Spatial sea cucumber management in Vanuatu and New Caledonia

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Abstract

Many small-scale sea cucumber fisheries have been declining worldwide at an alarming rate as a result of rapid overharvesting and inefficient management. This paper presents the new common management strategy for Vanuatu and New Caledonia's Northern Province, which was defined as part of an experimental initiative launched in 2008 in 15 small single- and multiple-species pilot fisheries. The results highlighted four main efficiency factors: (i) spatial management and shared governance of fisheries; (ii) defining total allowable catches (TACs) per species and area, using stock biomass; (iii) implementing TAC-based operational spatial management; and (iv) the technical and financial capacities that managing departments need to acquire. Each of these factors was analysed based on the examples examined, and the study shed considerable light on the type of approach that needs to be developed for restoring sea cucumber stocks and improving the management of related small-scale fisheries. The experiment could be tried out in the various Pacific social and political contexts, as the outcomes were encouraging.

Introduction

With stocks and catches dwindling fast in most Pacific islands over the last 20 years or so, governments have started taking emergency action and reviewing their sea-cucumber management policies (Pakoa and Bertram 2013). Standard regulations on small-scale sea cucumber fisheries cover minimum catch sizes per species to reduce juvenile and sub-adult mortality rates; bans on destructive methods and certain types of gear, such as scuba-diving equipment; fishing and transport licensing; processing and exports; and national overall or species-specific quotas (FAO 2012, 2013). As in other tropical areas, however, effectively applying and enforcing these regulations in the Pacific is very difficult and countries are increasingly using moratoria as a last resort (Purcell et al. 2013). National regulations also often overlap local practices based on territorial fishing rights and customary restrictions. Setting aside certain reef areas has, therefore, proved to be one of the most easily accepted restrictions socially and the one best suited to modern regulations, such as rotational management and limited fishing seasons (Aswani 2005; Léopold et al. 2013a). Harmonising both governance levels is a major challenge towards making small-scale coastal fishery management more effective.

If effective fisheries regulations are to be defined and implemented, therefore, space and time scales, biological and fisheries data and appropriate governance methods must be determined. As sea cucumber fisheries could well collapse and biological and environmental information on harvested species is lacking, judicious management strategies need to be developed in order to give a new lease of life to both the species and the industry. This is the backdrop to the research conducted into the spatial management of sea cucumbers in Vanuatu and New Caledonia (Léopold et al. 2013b,c; Léopold 2014).

Although these countries are both minimal contributors to worldwide beche-de-mer exports (FAO 2008; Conand et al. 2014; Affaires Maritimes de Nouvelle-Calédonie, pers. com.), their fishing industries are different. Vanuatu has depleted its stocks, despite introducing minimum catch sizes and a total allowable catch (TAC) of 26 export tonnes in 2005, following peak production years in 1992 and 1994 of nearly 70 t of exported beche-de-mer annually. A national moratorium was introduced from 2008 to 2013 so the stock could recover and a five-year national management plan was launched in 2015, after an experimental phase in 2014 (see this paper). In New Caledonia, beche-de-mer exports appear to have stabilised at 20–40 t year^{-1} compared to 94 t in

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2007 (Vanuatu Fisheries Department, pers. com.). Provincial fisheries departments, however, noted that high-value species catches had fallen off and responded in the 2000s by reviewing regulations, particularly in the Northern Province, where a provincial management plan is currently being developed for implementation as from 2017.

Alternative breeding programmes in pens and at sea developed in tandem in both countries are not discussed in this paper (Purcell et al. 2012; Vanuatu Fisheries Department, pers. com.).

This paper presents Vanuatu and the New Caledonian Northern Province's new common sea-cucumber management strategy. It has been developed based on an experimental approach introduced in 2008 for 15 pilot fisheries. Four of the approach's effectiveness factors are discussed: (i) fishery spatial management and shared governance; (ii) defining TACs by species and area; (iii) spatial TAC-based management implementation; and (iv) managing departments acquiring technical and financial capacity. The information used and outcomes obtained are described and discussed for each factor in order to explain how each approach was gradually rendered operational between 2008 and 2014.

