume, high-mark-up products — although high-volume, low-markup species, such as lollyfish, have particular merit from a socioeconomic perspective.

Over the period illustrated in Figure 2, prices have strengthened, so while volume has declined, in dollar terms the overall value of production has generally increased, which creates a false sense of security around the status of stocks. Furthermore, the species mix has shifted to lower-value species and the overall volume has decreased substantially (for many species the average size of individuals harvested has declined as well). Recent harvests have declined in scale and quality, and even with "rest" periods, stocks are not returning to the levels found in the 1980s.

Figure 3 shows the same dataset disaggregated by country, noting that four of the five fisheries were subject to a moratorium late in the data series.

Given its geographic size, PNG is consistently the highest sea cucumber producer among the five countries, with significant but lesser volumes produced by Fiji and the Solomon Islands. Production from Tonga in 2008 and 2009 exceeded that of Fiji, but it is clear that despite the ten-year moratorium and the setting of provincial fishing quotas (which were considered conservative at the time), the fishery has been all but fished-out over the course of two seasons.

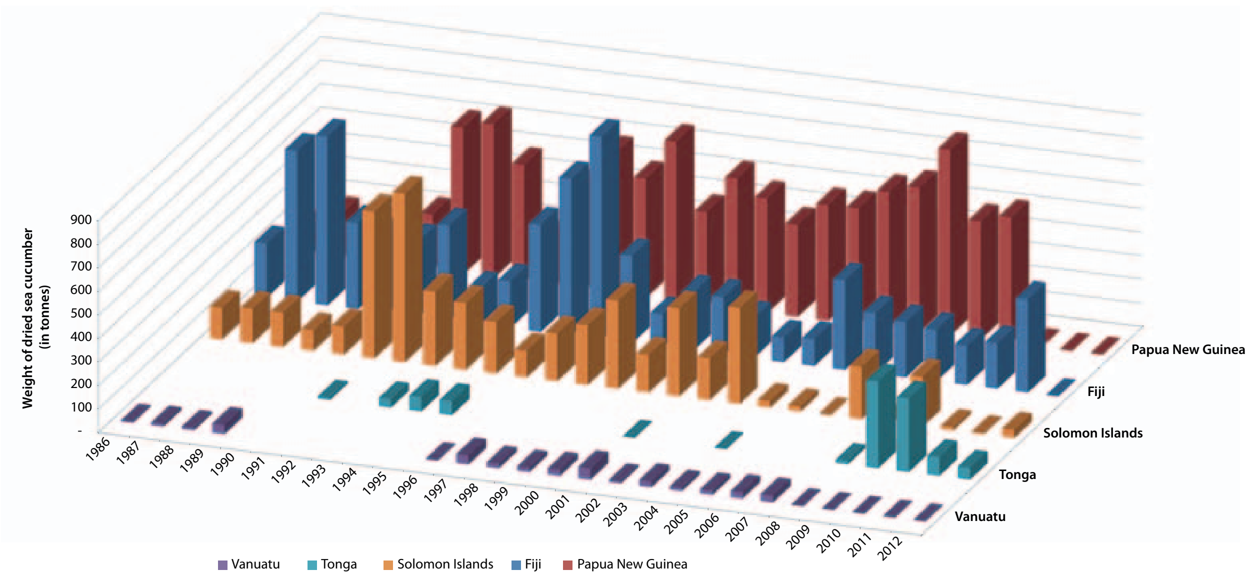


Figure 3. Export volume of beche-de-mer, 1986–2012, tonnes of product (dried weight).

[8] Note that New Caledonia, not included in this study, is a significant regional beche-de-mer producer and exporter.

[9] The Tonga fishery has been closed again as from the beginning of 2013.

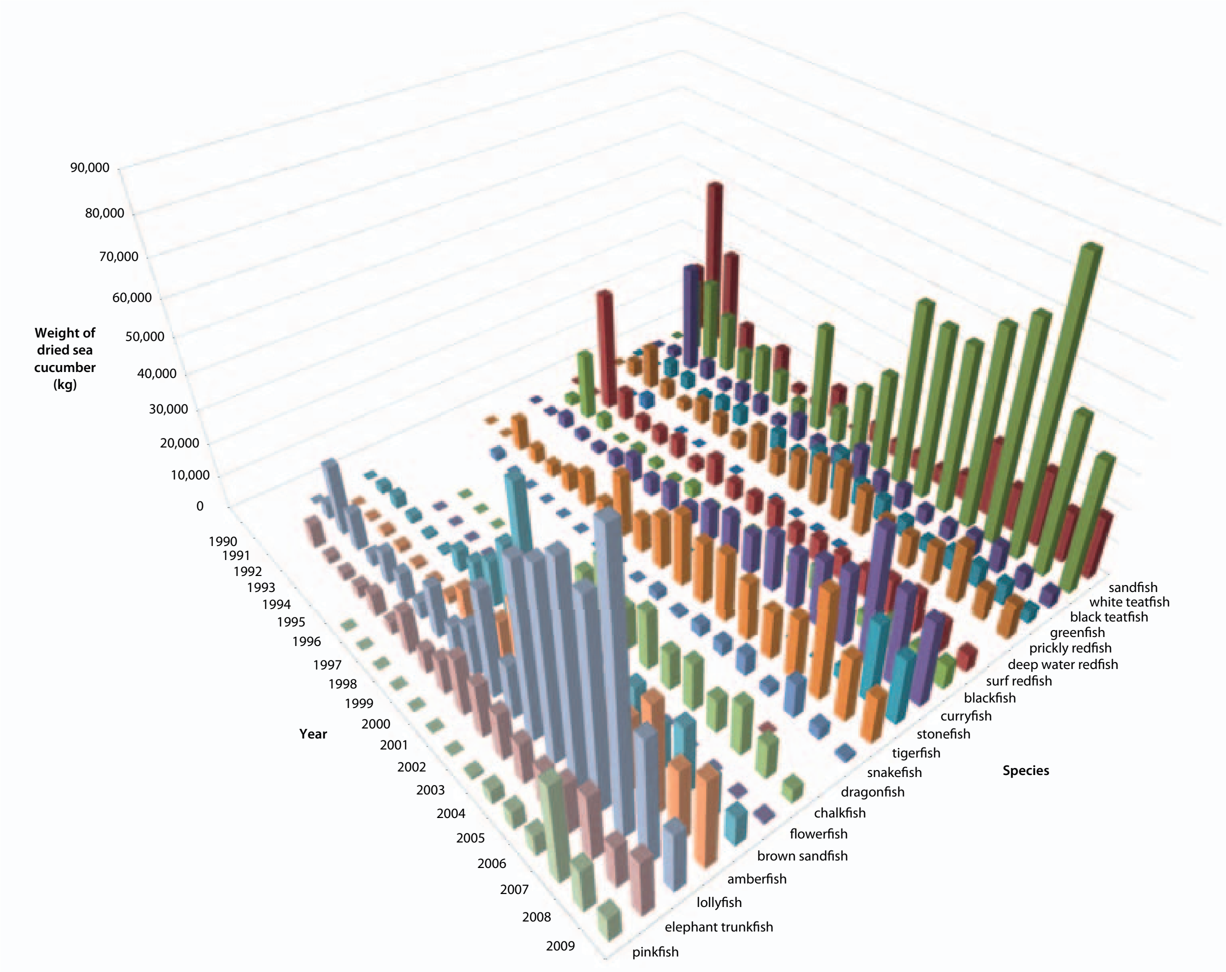


Figure 4. Estimated volume of dried beche-de-mer exports originating from Milne Bay Province, Papua New Guinea, by species. Source: Papua New Guinea's National Fisheries Authority trade database.

Figure 4 gives an example of production data at the provincial level (Milne Bay Province, PNG), where it is evident that much effort was put into harvesting sandfish in the early period of this time series, with harvests quickly dropping off and not building up again until about 10 years later. By the late 1990s, white teatfish and lollyfish had clearly become the main targets of fishing effort, which were accompanied by high harvests of black teatfish, greenfish, prickly redfish, tigerfish and brown sandfish, but these harvests quickly decreased as the resources became depleted.

Analysis of the boom-and-bust cycles typical of sea cucumber fisheries shows that, in general, the heights of earlier cycles are rarely repeated; by all indications, stocks do not fully recover. Analysis of the changing harvests of the different species over time also confirms this pattern. Anecdotal evidence suggests that the larger specimens available at the outset of a boom are soon exhausted and that the average size of each species harvested decreases over time. Accompanying the decline in average sea cucumber size is a shift to exploit lower-value species.

Overall, the indications are that historic levels of exploitation are not sustainable, and that different harvesting strategies could sustain both higher biomass extraction, and higher average value of sea cucumbers extracted.

The study compiled data at the provincial level for each country, and Figure 5 shows provincial and district boundaries. Production by province is shown in Figure 6, where the reported volume of beche-de-mer exports over the 15-year period 1997–2011 has been averaged, and then valued, based on a representative species mix for that province. The value of production is shown on the basis of the following categories: high-value, medium-value and low-value species (see Table 1).

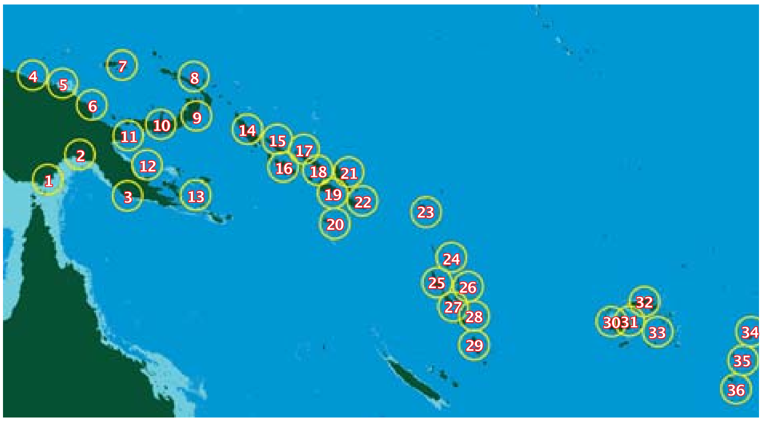


Figure 5. Division of area according to existing administrative boundaries.

