Working Paper 8

Original: English

Managing sea cucumber fisheries using stock biomass estimates and spatial catch quotas: experience from New Caledonia and Vanuatu

Marc Léopold, Nathaniel Cornuet, Serge Andréfouët, Zaccharie Moenteapo, Cécile Duvauchelle, Jason Raubani, Jayven Ham and Pascal Dumas

Managing sea cucumber fisheries using stock biomass estimates and spatial catch quotas: experience from New Caledonia and Vanuatu

Marc Léopold[1,2], Nathaniel Cornuet[3], Serge Andréfouët[1], Zaccharie Moenteapo[3], Cécile Duvauchelle[1], Jason Raubani[2], Jayven Ham[2] and Pascal Dumas[1,2]

[1] IRD (Institut de Recherche pour le Développement), U227 COREUS2, BP A5, 98848 Nouméa cedex, New Caledonia
[2] Fisheries Department of Vanuatu, Private Bag 9045, Port-Vila, Vanuatu
[3] Fisheries Department of the Northern Province, BP 41, 98860 Koné, New Caledonia

Introduction

1. To sustain sea cucumber fisheries in the long term, the fundamental goal is to implement precautionary management that maintains sea cucumber resources above their biological recovery threshold, whilst also supporting sustainable harvesting activity. Uncertainty in resource assessments needs to be taken into account to establish regulatory measures in the case of sea cucumbers. However, approaches based on indicators and reference points have been considered expensive and difficult to implement in data-limited contexts, such as those found for small-scale fisheries in poorly developed countries.

2. This study describes the strategy applied to New Caledonia and Vanuatu for the operational management of sea cucumber fisheries in data-limited contexts. Specifically, an adaptive co-management system was put into effect in 2008 in New Caledonia to manage a previously depleted small-scale single-species sea cucumber fishery. Biological and economic performance and the key factors for success of the co-management system have been evaluated. The methodology for estimating the stock biomass has been generalized to multispecies sea cucumber fisheries in Vanuatu, where a 5-year moratorium was established in 2008. Lessons from these case studies provided fresh insights into the spatial up-scaling (i.e. from one site to multiple sites) of the resource assessment method and have been used to develop an operational framework to inform sea cucumber fisheries policy in these two countries.

Methods

The small-scale sandfish fishery in New Caledonia

3. The study focused on the main fishery for sandfish *Holothuria scabra*, one of the highest-value sea cucumber species, in New Caledonia. This was a single-species fishery located in the Northern Province on a 26 km² shallow coastal reef flat covered by seagrass beds. The fishery has been traditionally operated and ruled since the 1990s by the fishers from the Melanesian village of Boyen (200 inhabitants). The only restrictive provincial fishing regulations were the ban on night fishing and a minimum harvest length of 20 cm (fresh whole sandfish). In the early 2000s, fishers reported a decline in commercial sized sandfish, suggesting that the resources had been depleted. Thus, landowners and the local fishers' organization temporarily closed the fishery in 2007. They then requested assistance from the provincial Fisheries Department to define the catch level according to the biological capacity of the fishing ground.

4. To define an appropriate TAC, the harvestable stock biomass (i.e., all legal-sized animals) was used here as the local reference indicator (hereafter HSB, in tonnes of live-weight animals) to address the risk of recruitment overfishing.

Estimating the harvestable biomass of the fishery

5. The HSB was estimated eight times between June 2008 and April 2012 through field census using a rapid and cost-effective survey method. The observation units were 100 m-long and 2 m-wide belt transects (i.e. 200 m^2 per transect). All individuals were counted and measured to the nearest 5 mm (length (L) and width (W)). Individual weight (P) was derived from Equation 1 (Purcell et al. 2009).

6. Depending on the stage of the tides, counts were conducted either by walking on the reef flat or snorkelling in areas down to 2 m depth. The teams consisted of two observers comprised of fishers and Fisheries Department officers.