Methods, outcomes and discussion

Spatial management and shared governance of sea cucumber fisheries

Geographic and inter-species variability of sea cucumber stocks

A stock assessment programme for commercial species has been implemented in Vanuatu since 2011 as part of defining a national management plan. Stock biomass and structures were estimated for each species in 13 areas in the island group (Fig. 1) based on a methodology defined by Leopold et al. (2013b). In each area, the marine habitats were mapped by visually interpreting a high-definition satellite image in Quickbird or WordView2 in order to identify the sampling layers. During assessment campaigns, the sea cucumbers were counted and measured in randomly pre-located stations (100 m x 2 m, i.e. 200 m²) in each habitat using a geographic information system (GIS). The sampling effort varied from 8 to 32 stations per km² among the areas, depending on habitat morphology and diversity. The assessments were conducted over two to four days by snorkelers and people on foot with support from local fishermen. Specimen weights were estimated based on available size-weight relationships for each species considered (Conand 1989; Purcell et al. 2009; Skewes T., pers. com.). Total biomass per size class and the corresponding 95% confidence intervals were estimated by statistical inference in proportion to habitat surface area and average biomass per m² for each species considered, based on a normal approximation of average sea cucumber biomass distribution due to the large sampling size (Table 1).

The study shed light on two major features of the stock. Firstly, stocks of commercial species varied considerably within a single zone. This can be partly explained by the zones' environmental potentials, e.g. geomorphology and marine habitats, and harvesting history, as high-value species are often more difficult to find and less abundant than commercially less valuable species (Table 1). Stock levels of a given species could also vary considerably from one part of an island group to another, particularly for less valuable species (Fig. 1). *Holothuria whitmaei* and *Holothuria atra* stocks, for example, stood at between 0.0 and 17.8 t km^{-2} ±2.1. The trend was also observed within a single province in Vanuatu and even a single island (Fig. 1 and Table 1). In New Caledonia's Northern Province, major variations in the main commercial species, *Holothuria scabra*, were also recorded in two areas barely 40 km apart (Fig. 1, Sites 15 and 16).

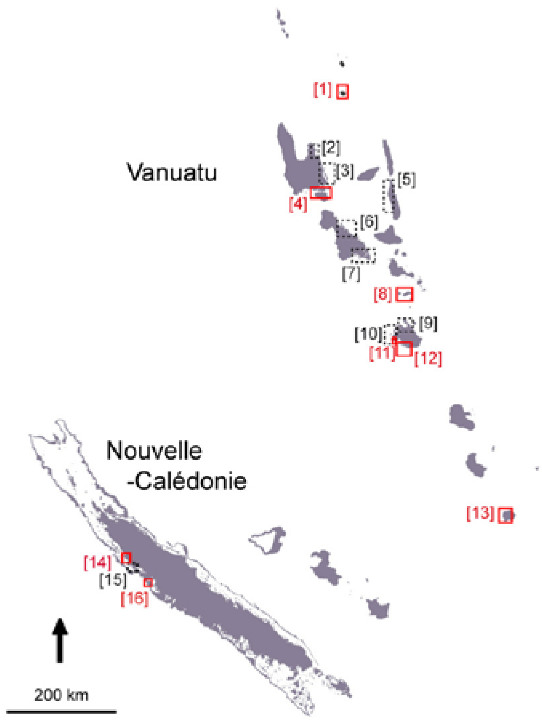

Figure 1. Locations of the 15 study sites where sea cucumber stock biomass assessments were conducted (except for Site 14) and which are fisheries management areas in Vanuatu and New Caledonia (Léopold et al. 2013c for Sites 2, 3, 6, 7, 9, 10 and 15; in this paper for the other sites). Black dotted line: areas where harvesting was authorised in 2014 based on TACs (total allowable catches) per species. Red line: areas were TAC-based studies should be carried out in 2015.

Table 1. Stock biomass (t) per commercial sea cucumber species estimated based on *in situ* assessments carried out in 2011 and 2014 in Vanuatu. The estimated 95% biomass confidence interval is indicated, as is the legal minimum catch size (cm). n: number of sample stations; -: species not observed during the census; *: estimated biomass less than 1 t; **: species not targeted by assessments. The sites are indicated in Figure 1.

