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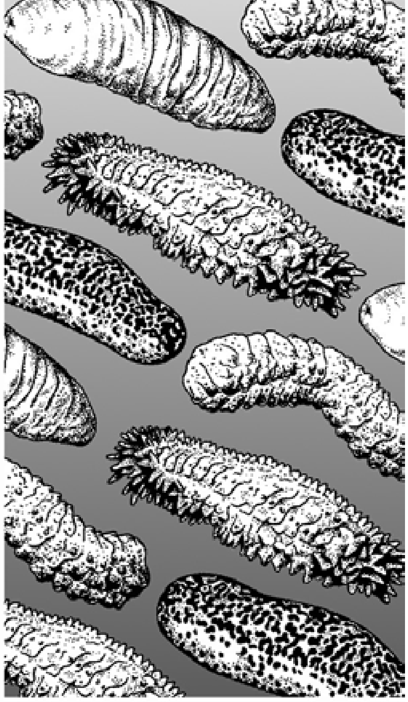

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Editorial

The 35th issue of Beche-de-mer Information Bulletin has eight original articles, all very informative, as well as information about workshops and meetings that were held in 2014 and forthcoming 2015 conferences.

The first paper is by Marc Léopold, who presents a spatial management strategy developed in Vanuatu and New Caledonia (p. 3). This study provides interesting results on the type of approach to be developed to allow regeneration of sea cucumber resources and better management of small associated fisheries.

Species richness, size and density of sea cucumbers are investigated by Roger G. Dolorosa (p. 10) in the Tubbataha Reefs Natural Park, Philippines. The data complement the nationwide monitoring of wild populations.

Ana Setyastuti and Pradina Purwati (p. 19) provide a list of all the species included in the Indonesian *trepang*, which have ever been, and still are, being fished for trade. The result puts in evidence 54 species, of which 33 have been taxonomically confirmed.

Frédéric Ducarme (p. 26) describes the result of a survey that was conducted on the coral reefs in the north of Baa atoll (Maldives) for two months in 2014. This study increases the number of holothurian species recorded in the Maldives to around 24.

Nurzafirah Mazlan and Ridzwan Hashim (p. 32) give the first report of induced spawning and larval rearing of *Holothuria scabra* in Malaysia. Survival rate of 4.2% was recorded from three successful spawnings.

Thierry Lavitra et al. (p. 37) analysed the effect of the size of juveniles released within and without nurseries inside marine pens in Madagascar. This experiment showed that the use of nurseries is not necessary in farming sites with a low density of predators and that juveniles less than 5 g can be released in these sites.

Haruko Koike et al. (p. 42) report the result of an independent baseline fishery survey conducted around the islands of Old Providence and Santa Catalina, Colombia in 2014. Total population size was considered too low to sustain a fishery.

Vianys Agudelo and Adriana Rodríguez (p. 50) report handling conditions, water quality and limitations associated with the spontaneous reproduction of *Stichopus* sp. from Caribbean Sea, Colombia. The larval culture they made is described.

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Chantal Conand (p. 58) reports information on lesser known *trepang* markets, including Pyongyang (Democratic People's Republic of Korea), Pusan (Republic of Korea) and San Francisco. Choo Poh Sze and Chantal Conand (p. 60) also give information on the sea cucumber products present at the last China Fisheries Exposition.

There were many workshops and meetings about sea cucumbers in 2014. A summary of the presentations / discussions is given in this issue, with details about conferences that will be held in 2015. Readers will also find web-site addresses with sea cucumber movies and general information and observations on holothuroid juveniles.

Bonne lecture !

Congratulations are due to François Michonneau, whose thesis ''Species limit and diversity in sea cucumber'' won him his PhD at the University of Florida.

Igor Eeckhaut

Spatial sea cucumber management in Vanuatu and New Caledonia

Marc Léopold[1,2,*], Jayven Ham[2], Rocky Kaku[2], Sompert Gereva[2], Jason Raubani[2] and Zacharie Moenteapo[3]

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 m^2) in each habitat using a geographic information system (GIS). The sampling effort varied from 8 to 32 stations per km^2 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 m^2 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).

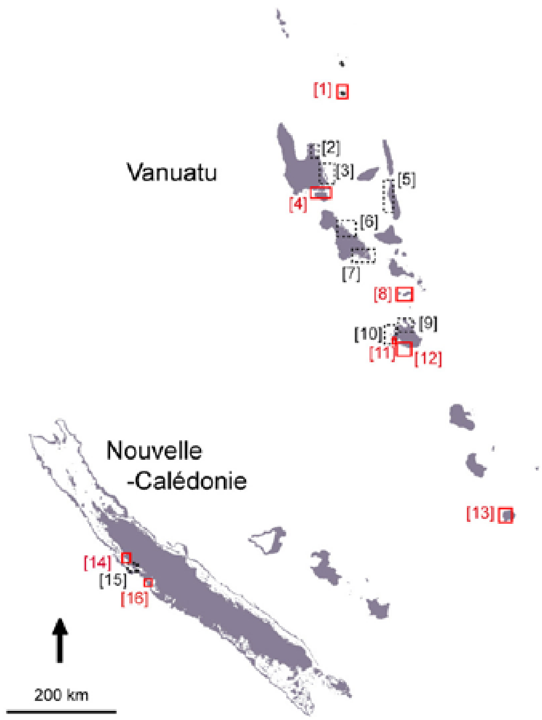

Figure 1. Locations of the 15 study sites where sea cucumber stock biomass assessments were conducted (except for Site 14) and which are fisheries management areas in Vanuatu and New Caledonia (Léopold et al. 2013c for Sites 2, 3, 6, 7, 9, 10 and 15; in this paper for the other sites). Black dotted line: 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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References

Aswani S. 2005. Customary sea tenure in Oceania as a case of right-based fishery management: Does it work? Review in Fish Biology and Fisheries 15:285–307.