1 Western (Fly)	10 New Ireland	19 Guadalcanal	28 Shefa
2 Gulf	11 Morobe	20 Rennel & Belona	29 Tafea
3 Central	12 Oro (Northern)	21 Malaita	30 Western
4 Sandaun (West Sepik)	13 Milne Bay	22 Makira-Ulawa	31 Northern
5 East Sepik	14 AR Bougainville	23 Temotu	32 Central
6 Madang	15 Choiseul	24 Torba	33 Eastern
7 Manus	16 Western	25 Sanma	34 Vava'u
8 West New Britain	17 Isabel	26 Penama	35 Haapai
9 East New Britain	18 Central	27 Malampa	36 Tongatapu

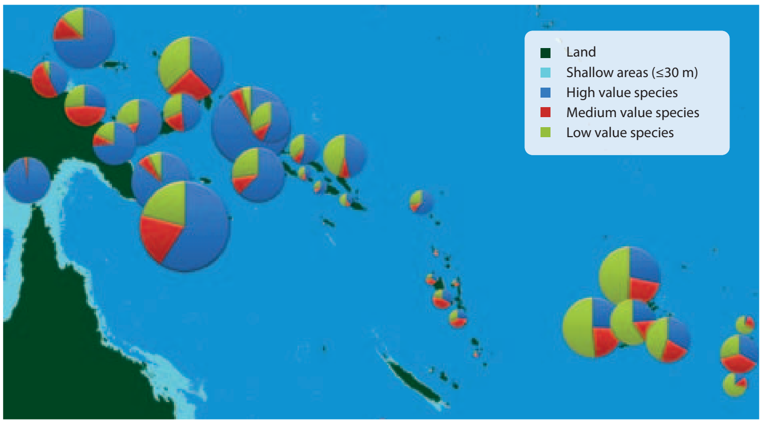


Figure 6. Fifteen-year average value of sea cucumber production by administrative area. Note: Milne Bay Province (the largest roundel) represents a value of USD 2.9 million.

Figure 7. Relative area of shallow water surrounding each administrative area. Note: Data extracted from NASA seaWIFS bathymetry graphics. Shallow water areas selected using colour coding; areas calculated from pixel estimates.

As a cross-check, shallow water area (<20 m) was estimated for each province. These data are illustrated graphically in Figure 7 and show good general correlation with the data in Figure 6.

Examination of potential production

Coastal communities rely heavily on sea cucumber harvesting, because it is one of their few sources of cash income. This encourages exploitation of the resources at unsustainable levels, resulting in significant reductions in the total biomass of each species that can be harvested in subsequent boom-and-bust cycles; it significantly slows stock recovery, makes it necessary to impose long moratoria on fishing and trade.

The relative impact of the different types of exploitation patterns is illustrated in Figure 8 (using notional values only). Stable exploitation — either retaining the same level each year or retaining a low–level, boom-and-bust form — gives the highest overall yield, and ensures a steady and predictable income to fishing communities year after year. Putting resources under very heavy fishing pressure results in slower stock recovery, and leads to lower harvest levels, which yields less and less product, and increasingly longer recovery periods. Taken to its extreme, this results in an exhausted fishery yielding very low returns with long periods of low or no production.

For illustrative purposes a tonnage figure has been added for each exploitation pattern, representing the summation of all harvests under each system over a 30-year period. In this fictitious example, an exhausted fishery yields less than one-third of the biomass of a well-managed fishery. Added to this, sustainable exploitation yields a steady income each year, whereas even with a regularly managed boom-and-bust cycle, communities would have little to no income for 6 of the 30 years. With a declining boom-and-bust fishing cycle,

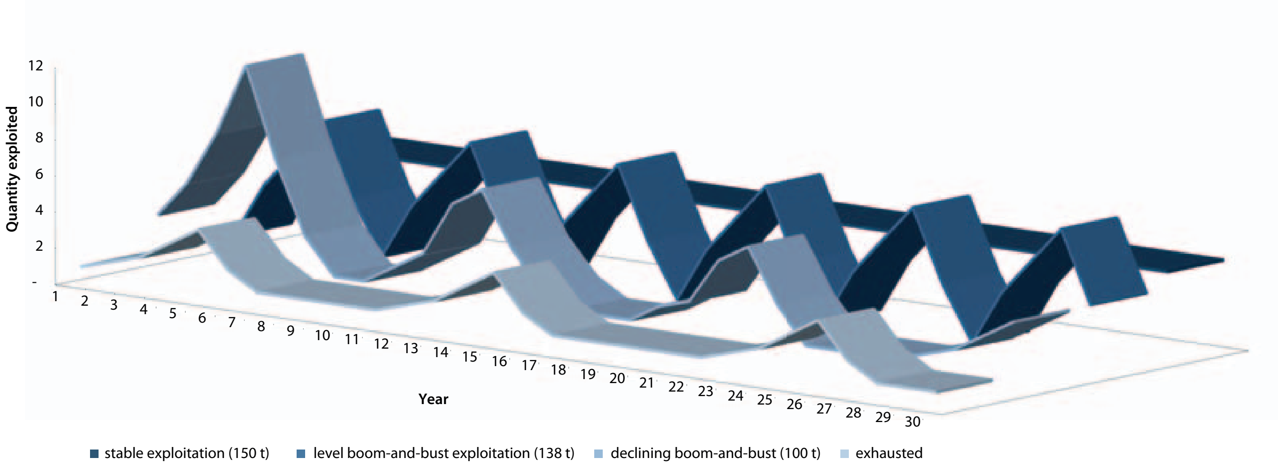


Figure 8 . Example of the resource yield from different exploitation patterns.

there would be 9 years of little to no income, and the exhausted fishery would produce 15 years of little to no income. In addition, the unit value of catches achieved each year is likely to decline across each boom-and-bust cycle as larger specimens are removed from the fishery and the focus shifts to smaller and lower-value species.

In practice, in the countries under study, the evolution of sea cucumber fisheries — as supported by the statistical record, anecdotal evidence from interviews, and illustrated in Figures 2 and 4 — is as follows:

- Fishing effort steadily increased in the early years, going beyond levels that could be readily replaced and building to levels of extraction beyond the replacement capacity of the resource.
- In subsequent years, harvests of the primary target species were much reduced (both in volume and in size) and effort shifted to other species; the latter target species were subsequently fished down.
- Exploitation of lower-value species proceeded throughout the cycle, but increased once higher-value species became difficult to find; over time, these resources were also depleted, and effort shifted to species that were not previously exploited.
- As high-value stocks recovered, this attracted more fishing effort; following a long period of relatively flat prices, from the mid-2000s prices for most high-value species steadily increased, which encouraged fishers to dedicate more effort to harvesting high-value species, with extraction again far beyond sustainable levels.
- At this point in the exploitation cycle, most countries found it necessary to close exhausted fisheries in order to allow them to recover; in Fiji, where no closures have implemented, the statistical record indicates that the underlying scale of harvests is declining steadily, and has been buoyed up, to an extent, by the official licensing of UBA fishing.

Clearly, the potential economic impact on coastal and island communities can be highly significant because unsustainable practices lead to the stock being systematically depleted through fishing. To put this into perspective, the example of Tonga is a salutary lesson (see Fig. 9). Long-term overexploitation of the sea cucumber fishery forced the government to call for a 10-year moratorium in 1997. The fishery was re-opened for a month in 2008, seven months in 2009, three months in 2010 and four months in 2011. From harvest and trade statistics,

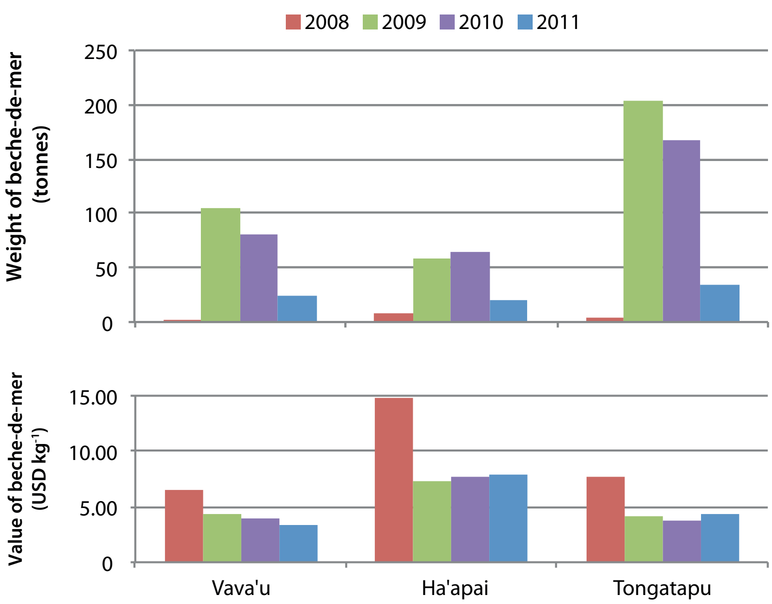


Figure 9. Evolution of sea cucumber harvests in Tonga.

it evident that the main stocks were all but fished out by the end of 2010, particularly higher-value species. The subsequent two years of harvests focused on very low-value species and the fishery was closed at the beginning of 2013. It is unclear when this will be re-opened, but the extent to which stocks have been depleted suggests the need for a 5–10 year period for stock recovery.

Regularly depleting stocks results in lower revenues than could be achieved using alternate harvesting and management strategies —specifically, harvesting stocks at lower annual levels so that both the scale and quality of harvests can be sustained over medium and longer terms.

Much can be done to strengthen the long-term scale and value of harvests, and therefore many benefits from these fisheries have been foregone as a result of recent and current systems of management. This is illustrated in Figure 10, using actual harvest figures. To remove the issue of rising prices across the time series, current constant prices are applied.

This exercise suggests that more sustainable management[10] might yield 10% less in export volume, but 25% more in export value without the processing discount (valued at buy-in price), and 50% more if the processing discount is applied. Limited to the time series covering the last 15 years, the difference is still greater — about a 5% increase in volume over the period — but an 80% increase in value without the processing discount, and a 100% increase in value with the processing discount.

Using constant prices (based on current buy-in prices), this suggests that annual income to coastal and island communities would have ranged from between USD 24 million at the highest peak in the late 1990s, down to a current level of some USD 4 million. Under the more precautionary and sustainable scenario described above, this would translate into an annual value of between USD 16 million and USD 22 million every year.