Species	Min. catch size (cm)	Total stock biomass (t)												
		Site 1 9.9 km² n = 150	**Site 2** 10.1 km² n = 76	**Site 3** 14.5 km² n = 182	**Site 4** 18.6 km² n = 216	**Site 5** 4.5 km² n = 81	**Site 6** 14.0 km² n = 199	**Site 7** 24.5 km² n = 286	**Site 8** 16.2 km² n = 207	**Site 9** 15.0 km² n = 171	**Site 10** 11.7 km² n = 266	**Site 11** 1.8 km² n = 54	**Site 12** 5.8 km² n = 186	**Site 13** 15.9 km² n = 273
Low value														
Bohadschia marmorata	15	-	*	*	*	-	*	*	-	*	*	-	9.5 ±8.8	-
Holothuria atra	20	39.6 ±11.4	19.4 ±15.0	54.4 ±48.4	10.8 ±4.7	8.7 ±6.0	70.7 ±26.3	247.6 ±70.2	86.8 ±21.6	15.5 ±5.2	23.9 ±5.4	*	15.6 ±4.5	282.4 ±33.2
*Holothuria coluber***	40	-	-	-	-	-	-	-	-	-	-	-	-	-
Holothuria edulis	20	-	*	*	*	-	1.0 ±0.6	*	*	*	*	*	*	-
*Holothuria flavomaculata***	40	-	-	-	-	-	-	-	-	-	-	-	-	-
Holothuria fuscopunctata	40	-	*	*	*	*	*	*	*	*	*	-	*	-
Pearsonothuria graeffei	30	-	-	-	-	*	-	-	*	-	-	*	-	-
Stichopus vastus	20	-	-	-	-	-	-	-	-	-	-	-	2.0 ±2.1	-
Thelenota anax	40	-	*	*	-	*	*	*	-	*	*	-	*	-
Medium value														
*Actinopyga lecanora***	20	-	-	-	-	-	-	-	-	-	-	-	-	-
Actinopyga mauritiana	25	*	*	*	*	*	*	*	6.8 ±4.5	*	4.0 ±1.6	1.5 ±1.1	3.0 ±1.3	14.9 ±4.3
Actinopyga miliaris	30	*	*	*	-	-	*	*	*	*	*	*	*	*
Actinopyga palauensis	30	-	-	-	-	-	-	-	-	-	-	-	-	-
Bohadschia argus	30	5.6 ±3.6	*	*	12.6 ±7.7	16.4 ±7.1	11.5 ±7.1	31.8 ±14.4	24.4 ±9.0	6.4 ±3.5	6.8 ±3.1	5.3 ±2.5	7.1 ±3.3	*
Bohadschia vitiensis	25	-	*	7.6 ±4.7	3.0 ±3.3	*	14.3 ±9.1	40.8 ±31.0	*	*	*	-	10.4 ±4.0	*
Stichopus chloronotus	20	7.6 ±4.2	28.1 ±24.7	4.3 ±2.2	12.5 ±6.5	*	10.4 ±8.0	9.4 ±6.4	18.2 ±7.5	9.0 ±4.4	14.8 ±4.1	2.3 ±1.4	*	40.5 ±11.1
Stichopus herrmanni	35	-	*	*	*	-	7.8 ±6.5	42.9 ±30.4	7.0 ±5.0	*	*	*	6.3 ±3.6	-
*Stichopus horrens***	20	-	-	-	-	-	-	-	-	-	-	-	-	-
Thelenota ananas	35	-	*	10.5 ±7.1	15.1 ±8.9	*	5.5 ±5.5	11.1 ±7.2	16.0 ±9.0	10.1 ±6.7	*	7.3 ±4.7	*	*
High value														
Holothuria fuscogilva	35	-	*	*	*	*	*	*	-	*	*	-	-	-
Holothuria lessonni	25	-	-	-	*	-	-	-	-	-	-	-	-	-
Holothuria scabra	20	-	*	*	-	-	*	*	-	*	*	-	1.4 ±1.9	-
Holothuria whitmaei	30	*	*	*	13.6 ±10.4	5.0 ±4.0	1.5 ±1.4	10.9 ±9.0	55.1 ±15.6	*	*	-	*	20.2 ±8.9