7. A map of marine habitats was used to spatially stratify data collection in the fishery. The mean sampling rate has increased across the study period from 2.5 transects.km^{-2} in 2008 to 4.2 transect.km^{-2} since 2009. The habitat map was created using a high resolution Quickbird satellite image as large-scale reef geomorphology maps derived from Landsat 7 sensors were inadequate in resolution for the purpose of this study. The image was imported into a geographical information system (GIS) and processed following a simplified, user-oriented protocol derived from Andréfouët (2008). Twenty-five polygons were defined reflecting different habitat zones. Habitat surface areas were calculated through GIS. This simple mapping process was used to compute stock estimates using habitat surface areas (in km^2) and sea cucumber density (in individual.km^{-2}).

8. Count data were integrated into a database that performed statistical estimations using user-defined algorithms. The mean density (in individual.km^{-2}) and biomass (live-weight, in kg.km^{-2}) of all and legal sized sandfish, with associated standard error, were firstly calculated within each habitat zone. Secondly, the total and harvestable stock abundance and biomass, and the mean density of sandfish were estimated. The associated 95% confidence intervals of all estimates were calculated. The reference HSB corresponded to the lower limit of the 95% confidence interval of the estimated harvestable stock biomass (i.e. live-weight, legal-sized animals) at the time of survey.

Generalizing the assessment of the stock biomass for multispecies sea cucumber fisheries

9. The harvestable stock biomass was estimated for 15 low- to high-value commercial sea cucumber species at 7 sites in Vanuatu, located on the islands of Malikolo, Maskelynes, Santo, and Efate. A map of marine habitats was created in each site using a high resolution satellite images following the procedure described above. The habitat maps of the sites exhibited a much greater diversity than the New Caledonian study site, with 37 to 80 habitat polygons per site. Sampling efforts reached between 171 and 286 transects per site, i.e. from 10 to 15 transect.km^{-2}. Data collection was conducted between 2011 and 2013 using the same methods as previously described for the survey in New Caledonia. The length-weight relationships for each species were taken from Conand (1989).

Results

Biological change in the New Caledonia sandfish fishery

10. The harvestable and total stock of sandfish regularly increased across the study period, emphasizing the strong positive biological effects of the co-management regime across all of the size classes. The reference HSB raised from 13 to 85 t. Similarly, the total biomass markedly increased from 115 ± 30 t (95% confidence interval) to 307 ± 49 t. While the HSB represented 11% of the total stock in 2008, it reached 28% in 2012. The increase in HSB was spatially restricted to the reef flat area perceived as very productive by local fishers.

11. Other biological indicators showed less marked and irregular fluctuations compared to the HSB across the study period. The mean sandfish density increased from 18,300 to 75,400 individual.km^{-2} between 2008 and 2012, even though a sharp decline occurred in 2011 due to unidentified factors.

Integrating the HSB in a management cycle in the New Caledonia sandfish fishery

12. The fishers' organization has developed an iterative and adaptive management procedure to set fishing restrictions based on biological monitoring data. The HSB was implemented following an innovative co-management cycle structured in four steps (Fig. 1).

    i. The reference HSB was estimated following the methods described above.

    ii. The HSB was discussed between the Fisheries Department officers and the fishers' organization to set a collective TAC (live weight) equal to or lower than the reference HSB. Fishers were therefore allocated the lower limit of the 95% confidence interval or a lower level of the total harvestable biomass. As fishers eviscerated sea cucumbers at sea and marketed 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 the recommendations of Skewes et al. (2004).

    iii. The fishery was opened for short periods of time (one to three days each) to control the level of catch and prevent illegal fishing, followed by interval closures of one to four weeks. There were from two to seven open periods in each co-management cycle, depending on the size of the TAC and the fishing yields. Local fishing rights were regulated through both individual quotas per open period, to prevent a "race" for sea cucumbers and individual appropriation of the TAC, along with annual fishing licenses per vessel. The total number of licenses has been limited to 27 since 2009. Sales to middlemen took place immediately after each open period. Sale prices, individual catch and the cumulative catch sold since the first opening day of the co-management cycle were monitored by a Fisheries Department officer and a leader of the fishers' organization to check compliance with the TAC.

    iv. The fishery was closed again as soon as the TAC was reached, until the fishers' organization planned a new survey to estimate the HSB, one to eight months later, marking the beginning of a new co-management cycle.