Across the most recent 15-year time series, this translates into revenue generation of some USD 160 million under current circumstances, and USD 320 million under more precautionary management and improved standards of processing. Clearly, the difference is huge, but it also comes with other distinct advantages:

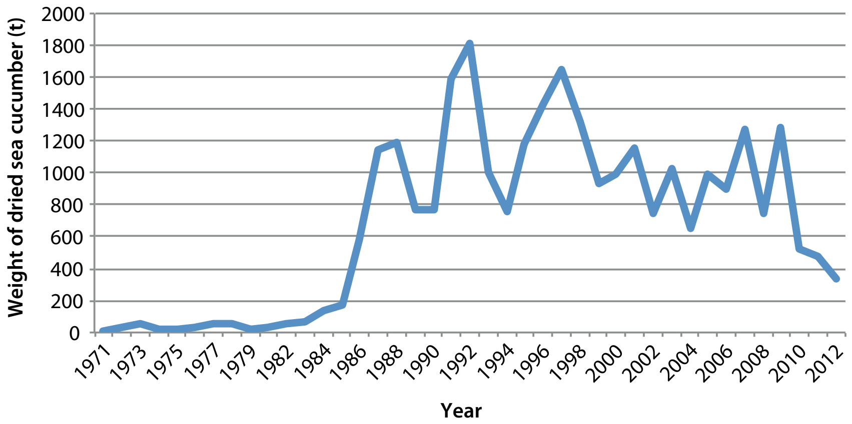
- Under the more precautionary management regime there is no need for moratoria, so coastal and island communities can generate income from sea cucumber harvesting and processing every year, and the harvesting regime becomes more predictable; bearing in mind that many of these fisheries are currently overexploited and/or in recovery, this more stable management regime would need to be preceded by a period of managed stock recovery.
- There is arguably less pressure to engage in illegal, unreported and unregulated fishing.
- More consistent and predictable levels of income are likely to provide greater incentive for coastal and island communities to take increased control over their fisheries..
- The provincial focus is likely to provide impetus for significant improvement in the capacity of provinces to manage and monitor coastal fisheries.

On this basis, regional harvests in 2006 totalled 930 tonnes (t), representing a current value of USD 15.8 million. Under a more moderate exploitation regime, we estimate that the harvest volume could have been on the order of 850 t, representing a current value of USD 18.4 million. In subsequent years, the sea cucumber fisheries of PNG, Solomon Islands and Vanuatu were closed to allow stocks to recover, and to compensate for previous excessive harvests. Tonga's sea cucumber fishery was opened, but was all but exhausted by the end of 2012, and Fiji's fishery has remained open, but harvests have been well below those achieved in the 1980s and 1990s. From 2007 to 2012, the five countries under study exported an average of 600 t of beche-de-mer per year, whereas under the precautionary management regime this would have been closer to 1,000 t per year, and increased annual revenues by about USD 13 million.

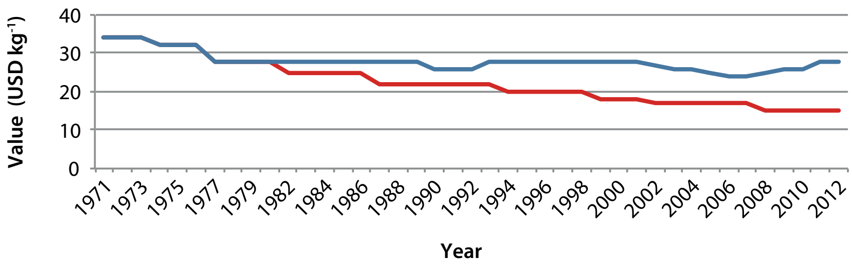
This exercise demonstrates the significant economic loss that results from overexploitation (a high proportion of lower-value species, smaller animals and poor processing practices), which ultimately results in fishery moratoria where no revenues are realised. More precautionary production levels, with improved processing and fishery management, increase economic value (a higher-value species mix and larger sea cucumbers) with no need for moratoria, and so revenues are realised every year.

Part B hereafter discusses management strategies that facilitate improved fishery and trade management, which translate to higher economic return value derived from these important fisheries.

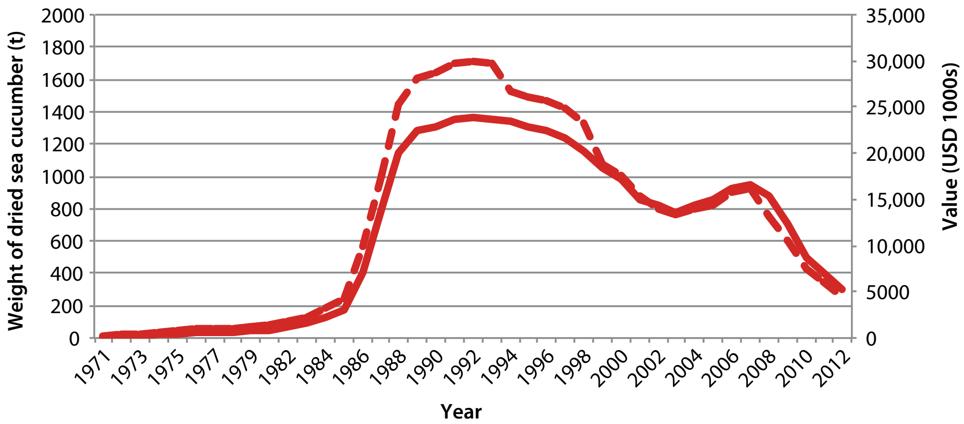
[10] It should be stressed that this analysis is based primarily on the trade record, albeit with some recognition of biological processes. In terms of determining a biologically sustainable level of exploitation, key data (size, distribution of animals, and the area over which they exist) that would enable the calculation of stock size, biomass, and maximum sustainable yield (MSY) are missing, except in the work currently being undertaken in Vanuatu, where stock assessments are being prepared on a small-area basis (Leopold et al. 2013 and Duvauchelle 2010). As an alternate approach to modelling stock size, stock condition and MSY, we have undertaken preliminary modelling of the trade and value record (with encouraging results), and are of the strong view that this warrants further work. The figures emerging from this modelling, which was based on the trade series for Milne Bay, bear credible similarity to exploitation levels proposed by NFA, but we would caution that further work needs to be undertaken to bring these approaches together in support of a single fishery management proposal.



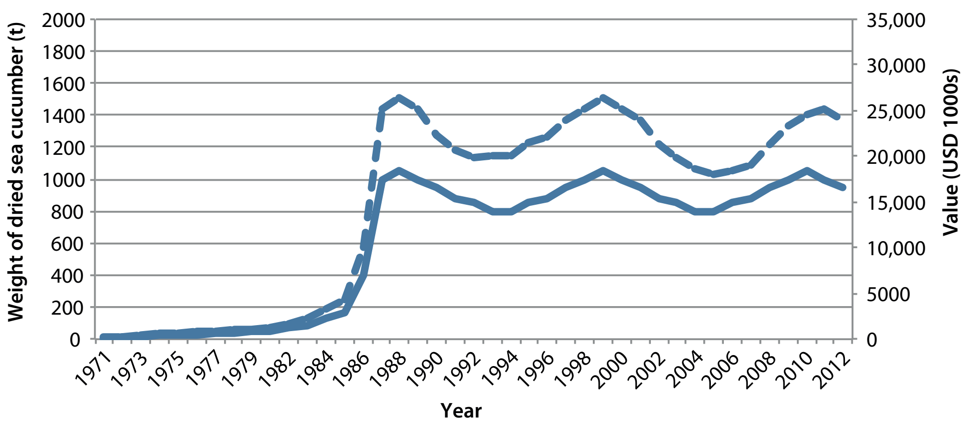
Regional exports of beche de mer (tonnes of dried weight). Taken from export statistics for the five countries under study.



Likely average unit buy-in price at today's prices (USD kg^{-1} of dried weight) (i.e. price reflects changes in species mix and size).
Red = overexploitation
Blue = sustainable exploitation



Smoothed production curve under current overexploited scenario. Solid line is production (tonnes of dried weight; left-hand axis); dotted line is value, including 20% discount for poor processing (USD 1000s; right-hand axis).



Smoothed production curve under sustainable scenario. Solid line is production (tonnes of dried weight; left-hand axis); dotted line is value, including 20% discount for poor processing (USD 1000s; right-hand axis).

Figure 10. Illustrations of valuation of beche-de-mer exports under different assumptions.

Part B: Managing sea cucumber fisheries and the beche-de-mer trade

Approaches to managing sea cucumber fisheries

This section introduces global experiences in managing sea cucumber fisheries, including an assessment of the strengths and weaknesses of alternative approaches, and opportunities to reinforce implementation of these approaches through economic and fiscal measures.

Status and pressures

Experience of sea cucumber fisheries management in the Pacific and globally has been reviewed and summarised by Kinch et al. (2008), Purcell et al. (2013), and Anderson et al. (2011). Many management issues are also addressed in Purcell et al. (2012). According to these and other studies, the key management issues pertaining to sea cucumber fisheries include the following.

1. Significant problems associated with managing sea cucumber species, with many or most species showing signs of overexploitation. For example:
   - 38% of sea cucumber fisheries globally are currently overexploited (Purcell et al. 2013), and many of these in the Pacific;
   - regional assessments have revealed that population declines from overfishing occurred in 81% sea cucumber fisheries, average harvested body size declined by 35%, harvesters moved from near to offshore regions in 51% and from high- to low-value species in 76% of sea cucumber fisheries;
   - 38% of sea cucumber fisheries remain unregulated, and illegal catches were of concern in half of these (Anderson et al. 2011).
2. Pressure on fisheries in recent years has been increasingly intense, and is associated with:
   - improved market access and high prices;
   - increased use of boats, which allow for the exploitation of previously virgin stock; and
   - poverty[11] coupled with income generating aspiration, which results in an incentive to fish even when sea cucumber densities are extremely low.
3. Sea cucumbers are highly vulnerable to overexploitation because they are:
   - sedentary, shallow water animals and readily accessible to harvesting;
   - long-lived, slow maturing, broadcast spawners dependent on minimum densities for successful reproduction; and
   - harvested as mixed-species fisheries. When target species dip below commercial densities, fishers continue to fish. Although they are targeting other species, they nonetheless continue to catch the previous target species, pushing these further below viability, and possibly towards local extinction.

Management response

A wide range of management instruments have been applied, mediated through customary marine tenure, provincial and national government initiatives, aid projects and non-governmental organisations. They have included size limits, gear restrictions, spatial and temporal closures, quotas and marine reserves.

The use of different management measures in sea cucumber fisheries worldwide has been reviewed by Purcell et al. 2009, and the frequency of use of these measures is summarised in Table 3.

Table 3. Use of different management tools in sea cucumber fisheries worldwide (after Purcell et al. 2009).

Management tool	Proportion of sea cucumber fisheries
Moratoria	39%
Gear restrictions	39%
Minimum size limits	34%
Catch quotas	28%
Fleet controls (numbers or size of vessels)	22%
Rotational harvest strategies (industrial fisheries only)	5%

[11] Stock depletion and overexploitation has been shown to be correlated with low human development index and poor enforcement of regulations (Purcell et al. 2013).

Generally speaking, these management tools have failed to curb overfishing. The main reasons relate to powerful drivers and the ease of overexploitation as described above, as well as more practical issues of limited funds and lack of enforcement, especially where large numbers of widely dispersed fishers are involved.