Defining local management or social and environmental systems

As a result of the biological observations in 15 areas, i.e. 13 in Vanuatu and two in New Caledonia, the authorities felt it would be appropriate to introduce spatial management of sea cucumber fisheries using fishing rules based on species and areas to keep catch sizes compatible with local environmental capacities. Spatial management needed to be made official by way of regulations defining fishing requirements and clearly defining the roles and duties of the various levels of government, i.e. local, provincial and national in Vanuatu, and local and provincial in New Caledonia. A shared fisheries governance system was subsequently set up, granting exclusive communal fishing rights to local communities and involving them in fishing-related decisions in their areas, e.g. regarding seasons and allowable catch levels. One of the major issues was the involvement of local fishermen and communities in the management system (Leopold et al. 2013b) while recognising that informal co-management undertakings are vulnerable to internal conflicts and rivalries. In one of the New Caledonian areas (Fig. 1, Site 15), the fact that there was no legal framework enabled a minority of fisherman to circumvent informal arrangements between the community and the provincial fisheries department by using their social ties, leading to overharvesting from late 2011 onwards. In response to local demand, the co-management system launched in 2008 was formalised in November 2014 so that management decisions could be made official and the local authorities could enforce joint fishing rules.

Each fishery ultimately constitutes a social and environmental system whose geographic boundaries are defined through an operational compromise between sometimes conflicting factors, i.e. (i) the state of the stocks; (ii) local fisheries arrangements, including possible territorial access rights; (iii) existing administrative and traditional boundaries; and (iv) management and operating cost containment (see below). In both Vanuatu and New Caledonia, the systems were small, covering a few dozen kilometres at most and containing populations in the hundreds or thousands. Taken together, they formed a patchwork of shared-governance management areas that could eventually reach approximately 20 in number in each country (Fig. 1). The boundaries are still in the process of being defined, particularly in New Caledonia.

Defining species- and management-area-based TACs using stock biomass

As the general management objective is not to endanger natural sea-cucumber stock replenishment, the most effective rule has been determining sustainable catch volumes per species and management area. Such community-based TACs are easy to understand and, according to fishers and fisheries departments in both Vanuatu and New Caledonia, a highly operational measure.

TACs are the estimated biomass of the harvestable stock at the time of the assessment, i.e. all the specimens that have reached the legal catch size. They are expressed in tonnes of live sea cucumbers so as to overcome uncertainty over dry-weight conversion factors. Specifically, the criterion for TACs is the lower limit for the 95% confidence interval of estimated harvestable stock (Léopold et al. 2013c). Also TACs cannot exceed 20 to 30% of the total stock biomass so as to prevent overharvesting if few juveniles or sub-adults were recorded during evaluation. In other words, TACs are quite probably underestimated catch volumes, but such a precaution was felt to be warranted during the stock recovery stage and was readily accepted by fishing communities in New Caledonia and Vanuatu.

Average sea cucumber density was not used as a criterion for setting TACs, despite the fact that this indicator is often recommended for sea-cucumber fisheries management, as it did not lead to accurate TAC estimates in the areas investigated. Also, insufficient biological data were available for most species for determining the density threshold above which a particular stock could be harvested and which probably varied from one area to another. This was also why we did not use the hypothetical biological parameters for natural mortality, specimen growth or recruitment rates to define TACs.

Implementing TAC-based spatial management

Experiments in New Caledonia and Vanuatu

TAC-based, species-specific spatial management has been implemented in New Caledonia since 2008 and Vanuatu since 2014 for single-species *Holothuria scabra* harvesting (Fig. 1).

As far as New Caledonia is concerned, the positive biological and economic effects of the approach were measured both in *Holothuria scabra* stocks and catches. The particular area's total biomass rose from 115 t ±30 in 2008 to 307 t ±49 in 2012 and aggregate yearly catches from 20 t (~ USD 136,000) to 50 t (~ USD 340,000) for approximately 60 fishers (Léopold et al. 2013b). Stocks, and therefore TACs, then fell in 2013, reaching 152 t ±36 in 2014. The fall coincided with heavily-exceeded TACs in 2011 to 2013, although natural causes could also be involved. Despite this recent trend, observations demonstrated that TAC-based management had performed well for this species during that period. The effective performance in turn strengthened the system against internal social tensions over TAC compliance. Biomass fluctuations also suggested that it was difficult to predict changes in *Holothuria scabra* stocks, even over the short term, once the TAC had been harvested and that one year's TAC should not be applied to the following year without first being re-evaluated.