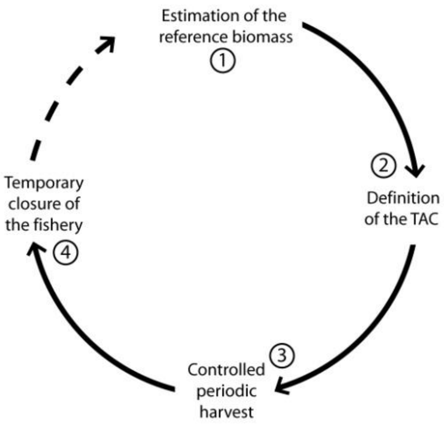

Figure 1. Four-step co-management procedure implemented in the surveyed sandfish *Holothuria scabra* fishery in New Caledonia between 2008 and 2012.

Management outputs

13. The co-management cycle was repeated eight times between 2008 and 2012 (i.e. once or twice per year) in the sandfish fishery, and each time the TAC was updated based on the HSB. Catches recorded at each cycle increased from 8 to 35 t over the period. Excess catches have been observed since 2011 in particular, as returns from catches generated high incentives among fishers to increase allowed catches.

14. The mean number of fishers increased from 30 to 61 while the income gained by each fisher increased from 175,000 XFP to 340,000 XFP between 2008 and 2012 (~USD 1900 to USD 3700). Annual catches raised from 20 t in 2008 to 50 t in 2012, generating 13,000,000 XFP and 31,500,000 XFP respectively (from ~USD 138,000 to USD 341,000). These results showed the excellent performance of the fishery, both biologically (increased resource biomass) and economically (increased incomes).

Estimates of the harvestable biomass in Vanuatu multispecies fisheries

15. In Vanuatu, the HSB of sea cucumber stocks in the 7 study sites was very low for almost all surveyed species. The reference HSB reached less than one tonne for 67% to 86% of the species in all sites. This finding suggested that the sea cucumber resources had recovered little, after 4–5 years of moratorium. In particular, the reference HSB for sandfish was lower than one tonne. This was well below the level observed in New Caledonia before the launching of the co-management process (i.e. 13 t).

16. Although most sea cucumber stocks appeared depleted in the survey sites, biomass estimates showed marked spatial difference. Specifically, total stock and HSB of four low to medium-value species were significantly higher in the Maskelynes Islands. The reference HSB of these species represented from 11% to 49 % of the total stock biomass.

17. The current moratorium on sea cucumber harvesting in Vanuatu at the time of the surveys did not allow for the implementation of the HSB in the study sites in this country. However, HSB advocated for an extension of the fishing ban for all species given the very low expected catch and incomes.

Discussion

Addressing uncertainty issues in stock estimates

18. We did not use minimum density as a reference indicator although a minimum density of sea cucumbers has commonly been recommended as a biological threshold for fisheries. Indeed, quantitative data on the related density-dependent processes (e.g. recruitment, mortality) is lacking for most exploited sea cucumber species. Additionally, a change in mean density of sea cucumbers would not directly and accurately determine a percentage increase or decrease in catches.

19. The study provides evidence that the management system has performed more efficiently than previous regulations set by the provincial Fisheries Department in New Caledonia, in particular the minimum harvest size for sandfish. Difference in management outputs may come from higher biological performance of and compliance with the TAC and associated regulatory measures in the area. Conservative levels of RB have probably allowed for harvesting only part of the legal-sized biomass and, consequently, for setting a lower fishing mortality than that induced by the harvest size limit alone. TAC and short open fishing periods may have also mitigated the opportunistic harvest of sandfish, as observed in other high-value sea cucumber stocks (Purcell et al. 2011). Overall local fishing restrictions have very likely contributed to the rapid recovery of sandfish resources and the resulting increase in catches, which have both urged co-managers to enforce the local regulatory measures in the absence of permanent outside controls. The unexpected rapid recovery of the resources in New Caledonia survey site may be partly attributed to high recruitment rates of sandfish in the area due to higher initial density (i.e. around 20,000 individuals.km^{-2}) compared to survey sites in Vanuatu and other Pacific countries, where depleted sea cucumber stocks showed low replenishment rates.

20. More globally, these results suggest that the enforcement of very conservative minimum harvest sizes (i.e. larger than maturity sizes) of commercial sea cucumber species would likely efficiently sustain resources. In particular, this seems achievable for exported species in Pacific Islands countries at affordable costs for government agencies as the limited number of export avenues would facilitate catch monitoring when sea cucumber are not consumed locally, as in New-Caledonia and Vanuatu. More biological studies are however needed to improve knowledge on sizes at maturity for all commercial sea cucumber species.