This management failure has led to crisis management in the form of moratoria, which have been introduced in many countries in the Pacific and elsewhere, including the Commonwealth of the Northern Mariana Islands, Costa Rica, mainland Ecuador, Egypt, Fiji, India, Mauritius, Mayotte (France), mainland Panama, Papua New Guinea, Solomon Islands, Tanzania, Tonga, Vanuatu and Venezuela (Purcell 2010). Despite these extreme measures, populations of some species have failed to recover; in some examples no recovery has occurred even 50 years after fishing stopped (Battaglene and Bell 2004), and local extinctions have been reported (Friedman et al. 2011).

There are, however, some examples of what appear to be sustainable sea cucumber fisheries, and Purcell et al. (2013) concluded that success relates to a number of factors, including enforcement capacity, number of species harvested, fleet (vessel) controls, limited entry controls, and rotational closures. It is, however, unclear that these factors apply to sea cucumber fisheries in Melanesia.

There is also a widespread view, especially in the Pacific Islands, that more effective management will depend on empowering local management systems with help, support or advice from central government fisheries administrations, although successful instances of this are limited. According to Purcell et al. (2009), co-management systems existed in just 12% of sea cucumber fisheries, although a greater emphasis is anticipated. Given the very strong incentives that encourage overfishing, however, and the high vulnerability of sea cucumbers to overexploitation, it is clear that empowering local communities is likely to be only one part of a more comprehensive approach to regulating and managing sea cucumber exploitation.

It is notable that the use of fiscal and economic tools to reinforce fisheries management is hardly referred to in the literature on sea cucumber management; and indeed, is little discussed in the general fisheries management literature, except in relation to quota valuation and trading.

Stock assessment

One of the weaknesses of management to date has been the lack of a clear relationship between the state of the stock and management response. This relates in large part to the difficulties of stock assessment, which in turn is related to:

- the number of species involved;
- the difficulty of identifying larvae;
- cryptic juveniles;
- the difficulty of tagging soft-bodied animals;
- there being no clear age-weight relationship; and
- difficulties in establishing recruitment to the spawning stock.

Young and adult sea cucumbers (excluding juveniles) are, however, relatively easy to find, measure, weigh and count, and size distributions and density mapping by species is relatively straightforward. Estimating potential productivity from habitat mapping coupled with some biological characteristics may offer a way forward, but is complicated by the limited availability of habitat maps, and the fact that the relative distribution of different sea cucumber species is not clearly delimited by habitat (although there are clear differences in the probability of finding a particular species in one habitat over another). Nonetheless, the combination of habitat mapping and density surveys might enable rough estimates of productivity and stock status (see Hamel and Andréfouët 2010; Hajas 2011; Skewes et al. 2010; Skewes et al. 2006; Skewes et al. 2004; Preston and Lokani 1990) and possibly modelling estimates of target reference points.

In Melanesia, the stock health has been periodically monitored through surveys focused on recording the densities of different species in different habitats. Over time, these data have been used to develop threshold values of what might be considered indicators of a healthy stock.

The study explored the potential use of species trade data (an index of catch) and value data (a proxy for effort) as a means of assessing stock size and MSY (using a methodology adapted from Vasconcellos and Cochrane 2005). Acceptable model fitting was achieved, yielding estimates of stock size, MSY and the likely impacts of different harvest control rules (HCRs). The conclusion was that this is a valid and practical means of estimating key stock parameters where good time series trade data (discriminated by species) are available. The value of such modelling could only be further strengthened where additional datasets were available, indicating the size composition of exports, and the spatial distribution of each species (linking to habitat data).

Regulations and potential HCRs

Depending on the information available and the management institutions in place, general restrictions or more specific HCRs or targets for the country, district, lagoon or reef may be set.

Density limits

Minimum viable population density has been discussed as a possible HCR. Bell et al. (2008) review the limited research on minimum viable densities for successful fertilisation in sea cucumbers, and speculate that the "threshold densities to avoid depensation for most tropical sea cucumbers will be in the range of 10–50 individuals ha^{-1} over substantial areas, depending on species and location". Purcell (2009) suggests the following rules of thumb: <100/ha = low; <30/ha = near critical for population maintenance. Higher target densities based on target reference points would depend on more sophisticated stock assessment models.

The objective of any such HCR would be to maintain a minimum viable density to ensure recruitment.

Reserve areas and geographic closures

Reserves or marine protected areas (MPAs) are widely discussed as a possible way forward. Based on analysis of the movements of sandfish, Purcell and Kirby (2006) suggest that reserves of a couple of hundred hectares would probably be sufficient for preserving and promoting breeding populations of sea cucumbers, giant clams and trochus, and that these could serve as sources of larvae for fished sites.

Seasonal closures and open seasons

The limited movement of these organisms and other life cycle characteristics is such that there is limited rationale for a seasonal closure to protect spawning stocks (e.g. breeding aggregations) or vulnerable juveniles. A limited nationally or regionally coordinated open season may, however, serve as a simple rough measure to limit total catch and to maximise product availability at times of highest demand.

From the perspective of monitoring and enforcement at the point of export (where product concentration occurs and where monitoring, control and surveillance [MCS] resources can be most easily focused) it would be difficult to police the situation where different parts of a country were subject to different open and closed seasons. In this context, opening the fishery for very brief periods only (pulse fishing) offers a more appropriate means of controlling fishing effort (a measure examined by Friedman et al. 2011). Activity at the community level could be restricted to a few short fishing seasons, each lasting a few days or weeks.

While there is no obvious rationale for having a closed season to protect spawning stock, allowing buyers and exporters the opportunity to do business across the year is likely to undermine more local management measures, and add to the costs of MCS, and should be seen as non-precautionary. Clearly, trading outside the season would raise questions, although the ability to store beche-de-mer makes strict policing of closed seasons at the point of export difficult. It is for this reason that the use of national closed seasons should be accompanied by the application of per-species export caps as a means of making stockpiling and contravention of other less commercially attractive controls. Accordingly, it is for the purposes of controlling trading rather than fishing activity that it is recommended that national closed seasons should be maintained, ideally lasting between six and nine months or more.

Size limits

Sea cucumbers generally become sexually mature when they reach a significant size and the limited data available on this issue (Conand 1993) suggest that simple size rules relating to groups might be feasible (e.g. fresh weight limits).

In principle, inspecting consignments for size at key trading posts and/or at the point of export should be possible, and economic disincentives (taxes or fines) are applicable.

Gear bans

Some countries implement bans on the use of scuba or hookah in order to protect a reservoir of larger animals in deeper water. Gear bans are not easily enforced at the national level but should be relatively easy to implement at the local or provincial level by confiscating gear.

Catch targets and quotas

Quotas may be set for individuals, families, boats, communities, lagoons, provinces or even countries, and may be implemented as bag limits, total quantity limits or as management targets to be achieved through other means. Controls at the point of export have been applied with a fair degree of success (all export shipments are required to be accompanied by comprehensive documentation and subject to inspection), but only when beche-de-mer is exported through formal channels.

Setting appropriate limits on catches from the sea cucumber fishery or of a particular species is difficult given the limited state of knowledge of population dynamics and stock productivity. To be more effective, a quota would necessarily have to be accompanied by several HCRs, including a "move-on" rule (e.g. once catch rates or observed densities per species fall below threshold levels, fishers need to move on to other fishing grounds).

Notwithstanding these reservations, a global review suggests that quotas work (Costello et al. 2008). Furthermore, modelling based on various datasets (catches, size distribution, density, prices) can certainly assist and can be further supported from practice (operation of an adaptive management regime), and more subjective survey information (e.g. fishermen's or trader's views on catch per unit of effort, average sizes caught, and abundance).

Given the largely sessile nature of these organisms, the limited range of larval dispersion and recruitment to commercial stocks, and the very local nature of exploitation, the setting of quotas is not a precise activity, and while it should provide a useful control at national and provincial levels, it would be inappropriate to extend this particular system to the local level. We propose that local communities be encouraged to set and apply HCRs based on changes in the average size of sea cucumbers harvested, thereby shifting effort between stocks or stock groups and, where feasible, using area closures.

Implementation

There are three key elements to the effective implementation of harvest control rules:

- address the factors that drive overexploitation;
- agree on practical and effective harvest control rules; and
- strengthen compliance through legal and financial incentives or disincentives.

> Most measures would be more effective if they were combined with limited fishing seasons (input control), controls on fishing methods (input control), minimum size restrictions (output control), and more effective monitoring throughout the supply chain (output control).

Broader measures

Re-stocking and stock enhancement offer some opportunities to re-establish depleted fisheries.

Limits to entry, including restricted allocation of individual quotas, are likely to be controversial for a small-scale fishery with very broad participation, such as that for sea cucumber. It is also likely to be difficult to implement unless a particular community with very strong internal ties and well-established and respected local authority systems decides to implement such a system.

Fiscal, economic and trade measures

Sector management can be improved substantially through the use of a variety of fiscal, economic and trade tools as a means of:

- regulation;
- providing incentives or disincentives to certain behaviour; and
- providing the environment within which market forces can encourage and maintain discipline.

Such tools can also be used to support and/or deliver particular policy objectives, including the potential to recoup all or part of the costs of management and regulation.

In the following section we discuss these tools under four distinct headings:

- information and its veracity — informing policy and practice;
- limiting resource access as a means of encouraging economic as well as biological optimisation — input controls and output controls;
- cost recovery mechanisms, and a subset of fiscal incentives to specific behaviour patterns and policy objectives; and
- providing disincentives to non-compliance and illegal behaviour.

Informing policy

Information

Defining, monitoring and adjusting fiscal, economic and trade measures requires access to good and dependable information. All of the countries studied have well-developed trade data collection systems, but data are collected inconsistently and not routinely used for management purposes.

Much valuable information can be obtained from trade datasets, which provide a potent basis for managing the beche-de-mer trade and sea cucumber exploitation.

The major weaknesses identified in the collection and collation of trade and harvest data are that data collection protocols are not applied consistently, and the data are not routinely checked and analysed (a process that would allow the information to be used for management purposes, and expose inconsistencies and errors). Crucial data are not routinely collected on purchases, by species and by province.

Transparency

As long as data are hidden from view, and are incomplete and unprocessed, management of sea cucumber fisheries and exports will continue to be subject to commercial and political pressures that result in activities that are at odds with established policies and plans and, more importantly, sustainability of the resource and continued revenue generation.

To improve transparency of the beche-de-mer trade, it is recommended that:

- each country make clear, unambiguous annual declarations regarding industry performance and the rules that will govern industry performance in the subsequent period;

- fishery and supply chain data be used for management and control purposes;
- customs and fisheries departments share as much information as legal and commercial confidentiality limits allow, especially with regard to beche-de-mer shipments prior to export; and
- exporters declare the species composition and source (by province) for each shipment, with this information made available to fisheries departments.

Resource access

One of the main categories of economic control is limiting access to the resource and the product.