With regard to Vanuatu, the fisheries department reviewed minimum catch sizes for 23 sea cucumber species in 2014 and authorised 11 for harvesting in seven management areas, which amounted to 35 TACs for a total of 82 t (Table 2). No TAC exceeded 6 t (except for *Holothuria atra* in one area at 30 t) and 60% of TACs were below 1 t, showing how low overall stocks were. The low allowable catches were used to trial the new management system as well as to provide extra income for communities in areas where the stock biomass had been estimated. The impact of harvesting can be estimated starting in 2016, when the next stock assessments will be conducted in the areas investigated.

Supervised pulse fishing strategy and fishing ground rotation

When TACs were implemented in New Caledonia and Vanuatu, the question of catch monitoring and allowable catch compliance was immediately raised. In the areas mentioned above, TACs proved an effective means of restricting catches if an officer or authorised agent of the fisheries department was on site to supervise landings or first sales to middlemen or processing companies. When on-site checks were not carried out by a government authority, unauthorised catches, i.e. exceeding TACs or of prohibited species, were later reported, despite arrangements reached with the local communities who had endorsed or even requested sending a monitoring officer as a condition for opening the harvesting season.

A pulse fishing strategy was, therefore, successfully implemented to enhance the effectiveness and contain the cost of TAC monitoring, due to the large number and/or wide dispersal of fishers in the management areas. Fishing was allowed in each area for a very short time (one to five days) depending on the fisheries department's ability to monitor it. Such a small fishing window also facilitated joint monitoring of the TACs and feedback to fishers.

In Vanuatu, the strategy additionally featured a rotational pulse fishing system, which required that fishing be allowed in only one area at a time, thereby de facto restricting the number of harvests per year, as regulations required prior public notification periods for each open season. The fisheries department could thereby avoid spreading the human and financial resources available for assessments and for monitoring TACs too thinly.

The rotational system was not considered for New Caledonia, as no moratorium, which would otherwise have facilitated implementation, had ever been imposed. For practical reasons, spatial TAC

Table 2. Total allowable catch (TAC, in t) per sea cucumber species at each site where harvesting was authorised in Vanuatu in 2014. -: prohibited species; *: species that is not harvested in spite of its TAC due to its low value. The sites are indicated in Figure 1.

Species	Total allowable catch (t)						
	Site 2	Site 3	Site 5	Site 6	Site 7	Site 9	Site 10
Low value							
*Holothuria atra**	-	0.5	-	0.5	30.0	6.0	0.5
*Holothuria edulis**	-	-	-	0.5	0.5	-	0.5
Medium value							
Actinopyga mauritiana	-	-	-	-	-	-	1.0
Bohadschia argus	-	0.5	6.0	2.0	-	1.5	1.8
Bohadschia vitiensis	0.5	1.3	-	2.5	4.0	-	0.5
Stichopus chloronotus	-	0.5	-	1.0	0.5	2.0	3.5
Stichopus herrmanni	-	-	-	0.5	6.0	-	0.5
Thelenota ananas	-	0.5	-	0.5	2.0	1.3	-
High value							
Holothuria fuscogilva	-	-	-	-	0.5	-	-
Holothuria scabra	-	-	-	-	0.5	-	-
Holothuria whitmaei	-	-	-	0.5	1.0	-	-

management could not be conducted simultaneously throughout the provincial maritime domain, which covers hundreds of square kilometres where sea cucumbers could be harvested. It instead gradually spread across the various identified management areas (Fig. 1) giving preference to areas where sea cucumber stocks were highest and most endangered or where sea cucumber harvesting was less complex (e.g. small numbers of fishers or fewer targeted species). In such areas, a pulse fishing strategy could be ruled out if real-time catch monitoring can be effectively conducted. A provincial management plan should be operation by 2017 for the Northern Province.

