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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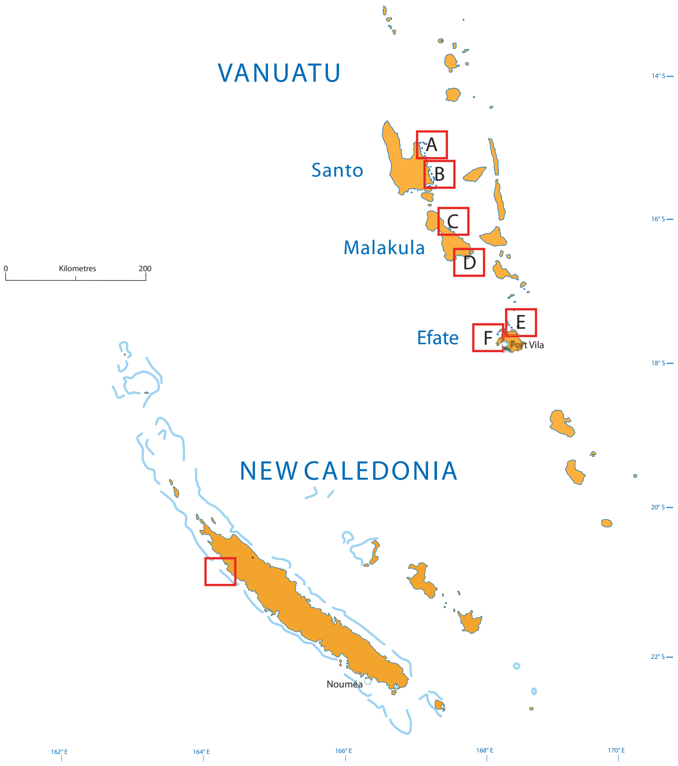

Figure 2. Sea cucumber fishing study sites in New Caledonia (n=1) and in Vanuatu (n=6).

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.

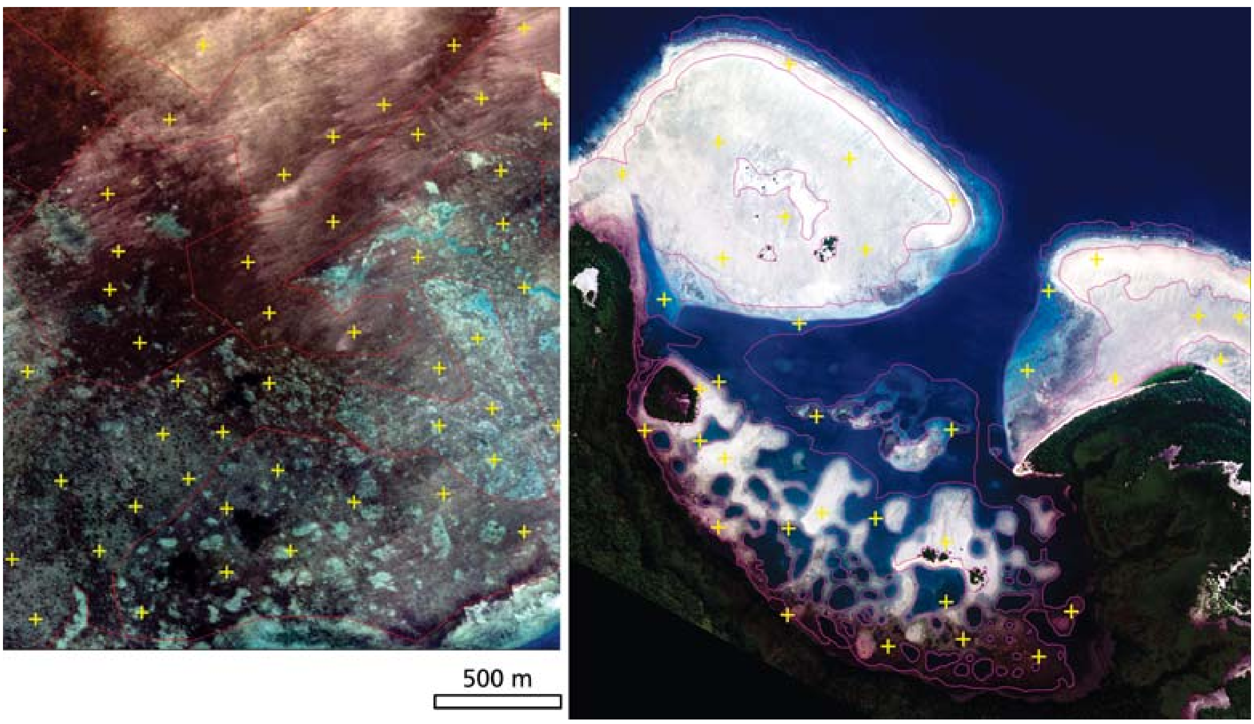

Figure 3. Satellite images showing the fishing areas (extract) and the positions of the transects used for sea cucumber stock assessments. Left: site in New Caledonia, Northern Province, Plateau des Massacres (Quickbird satellite). Right: Vanuatu site, Malakula, Crab Bay (WorldView2 satellite).

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.

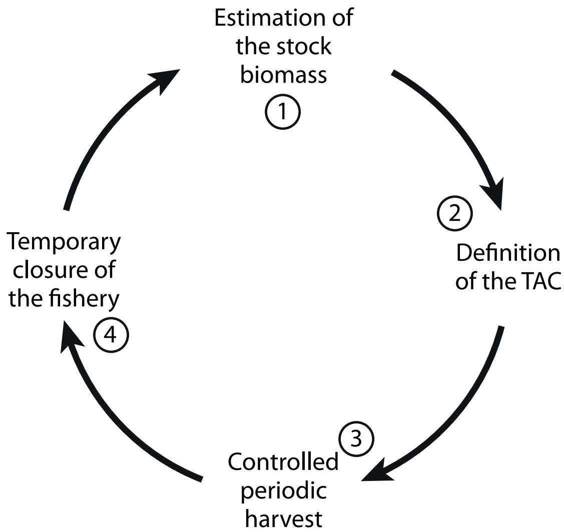

Figure 5. Four-step co-management procedure implemented in the surveyed sandfish, Holothuria scabra, *fishery in New Caledonia between 2008 and 2012.*

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 multispecies 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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