Licensing

Licensing fishermen is problematic in a widely dispersed, small-scale fishery that has limited management and administrative resources, and has traditionally relied on local-level, customary management. It is more practical to license the businesses that handle product throughout the supply chain (i.e. those involved in export, intermediary buyers, and processors where such activity is centralised, such as in Tonga).

When licensing, it is important to consider drafting eligibility criteria that restrict eligibility to the types of business that the national (and possibly regional) policy seeks to encourage. In the process of confirming eligibility, licensing authorities should be encouraged to enquire into who controls the companies, how they are financed, and how they can demonstrate that they are not engaged in any form of transfer pricing.[12]

Increasing the cost of an export licence may also be a means of discouraging applications from less serious businesses.

It is recommended that:

- all exporters be required to hold a valid license, and as a condition of that license be required to provide data on all purchases, by species and origin of product;
- exporters be required to provide details of the average size (length, weight) per bag of each species shipped, and that bags contain a single species to facilitate verification;
- the eligibility criteria for export licenses exclude operations unlikely to fully comply with license conditions, with greater scrutiny of the integrity and background of the business principals and partners;
- primary (i.e. excluding household and village-based consolidators) beche-de-mer buyers and processors operating at the provincial level be required to hold a buyer or processor license, a condition of which requires the provision of monthly species-based data related to volume, value and species that move throughout the processing facility, including details of the source fishery.

Production and export caps

Export caps as an economic measure

The main management issue with sea cucumber fisheries is persistent overexploitation. One of the key drivers for such behaviour is the value of the resource, and the ease with which it can be converted into cash. Downstream intermediaries such as buyers, processors, exporters and importers all profit from the beche-de-mer trade. The extent to which they profit from this business also drives these intermediaries to encourage the flow of more product along the supply chain, thereby contributing to the overexploitation of sea cucumber resources. Capping, such as limiting trade volumes, provides an effective means of reducing such behaviour and encourages other forms of profit optimisation (e.g. a focus on quality over volume).

It is recognised that deriving a numerical basis for determining sustainable levels of exploitation is difficult, expensive and time consuming; however, moderating export levels is a simple means of encouraging more responsible and sustainable behaviour, and is inherently an economic tool because it operates as a constraint on business.

While it is appropriate to set the export cap at the same level as a stock management tool, it has a different origin. Governments lack the resources to micro-manage exploitation at the local level, but placing an upper limit on exports can be relatively easily policed, and supports the work of resource managers.

Export caps should be established on a species basis, and wherever possible should be informed by information on stock management requirements. Crucially, however, export caps should be put in place as a precautionary measure even where no clear stock management information is available. Such caps can be periodically reset on the basis of feedback on stock conditions.

Species-specific export caps should, therefore, be set as a precautionary measure, even where a consensus on the status of sea cucumber stocks and harvest limits is absent. Where possible, such export caps should be subdivided at the provincial level so as to even out supply.

[12] Transfer pricing typically seeks to declare sale prices on commercial invoices, manifests and customs declarations that are substantially below the value of the product, as a means of reducing the scale of any export levies that may attach to the export, and as a means of artificially returning profits to the importing rather than the exporting country. Transfer pricing is most commonly found in trade arrangements where the importer is a major direct or indirect investor in the exporting company, through shareholding, trade financing or provision of working capital.

Cost recovery and economic incentives

Actual and potential mechanisms for cost recovery include:

- export levies on product value;
- licensing of exporters;
- licensing of processors; and
- access charges.

At present, most governments recoup some of the costs associated with managing this fishery through a levy on export value, which is based on quantity and (usually) a notional value, with the latter often under-representative of export values. This system needs to be revisited with the intention of ensuring that resulting revenues are realistic in the context of beche-de-mer market value. Customs and fisheries departments should require that a detailed commercial importer invoice form part of customs export documentation on which levies can be calculated.

Variable export levies could be deployed as a means of encouraging desired behaviour. A key issue is that in overexploited fisheries, fishers have little option but to catch and sell smaller animals. Assuming that minimum legal size limits are enforced, another management control is to apply a levy per piece of beche-de-mer exported. For example, a levy of USD 1 per piece would discourage exporters from shipping smaller sized beche-de-mer. If the levy is set at the right level, it encourages buying and selling larger beche-de-mer. Such a levy could be applied to all species, or only to those species considered threatened with overexploitation.

A secondary positive effect of such a policy would be increased pressure on customs and fisheries departments to inspect and weigh a sample of each export shipment. This would result in increased monitoring and control of the trade, and monitoring and recording of the average size of product shipped. The resulting data would help managers assess the impact and inform the adjustment of export caps, and contribute to stock assessment modelling and the setting of catch limits.

Revenues are also achieved through licensing exporters and processors.

In conclusion, it is recommended that:

- all beche-de-mer production be subject to a management levy collected at the point of export through an *ad valorem* (according to value) tariff, and that the provision of a valid commercial invoice be a prerequisite of customs clearance;
- the fee accompanying the issuing of export licenses be significant;
- to facilitate the setting of license fees, export levies and variable per-species levies be further studied (specifically, the costs and revenues associated with the beche-de-mer value chain); and
- consideration be given to applying a per-piece levy on different beche-de-mer species.

Monitoring, control and surveillance, and measures to discourage illegal, unreported and unregulated fishing and trade

Fishery closures force the trade underground

It is well known that beche-de-mer is exported illegally when sea cucumber fisheries are closed, and that in response to this, increased MCS resources are deployed in an effort to discourage and curtail such activity. The evidence (from inside the countries of this study and through discussions with traders in Hong Kong and mainland China) suggests that illegal shipments continue to be made. This is considered to be a direct result of closing these fisheries.

For various reasons — in combination with socioeconomic and market conditions — there is strong support for shifting sea cucumber harvesting from a boom-and-bust cycle to a more level and predictable fishery, year after year. It is evident that closure of at least some fisheries simply results in the trade going underground, as communities and exporters seek to continue generating cash income and profits. This results in stocks being overfished, with all activities performed outside the law, beyond the control of fisheries managers. In addition, closing the fishery without management cost-recovery forces governments to increase MCS expenditures.

Fishing with UBA gear

The illegal harvesting of sea cucumbers using UBA gear is thought to be taking place in all countries. The deeper water sea cucumber resources are considered to provide an essential reservoir of adult breeding stock of key species, and exploitation of these stocks is thought to adversely impact recruitment and re-stocking in overexploited areas in shallower water.

Existing bans on the use of UBA gear in sea cucumber harvesting should be maintained, with increased effort to enforce the bans.

In conclusion, it is recommended that:

- sea cucumber fisheries be managed to preclude the need for closures — stocks should be rebuilt and then managed more conservatively; and
- the use of UBA gear in exploiting sea cucumber resources be banned, and the ban effectively enforced.

A sea cucumber/beche-de-mer sector management framework

Sea cucumber management experience

The record of successful management of sea cucumber fisheries has not been good, and with the ever-growing demand for beche-de-mer, the incentives to harvest remain strong.

This study did not seek to revisit past analyses, but to explore new approaches, with an emphasis on economic and trade management. Accordingly, the study explores issues associated with the structure and operation of the beche-de-mer supply chain, and whether economic tools can provide the discipline and incentives needed to moderate the boom-and-bust nature of these fisheries. It would be naïve to suggest that there is a single or simple solution to managing these fisheries, but they can certainly be better managed than is currently the case.

The overriding influences on the management and trade of sea cucumber fisheries will undoubtedly remain the extent to which local fishers' activities can be brought within and influenced by a local management regime. Local conditions, traditions and influences will dictate what management systems will work in practice, particularly given that practical management and control of sea cucumber fisheries will be a local affair. While trade and supply chain rules and interventions are amenable to application at the national and regional level, fishery management will be much more local.

However, it is clear that the incentives to quickly deplete stocks far outweigh the disincentives, because these resources are treated unrealistically as a no-cost cash crop. Such a boom-and-bust strategy might have greater credibility if the benefits of the strategy were evenly distributed across adjacent coastal and island communities, but in practice it is more usual that benefits go to a small group of individuals. Such behaviour represents significant foregone economic gain — a loss of some significance to local coastal communities as well as to the economy as a whole.

Reinforcing management through trade information

The key to reinforcing the implementation of existing management measures lies in the marketing and distribution chain.

All countries require beche-de-mer traders and exporters to be licensed; some require intermediary buyers and traders to be licensed, either at the national or provincial level. Minimum size restrictions are applied in each country and are seemingly not widely known in fishing circles, so size controls are mainly (although not always) applied by traders and exporters. Another key group of management tools applied to traders is the mandatory submission of purchase records, packing lists and shipping manifests, which provide an important formality to the trade and an example of visible oversight, and thus serves as a deterrent to overharvesting and mismanagement. Trade records also act as a potential tool to enhance compliance with quota or size restrictions.

Establishing precautionary export caps and target catches

At the beginning of 2013, the stock situation in each country was as follows:

- PNG's resources should be improving after four years of closure, with the closure extended for another three years. Illegal, unreported and unregulated (IUU) fishing is proving problematic.
- Solomon Islands' fisheries have been mostly closed for at least four out of the last seven years, and stocks should be in recovery, although there has been significant IUU fishing.
- Vanuatu's fisheries have been closed for five years, and it has recently been announced that they will remain closed for another five years;
- Fiji's fisheries remain open, but stocks are thought to be in poor condition.
- Tonga's fishery has just been closed following five years of heavy exploitation and all stocks are considered to be in poor condition.

Management framework conclusions and recommendations

The foregoing suggests a complex picture with 1) a wide range of management interventions and suggested HCRs; 2) substantial difficulty in promoting or enforcing these mechanisms at local level; 3) substantial data collection at various points in the supply chain, but limited analysis and feedback into management; and 4) very little attempt to reinforce local or provincial management measures through checks and balances at the point of export. Given the relatively limited total volume of this high-value product, and therefore the relative ease with which trade depot and/or export inspection of consignment could be done, this is a lost opportunity.

The beche-de-mer management plans in operation, and the current draft revisions, form a sound and coherent basis for sector management. There are weaknesses in dissemination and compliance, but the main shortcoming is the absence of any clear mechanism for adaptive management and for making future decisions in a way that responds to evidence regarding past actions.

The following are the four key elements required in an effective management system for sea cucumbers.

In 2006, PNG introduced a provincial quota system, setting two export caps per province: one covering high-value species and the other covering low-value species. These caps approximated the peak volumes of historical exports and are considered to be excessive. An export cap closer to the historical average exports (15-year average of 450 t) would seem more appropriate (i.e. at 380 t, some 60% of the values put forward in the 2006 management plan).It is estimated that this would yield, over time, the same volume of harvests, but would avoid a fishery closure, and species composition would comprise more valuable species and individuals of greater average size.