Incorporating the reference stock biomass into spatial multispecies fisheries policy

21. This study proposes an innovative TAC-based management strategy to artisanal sea cucumber fisheries based on both fine-scale and large-scale regulatory measures. The spatial and social up-scaling of the co-management system will be challenging as it has only been applied to a single species fishery to date. The generalization of this system to multispecies fisheries involving a large number of fisher communities is currently being investigated at a provincial and national level in New Caledonia and Vanuatu, respectively, using the practical assessment and management guidelines provided by this study. A spatial management framework is currently under development to fine-tune fishing regulations to the ecology of the resources and the activities of the fishers. Indeed our results suggest that multispecies sea cucumber fisheries management at a large spatial scale should take into account spatially-explicit regulatory measures set for each commercial species separately, given marked difference in biomass estimates among fishing grounds.

22. This framework should also be rationalized with the technical, financial, and enforcement capacities available to government agencies in the long term. In particular fisheries management costs (i.e. for monitoring, participative planning and decision-making, enforcement and controls) should be internalized, proportional to expected financial returns from catches and supported by all beneficiaries following the widely accepted "user-pays principle". In our case studies, the start-up costs of the HSB monitoring ranged from 4300 XFP.km^{-2} to 8600 XFP.km^{-2} (from USD 47 km^{-2} to USD 93 km^{-2}). The recurrent costs of the HSB monitoring ranged from 13,600 XFP.km^{-2} to 47,700 XFP.km^{-2} (from USD 147 km^{-2} to USD 514 km^{-2}). These costs varied according to the extent of the survey area and the transport costs for Fisheries Department officers. Recurrent catch monitoring costs ranged from 5400 XFP.km^{-2} to 18,800 XFP.km^{-2} (from USD 58 km^{-2} to USD 204 km^{-2}) in the New Caledonian study site according to the number of fishing periods (and therefore sale dates) opened to reach the TAC. In this fishery, total recurrent costs averaged 22,200 XFP. km^{-2} (USD 240 km^{-2}) in 2008 and 2012, i.e. 10.9% and 1.6% of the returns from sandfish catches, respectively.

23. The shift from high to low value species and the slow replenishment of severely depleted sea cucumber fisheries would undermine the financial levy of Fisheries Departments to support HSB assessments and co-management processes. Management costs may however be rationalized with expected returns from catches by 1) implementing the spatial management framework in key sea cucumber fisheries, 2) setting fishing, processing and/or exporting license fees proportionally to allowed catches, and/or 3) decreasing the frequency of open fishing periods and HSB assessments in depleted and/or low-value fisheries.

Funding

24. This study was funded by the French Ministry of Environment (LITEAU Program, COGERON Project), the French Ministry of Foreign Affairs (Pacific Fund), the Government of New Caledonia, the Northern Province of New Caledonia, and the Government of Vanuatu (Fisheries Department).

Cited references

Andréfouët, S. (2008) Coral reef habitat mapping using remote sensing: a user vs producer perspective. Implications for research, management and capacity building. *Journal of Spatial Science* 53: 113–129.

Conand, C. (1989) *Les Holothuries Aspidochirotes du Lagon de Nouvelle-Calédonie: Biologie, Ecologie et Exploitation*. Paris, France : ORSTOM.

Purcell, S.W., Gossuin, H. and Agudo, N.S. (2009) *Status and Management of the Sea Sucumber Fishery of La Grande Terre, New Caledonia*. Studies and Reviews No 1901, Penang, Malaysia: WorldFish Center.

Purcell, S.W., Mercier, A., Conand; C., Hamel, J.F., Toral-Granda, M.V., Lovatelli, A. and Uthicke, S. (2011) Sea cucumber fisheries: global analysis of stocks, management measures and drivers of overfishing. *Fish and Fisheries* DOI: 10.1111/j.1467-2979.2011.00443.x

Skewes, T., Smith, L., Dennis, D., Rawlinson, N., Donovan, A. and Ellis, N. (2004) *Conversion Ratios for Commercial Bêche-de-mer Species in Torres Strait*. Cleveland, Australia: CSIRO.