Acquiring the necessary technical and financial capacities

As in all fisheries management systems, TAC-based spatial sea-cucumber fisheries management must be tailored to the technical and financial resources that the government, particularly its fisheries department, is able to deploy over the long term, in accordance with local regulations.

Technical capacity building for fisheries departments

As part of the sea cucumber management plan development exercise, both the New Caledonian and Vanuatu fisheries departments underwent gradual capacity building in terms of stock assessment methods, GIS use (QGIS freeware) and biological data processing. The BDMer 2.0 (Léopold 2014) data management and processing tool was developed to host the sea cucumber census data and semi-automatically estimate stocks and TACs for all the management areas and commercial species. So the fisheries departments have been able to use this tool to gain access to assessment outcomes within two days of the biological assessments, without needing any outside statistical or scientific expertise. The BDMer 2.0 database can be accessed from a laptop to analyse data on site in outlying local communities and on-line (http://bdmer.ird.nc/) to share information remotely and back up data.

This kind of tool is considered vital for the adopted management strategy. Fisheries departments can use it to independently implement more complex systems requiring regular biological data gathering and more sophisticated statistical processing.

Containing management costs and increasing income

Apart from funding for building management staff's technical capacities, the costs associated with this system are incurred mainly by biological monitoring and TAC surveillance. The cost of mapping fishing areas prior to assessment is less than USD 100 km^{-2} (Léopold et al. 2013b for Sites 6, 7, 9 and 15, Fig. 1; in this paper for the other sites [except for Site 14]). Recurrent costs related to stock monitoring depend on how large and remote the fishing grounds are, varying between USD 120 and 500 km^{-2} and they are inversely proportional to surface area. Recurrent catch monitoring costs come to approximately USD 50 to 200 km^{-2}, depending on how many fishing seasons are authorised before reaching the TAC. Such costs are lower when harvesting is carried out in only one or two seasons.

In overall terms, total recurrent costs (stock and catch monitoring) in Vanuatu came to approximately 60–70% of first sales in 2014, owing to very low TACs. On the New Caledonian site, however, because *Holothuria scabra* catches had risen between 2008 and 2012 following stock restoration, the ratio fell from 11% to 2%. These results show how important it is to authorise harvesting periods rationally based on stock levels, TACs and the expected financial benefits. In order to make harvesting more profitable in Vanuatu, harvesting could be authorised only once every two to five years with TACs per species above 2 t (as opposed to the 71% of TACs issued in 2014 below 2 t). On the other hand, harvesting at the New Caledonia pilot site, where *Holothuria scabra* stocks are richer, has been authorised every year since 2008 for one to three days each month until the TAC has been reached. Harvesting (and, therefore, stock assessment) frequency must be as low as possible, depending on local environmental, social and economic factors.

The costs were partly internalised by charging the system's beneficiaries. In Vanuatu, the 2014 on-site catch monitoring costs were paid for by three operators who had purchased sea-cucumber processing licences. The annual licensing fee was proportional to the authorised amount of sea cucumber for processing at USD 1 per kg wet weight, whereas licenses are free of charge in New Caledonia. The fishers and local communities made payment in kind by taking part in the assessments and providing small vessels. The overall contribution from the government was higher in New Caledonia's Northern Province than Vanuatu, where the department of fisheries enjoys more modest recurrent budget allocations.

Conclusion

This study provides examples of the types of approach that could be developed for improving sea-cucumber stock management. As the trials are monitored in Vanuatu and New Caledonia, it will become apparent whether the biological and financial objectives have been reached nationally and/or provincially. Although not exclusive to small-scale sea cucumber operations, the heavy pressure exerted by the industry and/or local fishers to increase TAC levels are weaknesses that will need to be overcome.

Against a backdrop of worldwide overharvesting in small-scale sea cucumber fisheries, the results of TAC-based spatial co-management would appear to justify extending this technique to other countries with modest financial and/or technical capabilities. The extent to which the four efficiency factors observed in the study can be generalised, however, remains to be seen in social and political contexts that differ from those in the Pacific region — something that may involve hundreds or thousands of fishers. The regular progress achieved in computer skills (GIS, databanks, data processing, etc.) by the fisheries and other government departments and institutional partners in these countries is an encouraging sign.

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