For the Solomon Islands, the application of a provincial export cap would go a considerable way to moderating local overexploitation, but weak provincial infrastructures and limited capacity at the provincial level place responsibility for moderating exploitation on community leaders and fishers. An annual export cap of about 140 t (15-year average is 165 t) would encourage a focus on quality rather than quantity, and generate predictable year after year production at levels well above those currently available. As more information becomes available on the biological characteristics of stocks and harvesting levels, these export caps should be modified.

Vanuatu has very limited sea cucumber resource capacity, and given its distance from other islands and it's the reduced likelihood of recruitment from outside sources, these resources are very sensitive to overexploitation. Following a period of recovery, it is suggested that an export cap of no more than 20 t per year be established (15-year average is 18 t per year).

Fiji's sea cucumber resources have been heavily exploited over a long period. Stocks need to recover, either through a moratorium or through drastically reduced production. A target export cap of 200 t of dried beche-de-mer (15-year average is 275 t) would seem appropriate, but a substantially lower ceiling might be necessary in the shorter term.

Tonga's fishery is exhausted and needs time to recover. Once it has recovered, a substantially lower export cap of no more than 60 t of beche-de-mer per year (15-year average, including a 10-year moratorium, is 55 t) needs to be introduced.

1. Engage resource users in setting overall national harvest targets and standards regulations, and developing and agreeing on local HCRs in broad conformity with these national targets.
2. Establish incentives and disincentives to promote compliance at all levels, including through inspections and economic incentives at the point of export.
3. Monitor and analyse information relating to the implementation of HCRs (and their impact on stocks) at the local, provincial and national level and feed this back into the management process.
4. Establish agreed on response mechanisms at the national and local level that take effect if data analysis suggests a decline or improvement in stocks.

Opportunities for regional cooperation

Adoption of common standards or joint activity through regional cooperation would be helpful in a number of areas. For Melanesian countries, an initiative through the Melanesian Spearhead Group (MSG) would yield dividends. Some opportunities for cooperation are highlighted below.

- Governments of producing countries should share information on the beneficial ownership of beche-de-mer trading companies that they license and that operate in their respective territories.
- Governments should be much more open in their reporting on sector performance, and the information should be consolidated in an annual regional report.
- Investigations into the functional dimensions of this trade, including statistical research, and liaison with the governments of importing countries, should be undertaken on a regional rather country-by-country basis, and research results that are not commercially sensitive should be routinely shared across the region.
- The traditional core of beche-de-mer exporting countries are Fiji, Indonesia, Philippines, PNG and Solomon Islands. Although their dominance in terms of total supplies has waned in recent years, they remain responsible for over 50% of global tropical supplies. Given the diminishing global beche-de-mer supply, producers should be trading in a "sellers" market. The Pacific Islands are not taking advantage of this situation; governments should ensure that the provision of a valid commercial invoice forms a necessary part of customs clearance procedures, and that the information provided is used by governments. This information should be shared to the degree commercial confidentiality allows, so that it can be used to better inform trade policy. Veracity with respect to prices is particularly important given that in many (but not all) businesses, the importer provides the working capital for beche-de-mer supply chain networks in-country.
- It is recommended that MSG members coordinate their fishing seasons. If open seasons are coordinated so that imports originating from Melanesia occur simultaneously, any trade outside the coordinated season would be illegal.

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References

Anderson S.C., Mills F.J., Watson R. and Lotze H.K. 2011. Serial exploitation of global sea cucumber fisheries. Fish and Fisheries 12(3):317–339.

Battaglene S.C. and Bell J.D. 2004. The restocking of sea cucumbers in the Pacific Islands. p. 109–132. In: Bartley D.M. and Leber K.M. (eds). Case studies in marine ranching. FAO Fishery Technical Paper, FAO, Rome.

Bell J.D., Purcell S.W. and Nash W.J. 2008. Restoring small-scale fisheries for tropical sea cucumbers. Ocean and Coastal Management 51(8–9):589–593.

Conand C. 1993. Reproductive biology of the characteristic holothurians from the major communities of the New Caledonia lagoon. Marine Biology 116:439–450.

Costello C., Steven D. and Lynham J. 2008. Can catch shares prevent fisheries collapse? Science 321:1678–1681.

Duvauchelle, C. 2010. Développement d'un guide méthodologique de suivi de la pêcherie d'holothuries « gris » *Holothuria scabra* dans le lagon nord-ouest de Nouvelle-Calédonie; Mémoire de fin d'études Spécialisation halieutique d'Agrocampus Ouest; IRD Noumea, Nouvelle Caledonie

Friedman K., Eriksson H., Tardy E. and Pakoa K. 2011. Management of sea cucumber stocks: patterns of vulnerability and recovery of sea cucumber stocks impacted by fishing. Fish and Fisheries 12(1):75–93.

Hamel M.A. and Andréfouët S. 2010. Using very high resolution remote sensing for the management of coral reef fisheries: Review and perspectives. Marine Pollution Bulletin 60(9):1397–1405.

Hasan M.H. 2005. Destruction of a *Holothuria scabra* population by overfishing at Abu Rhamada Island in the Red Sea. Marine Environmental Research 60(4):489–511

Kinch J., Purcell S.W., Uthicke S. and Friedman K. 2008. Population status, fisheries and trade of sea cucumbers in the Western Central Pacific. p. 7–55. In: Toral-Granda V., Lovatelli A. andVasconcellos M. (eds). Sea cucumbers. A global review of fisheries and trade. FAO Fisheries and Aquaculture Technical Paper. No. 516. Rome, FAO.

Léopold M., Cornuet N., Andréfouët Serge, Moenteapo Z., Duvauchelle C., Raubani J., Ham J., Dumas Pascal. 2013. Comanaging small-scale sea cucumber fisheries in New Caledonia and Vanuatu using stock biomass estimates to set spatial catch quotas. Environmental Conservation, 2013: 1–13.

Preston G.L. and Lokani P. 1990. Report of a survey of sea cucumber resources of Ha'apai, Tonga; Inshore Fisheries Research Project Report, SPC.

Purcell S.W. 2010. Managing sea cucumber fisheries with an ecosystem approach. Edited and compiled by Lovatelli A.,Vasconcellos M. and Yimin Y. FAO Fisheries and Aquaculture Technical Paper. No. 520. Rome, FAO. 2010. 157 p.

Purcell S.W. and Kirby D.S. 2006. Restocking the sea cucumber *Holothuria scabra*: Sizing no-take zones through individual-based movement modelling. Fisheries Research 80(1):53–61.

Purcell S.W., Gossuin H. and Agudo N.S. 2009. Status and management of the sea cucumber fishery of La Grande Terre, New Caledonia. WorldFish Center Studies and Reviews No. 1901. The WorldFish Center, Penang, Malaysia. 136 p.

Purcell S., Ngaluafe P. and Tamuera K. 2012. Improving income of Pacific island fishers through better post-harvest processing of sea cucumber: scoping study; ACIAR small research project PARDI/2010/004; 57 p.

Purcell S.W., Samyn Y. and Conand C. 2012. Commercially important sea cucumbers of the world. FAO Species Catalogue for Fishery Purposes. No. 6. Rome, FAO. 2012. 150 p.

Purcell S.W, Mercier A., Conand C., Hamel J.-F., Toral-Granda M.V., Lovatelli A. and Uthicke S. 2013. Sea cucumber fisheries: global analysis of stocks, management measures and drivers of overfishing. Fish and Fisheries 14(1):34–59.

Skewes T., Murphy N., McLeod I., Dovers E., Burridge C. and Rochester W. 2010. Torres Strait hand collectables, 2009 survey: Sea cucumber. CSIRO Marine and Atmospheric Research, A report for the Australian Fisheries Management Authority,project # 2009/81. 57 p.

Skewes T., Taylor S., Dennis D., Haywood M. and Donovan A. 2006. Sustainability assessment of the Torres Strait sea cucumber fishery.. Torres Strait Research Program; CRC-TS Task Number: T1.4. 40 p.

Skewes T., Dennis D., Koutsoukos A., Haywood M., Wasserberg T. and Austin M. 2004. Stock survey and sustainable harvest strategies for Torres Strait beche-de-mer.. Torres Strait Research Program; AFMA Project Number: R01/1345.

Uthicke S., Byrne M. and Conand C. 2010. Genetic barcoding of commercial beche-de-mer species (Echinodermata: Holothuroidea). Molecular Ecology Resources, 10:634–646.

To A.W.L. and Shea S.K.H. 2012. Patterns and dynamics of beche-de-mer trade in Hong Kong and mainland China: Implications for monitoring and management; TRAFFIC Bulletin 24(2):65–76.

Vasconcellos M. and Cochrane K. 2005. Overview of world status of data-limited fisheries: Inferences from landings statistics — fisheries assessment and management in data-limited situations. Alaska Sea Grant College Program. AK-SG-05-02, 2005.

Towards a new management strategy for Pacific Island sea cucumber fisheries

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Introduction

This article summarises the main conclusions of a paper published in 2013 in a special issue of *Environmental Conservation* called "Politics, science and policy of reference points for resource management", and provides an update on the data for sea cucumber fisheries in Vanuatu.

The sharp decline in marketable sea cucumber resources in most Pacific Islands seems to indicate that a change is needed in current fisheries management approaches. If the sustainability of this fishery is to be ensured, it is vital to identify which biological data are actually useful for setting effective fishing regulations. Data uncertainty must also be taken into account, and precautionary management should be implemented to maintain sea cucumber resources above their biological recovery threshold.

This article describes the new total allowable catch (TAC) management strategy tested by fisheries departments in New Caledonia and Vanuatu. This alternative strategy could well be tested in other countries in the region.

Sandfish fisheries management in New Caledonia

Method

In New Caledonia, an adaptive TAC management system has been in use since 2008 for the Northern Province's main fishery for sandfish, *Holothuria scabra* (Fig. 1). The resource had been showing signs of overfishing, which fishers noted through the decrease in size of sea cucumbers in that area.

Methodology for estimating stock biomass

From June 2008 to April 2012, stock biomass in the study area (Fig. 2) was assessed eight times. An estimation method was designed using on-site censuses and detailed habitat mapping.

The census protocol is rapid and cost-effective. Depending on the stage of the tides, counting was done on foot on the reef flat or by free dives in areas less than 2 m deep. The survey teams consisted of two observers — one fisher and one fisheries department agent. Counting took place on permanent 100 m-long and 2 m-wide belt transects (i.e. 200 m^2 per transect). All specimens were counted and measured (length, L and width, W) to the nearest 5 mm, which made it possible to estimate their weights. Sampling covered 40–112 transects, depending on the size of the area being assessed and available logistical resources.

A map of marine habitats was needed to give a spatial dimension to data collection and to extrapolate census observations to the *entire* fishing grounds (12–26 km^2). This map was created using high-resolution Quickbird satellite images (Fig. 3), because the resolution of large-scale reef geomorphology maps derived from Landsat 7 sensors was not fine enough for the purposes of this study. The image was imported into a geographic information system (GIS) and processed using a simplified, user-oriented protocol. Some 25 polygons were defined, reflecting different habitats. Habitat surface areas were calculated through GIS. This simple mapping process

Figure 1. Sandfish, Holothuria scabra*, one of the most valuable sea cucumber species on the world market* (Image E. Tardy).

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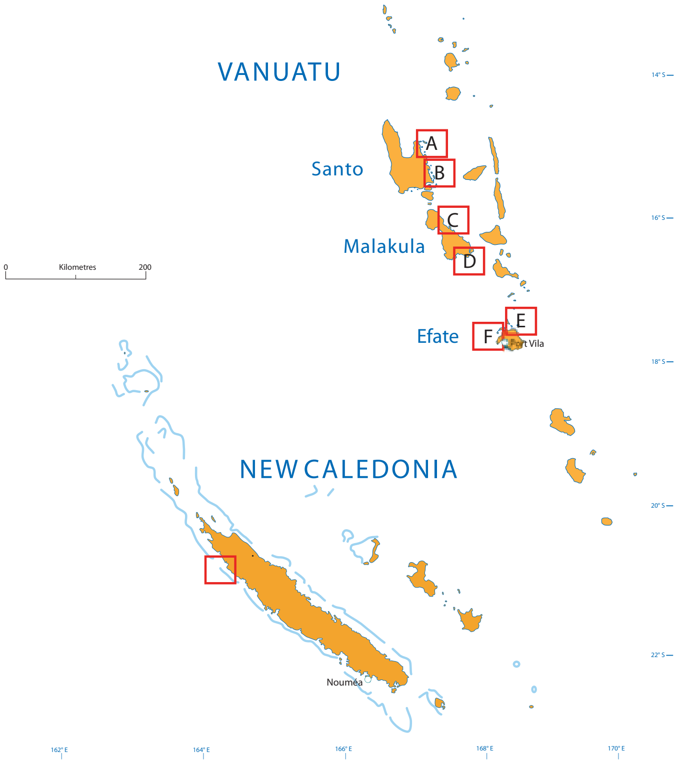

Figure 2. Sea cucumber fishing study sites in New Caledonia (n=1) and in Vanuatu (n=6).

was used to compute stock estimates using habitat surface areas (in km^2) and census data.

Statistical estimates were made directly by the same database used to enter census data so that the fisheries department would have rapid access to assessment results without any outside scientific or statistical expertise. It should be noted that the 95% confidence interval estimates were also calculated using that database so as to take into account uncertainty in the assessments.

Determining TAC

Accurate information on stock biomass allowed fishers and fisheries department staff to implement TAC management (or quotas). Before that, the only two provincial fishing restrictions were a ban on night fishing and a minimum harvest length of 20 cm (fresh whole sandfish).

A simple straight-forward rule was used to determine TAC: TAC corresponded to the harvestable stock biomass (composed of all legal sized specimens) for the censuses. TAC is expressed in tonnes of live sea cucumbers and is designed to avoid the risk of recruitment overfishing.

More precisely, it is the lower limit of the 95% confidence interval for the estimated harvestable stock biomass (hereafter called the precautionary harvestable biomass), which is the reference for TAC. So, it represents a catch volume that is below the total harvestable biomass so as to avoid the risk of overfishing.

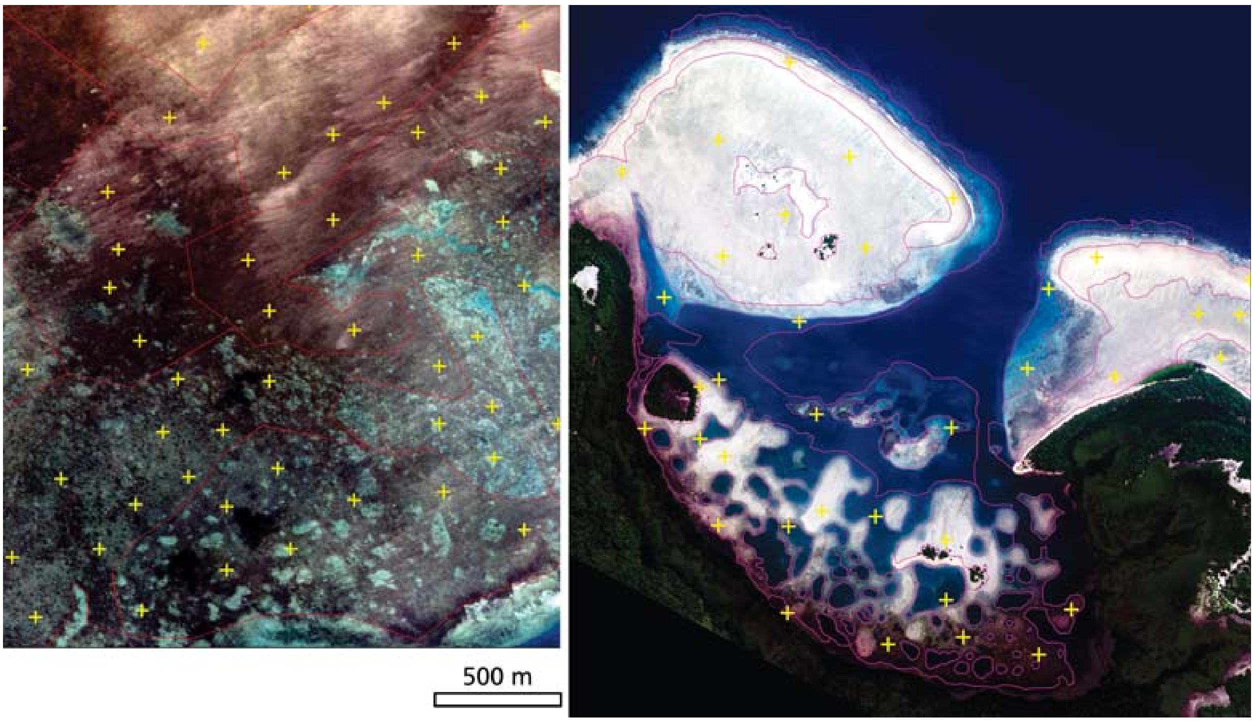

Figure 3. Satellite images showing the fishing areas (extract) and the positions of the transects used for sea cucumber stock assessments. Left: site in New Caledonia, Northern Province, Plateau des Massacres (Quickbird satellite). Right: Vanuatu site, Malakula, Crab Bay (WorldView2 satellite).

Figure 4. During assessment campaigns, fishers helped fisheries department staff count and measure sea cucumbers. These data were needed to estimate sea cucumber quantity and size for the entire fishing zone.

TAC management procedure

An adaptive management procedure was set up in the form of a four-stage cycle (Fig. 5).

1. First the precautionary harvestable biomass was estimated using the previously described methods.

2. Fisheries department agents and the area's fishers' association worked together to set a collective TAC. Because fishers eviscerate sea cucumbers at sea and market the salted product, the initial TAC was converted into a TAC of gutted and salted products. The rate (conversion from wet to salted) was set at 0.85 and then reduced to 0.5 based on recommendations in the literature.

3. Fishing was opened for several short fishing periods (one to three days each) until the TAC was reached in order to better control catch levels and avoid illegal fishing activities. Sales to middlemen were held on the days following each fishing period. A fisheries department agent and a leader of the fishers' association verified sales prices, each fisher's catch and the overall catch, beginning from the first fishing period, to ensure the TAC was followed. In addition, the fishers decided to apply individual quotas for each fisher during each fishing period to prevent a "race" for sea cucumbers and individual appropriation of the TAC. In order to fish, each boat also had to have a yearly permit issued by the provincial fisheries department. The total number of permits has been limited to 27 since 2009. Permits are only issued to those who earn most of their income from fisheries activities.

4. As soon as the TAC was reached (or slightly exceeded), fishing was again closed for several months (between one and eight months), until another stock assessment was scheduled by the fishers' association. The timing of assessments was based on the availability of fisheries department agents and fishers, and on outside constraints such as weather conditions and tides.

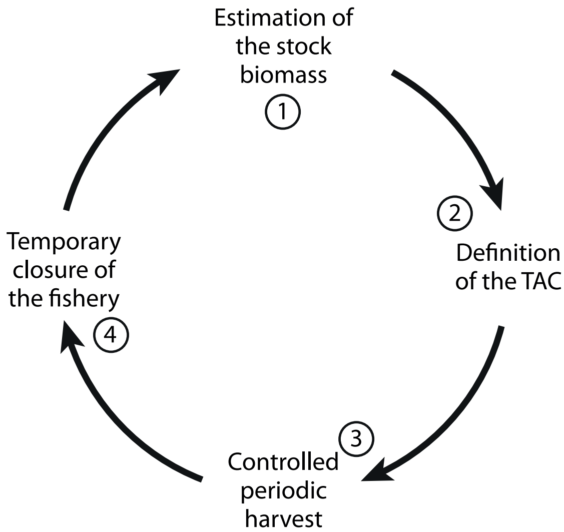

Figure 5. Four-step co-management procedure implemented in the surveyed sandfish, Holothuria scabra, *fishery in New Caledonia between 2008 and 2012.*

From June 2008 to April 2012, there were eight management cycles lasting 3 to 10 months each. This represented a total of 6–20 open fishing days per cycle. So, fishing was closed 95% of the days of the year.

Results

The co-management system was a success. Both harvestable and total sea cumber stocks have increased rapidly since 2008, which demonstrates strong positive biological effects across all size classes. The precautionary harvestable biomass went from 13 to 85 tonnes (equivalent to 170 t of live sea cucumber). Similarly, the total biomass markedly increased from 115 ± 30 t to 307 ± 49 t. The precautionary harvestable biomass accounted for 11% of the stock total in 2008, increasing to 28% in 2012.

Cumulative annual catches went from 20 t in 2008 to 50 t in 2012 — an increase of 150% valued at approximately USD 340,000 in 2012. The average income per fisher by management cycle (from 3–10 months) rose from USD 1,900 to USD 3,700 during the period even though the number of fishers continued to rise in the zone and sales prices decreased from USD 7 to 6.5 per kg of gutted and salted product. Excess catches have been observed since 2011, particularly because daily catches have grown significantly, which makes it increasing difficult to adjust fishing effort so as not to exceed allowable catch levels.

These results demonstrate the very good performances of the TAC management strategy and the precautionary approach used, both biologically (increase in stocks) and economically (increased incomes).

Other biological indicators showed irregular, less-marked fluctuations in comparison to harvestable stock biomass across the study period. The mean sandfish density, for example, increased from 18,300 to 75,400 specimens per km^2 between 2008 and 2012, although a sharp decline occurred in 2011 due to unidentified factors. Therefore, the precautionary harvestable biomass proved to be the most useful indicator for managers to set the TAC.

Extending the use of stock assessments to multispecies sea cucumber fisheries in Vanuatu

A five-year moratorium on fishing was enacted in Vanuatu in 2008 after stocks there collapsed. This study was designed to assess stock levels to support the national management plan beginning in 2013.

Method

The method developed in New Caledonia was adapted for Vanuatu in 2011 in order to assess stocks in multi-species sea cucumber fisheries. The harvestable stock biomass was estimated for 15 low- to high-value commercial sea cucumber species at six sites in Vanuatu, located in the provinces of Sanma (Santo), Malampa (Malikolo and Maskelynes) and Shefa (Efaté) (Fig. 2 and Table 1).

Data was collected from 2011 to 2013 during one- to five-day campaigns using the same methods described above. The study sites covered areas of 10–25 km^2. A map of marine habitats was created for each site using a high-resolution QuickBird and WorldView II satellite images (Fig. 3) following the procedure described above. The habitat maps of the sites frequently exhibited a much greater diversity than that found at the New Caledonian study site, with 21–100 habitat polygons per site. Sampling efforts varied from 76–286 transects per site (i.e. from 8–23 transects per km^2. The length-weight relationships for each species were taken from Conand (1989).

Results

At the six study sites in Vanuatu, the precautionary harvestable biomass was very low for all study species (Table 1). It was less the 1 t for 53–100% of the species at all sites. The results indicated that sea cucumber resources have only recovered slightly since the 2008 moratorium. In particular, the precautionary harvestable biomass for sandfish was less than 1 t. This was well below the level observed in New Caledonia before the co-management process was launched (i.e. 13 t in 2008 for an equivalent surface area and habitat type).

Although most sea cucumber stocks were very low at the survey sites, biomass estimates showed marked spatial differences even within the same province. Specifically, the total biomass and the precautionary harvestable biomass were significantly higher in the Maskelynes Islands for four low- to medium-value species (Table 1).

Table 1. Estimated total biomass and precautionary harvestable biomass of the stocks of 15 marketable sea cucumber species at 6 study sites in Vanuatu from 2011–2013. The 95% confidence intervals for the total stock biomass are given. Estimated biomass toneless than 1 t. The sites are shown on Fig. 1.*

		Total stock (t)						**Conservative harvestable stock (t)**					
	Minimum size limit (cm)	site A	site B	site C	site D	site E	site F	site A	site B	site C	site D	site E	site F
Actinopyga mauritiana	20	*	*	*	*	*	4±1.6	*	*	*	*	*	1.9
Actinopyga milliaris	-	*	*	*	*	*	*	*	*	*	*	*	*
Bohadschia argus	20	*	*	11.5±7.1	31.8±14.4	6.4±3.5	6.8±3.1	*	*	4.5	15.6	2.9	3.6
Bohadschia similis	-	*	*	*	*	*	*	*	*	*	*	*	*
Bohadschia vitiensis	20	*	7.6±4.7	14.3±9.1	40.8±31	*	*	*	2.5	5.2	8.1	*	*
Holothuria atra	30	19.4±15	54.4±48.4	70.7±26.3	247.6±70.2	15.5±5.2	23.9±5.4	*	*	*	2.5	*	*
Holothuria edulis	25	*	*	1±0.6	*	*	*	*	*	*	*	*	*
Holothuria fuscogilva	35	*	*	*	*	*	*	*	*	*	*	*	*
Holothuria fuscopunctata	-	*	*	*	*	*	*	*	*	*	*	*	*
Holothuria scabra	22	*	*	*	*	*	*	*	*	*	*	*	*
Holothuria whitmaei	22	*	*	8.4±14.2	10.9±9	*	*	*	*	*	1.7	*	*
Stichopus chloronotus	20	28.1±24.7	4.3±2.2	10.4±8	9.4±6.4	9±4.4	14.8±4.1	*	1.1	2.5	1.0	2.4	7.0
Stichopus herrmanni	25	*	*	7.8±6.5	42.9±30.4	*	*	*	*	1.3	11.7	*	*
Thelenota ananas	32	*	10.5±7.1	5.5±5.5	11.1±7.2	10.1±6.7	*	*	1.0	*	3.8	2.5	*
Thelenota anax	-	*	*	*	*	*	*	*	*	*	*	*	*

The precautionary harvestable biomass of those species accounted for 11–49 % of the total stock biomass.

Overall, the stock levels recorded support an extension of the fishing ban for all species given the very low expected catch and incomes. The Ministry of Fisheries in Vanuatu confirmed that recommendation by reinstating the moratorium for another five years beginning in January 2013.

What does this mean for sea cucumber fishery management in the Pacific Islands?

Setting a TAC and/or a minimum harvest length

Our five years of monitoring the site in New Caledonia showed that the TAC management system was more efficient than prior regulations set by the provincial fisheries department, most notably, the minimum harvest size for sandfish. How can this difference in performance be explained when the TAC is directly linked to the minimum harvest length?

First, because the stock's reference biomass was determined in a very conservative manner, probably only a portion of the legal sized sea cucumbers were harvested after each assessment. That led to a lower fishing mortality than with the harvest size limit alone, which, in principle, allows the harvest of *all* legal sized specimens. Moreover, setting a TAC responded to the main concern of fishers at the site (i.e. the number of sandfish that could be harvested sustainably in their fishing zone). For that reason, TAC management was socially acceptable and gained fishers' support. Finally, the rapid recovery of the resources and the increase in catches certainly encouraged fishers to carefully follow the TAC and closure periods, whereas the minimum length probably did not have such local support previously.

It should also be noted that resources at the study sites in Vanuatu did not recover as quickly as those at the New Caledonia site in spite of a total long-term closure to fishing (equivalent to a zero TAC for all species for five years), which suggests that major ecological processes are also involved. In particular, the very low sea cucumber density (from 0 to several hundred specimens per km^2 on average) in comparison to the New Caledonia site in 2008 (about 20,000 specimens per km^2) undoubtedly hampered stock recovery in Vanuatu. This situation probably exists in other Pacific Island countries, in spite of moratoriums when resources have been heavily overfished in the past.

Overall, setting conservative minimum harvest lengths (i.e. above the size at maturity), appears to be inadequate for controlling catch volumes. In the event that it is not feasible to have both TAC management *and* minimum sizes (e.g. for fisheries of low economic value), our results suggest that minimum lengths would be more effective if they were combined with short fishing periods and longer "fallow" times, thereby facilitating both catch limits and specimen growth.

Identifying those biological data that are really useful for fisheries departments

We did not use average sea cucumber density as a reference indicator for managing sandfish catches in New Caledonia, although this is a commonly recommended measure. In fact, there is a lack of biological data on most marketable sea cucumber species, which would be used to determine the density threshold for harvest. For example, the biological threshold for sandfish was not known at the study site in New Caledonia and it probably differs from one site to another depending on environmental factors. In addition, the average sea cucumber density would not make it possible to determine a TAC directly and accurately. In our study, the precautionary harvestable biomass proved to be the most effective information for setting a TAC.

We should also highlight the importance of identifying the TAC level through direct stock assessment, without, for example, any assumptions on optimal fishing mortality, natural mortality or recruitment. In fact, those poorly known data can lead to disputes between fishers and fisheries departments and be a source of disagreements with regard to the TAC. We preferred to use a rule that is easier to understand, as mentioned above, so that the entire precautionary harvestable biomass formed the TAC. This rule was vital for facilitating the decision-making process as no fisher could, in fact, ask to harvest more than the number of legal sized sea cucumbers in the area. So we recommend that the TAC level be based on the precautionary harvestable biomass using the methods described above.

In addition, our assessments in Vanuatu highlighted significant differences both in commercial sea cucumber species stocks and at the different study sites, even within the same province. The TAC should, then, be determined at the scale of each sea cucumber fishery, in other words 1) for each species and 2) at a small enough scale to take into consideration spatial variations in both resource status and fishing activities. This means carrying out stock assessments for every fishery where a TAC will be used because a census at a given site cannot be extrapolated to sites located farther away.

The fisheries-specific TACs can then be added together within a given province or country so as to set a provincial or national TAC.

Holding a prickly redfish, one of the 15 marketable sea cucumber species assessed in six sites in Vanuatu.

Is TAC management really possible in the Pacific Islands region?

The management strategy must, of course, be adapted to the technical, financial, and enforcement capacities available to government agencies over the long term. The results from New Caledonia and Vanuatu are very encouraging in terms of the progress in the technical capacities of fisheries departments after a training session on a GIS (Quantum-GIS software, which is free and easy to use) and the database used to make a quick estimate of stocks after an on-site census, without any specialised statistical skills.

With regard to the financial aspects of the case studies done, the cost of mapping fishing zones before the initial stock assessment varied from USD 47–93 per km^2. Recurrent costs for stock monitoring then ranged from USD 147–514 per km^2. Such costs depend on the extent of the fishing zone and travel costs for fisheries department officers. Finally, the recurrent costs for catch monitoring went from USD 58–204 per km^2 at the study site in New Caledonia, depending on the number of fishing periods (and so, the number of sales days) needed to reach the TAC. At that fishing ground, the increase in sandfish catches from 2008–2012 made it possible to decrease total recurrent costs (stock and catch monitoring) from 10.9 % down to 1.6 % of the profits from sales.

We recommend that TAC management (and minimum lengths) first target fisheries of strong economic interest in order to rationalise management costs e.g. assessments, work with fishers' associations, verification of sales; proportional to expected financial returns from catches. In order to reduce fisheries management costs, the frequency of fishing periods and stock assessments should also be reduced as much as possible, depending on the local environmental and social context. Finally, these costs should be internalised by having all those who benefit take part in funding the programme, on a user-pays basis.

It will not be easy to transpose the management system used at the New Caledonia site to a new social context and a wider geographic scale. Broadening this system to cover multispecies fisheries involving a large number of fisher communities is currently being investigated in New Caledonia (in the Northern Province) and in Vanuatu at the national level. As part of the Melanesian Spearhead Group, a trial run of this system is planned for Papua New Guinea with support from the Vanuatu Fisheries Department and IRD (French Institute of Research for Development), to see if it can be effectively applied in that country and in other interested Pacific Island countries.

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Reference

Conand C. 1989. Les Holothuries Aspidochirotes du lagon de Nouvelle-Calédonie : biologie, écologie et exploitation. Etudes et Thèses, ORSTOM, Paris. 393 p.

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