Conand C. 1989. Les holothuries Aspidochirotes du lagon de Nouvelle-Calédonie: Biologie, écologie et exploitation. Études et Thèses. Paris, France: ORSTOM. 393 p.

Conand C., Shea S. and To A. 2014. Beche-de-mer trade statistics for Hong Kong in 2012. SPC Beche-de-mer Bulletin 34:43–46.

FAO. 2008. Sea cucumbers: A global review of fisheries and trade. FAO Fisheries and aquaculture technical paper. No. 516. Rome, Italy: Food and Agriculture Organization. 331 p.

FAO. 2012. Report on the FAO Workshop on Sea Cucumber Fisheries: An Ecosystem Approach to Management in the Pacific (SCEAM Pacific). FAO Fisheries and Aquaculture Report No. 1003. Rome, Italy: Food and Agriculture Organization. 56 p.

FAO. 2013. Report on the FAO Workshop on Sea Cucumber Fisheries: An Ecosystem Approach to Management in the Indian Ocean (SCEAM Indian Ocean). FAO Fisheries and Aquaculture Report. No. 1038. Rome, Italy: Food and Agriculture Organization. 92 p.

Léopold M., Beckensteiner J., Kaltavara J., Raubani J. and Caillon S. 2013a. Community-based management of fisheries in Vanuatu: What works? Marine Policy 42:167–176.

Léopold M., Cornuet N., Andréfouët S., Moenteapo Z., Duvauchelle C., Raubani J., Ham J. and Dumas P. 2013b. Comanaging small-scale sea cucumber fisheries in New Caledonia and Vanuatu using stock biomass estimates to set spatial catch quotas. Environmental Conservation 40:367–379.

Léopold M., Ham J., Kaku R., Kaltavara J., Raubani J., Gereva S., Moenteapo Z., Andréfouët S. and Dumas P. 2013c. Towards a new management strategy for Pacific island sea cucumber fisheries. SPC Fisheries Newsletter 140:43–48.

Léopold M. 2014. Guide de l'utilisateur de la base de données BDMer. Version 2.0. 74 p. (available in English at http://bdmer.ird.nc/index1.php?lang=en&pays=vnt) .

Pakoa K. and Bertram I. 2013. Management state of Pacific sea cucumber fisheries. SPC Beche-de-mer Information Bulletin 33:49–52.

Purcell S.W., Gossuin H. and Agudo N.S. 2009. Status and management of the sea cucumber fishery of La Grande Terre, New Caledonia. Studies and Reviews. No. 1901. Penang, Malaysia: WorldFish Center. 134 p.

Purcell S.W., Hair C.A. and Mills D.J. 2012. Sea cucumber culture, farming and sea ranching in the tropics: Progress, problems and opportunities. Aquaculture 368–369:68–81.

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.

The sea cucumbers (Echinodermata: Holothuroidea) of Tubbataha Reefs Natural Park, Philippines

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Abstract

Sea cucumbers are among the large macrobenthic reef invertebrates that have received little attention in Tubbataha Reefs Natural Park, Philippines. To assess the status of sea cucumbers in the park, distance and opportunistic sampling were conducted between December 2009 and April 2010. In total, 18 sea cucumber species were recorded, 12 of which were new records and three are IUCN listed. *Stichopus chloronotus* had the highest density, *Holothuria atra* ranked second, followed by *Bohadschia argus* and *Thelenota ananas*. The mean density of all species at the North Atoll was much higher than it was at the South Atoll. Jessie Beazley Reef had the lowest density and species richness. Sizes were relatively big and some species were at their maximum lengths. The present findings suggest the absence of exploitation at the park but efforts to prevent any form of extraction are needed for the continuous recovery of sea cucumber populations and for the park to serve as a significant seed source for depleted reefs. Regular population monitoring of sea cucumbers and other reef invertebrates is needed and must include those in the lagoon, which was not covered by this study.

Introduction

Sea cucumber populations in the Philippines are in serious decline because of habitat degradation and unregulated exploitation (Schoppe 2000). For this reason, the Bureau of Fisheries and Aquatic Resources drafted an administrative order to implement conservation efforts to limit and regulate the harvest of wild sea cucumber based on size limits (Pagdilao 2009). This was a response to the two most urgent conservation needs for sea cucumbers — development of national fishery management plans and harmonised trade reporting — identified during the CITES[2] international workshop, held in Malaysia in 2004, on the conservation of commercially exploited sea cucumbers (Bruckner 2006).

Management of populations in the wild, however, proved difficult because of the limited information on the ecology, biology (Pagdilao 2009) and state of stocks (Bruckner 2006) of the sea cucumbers. In response to this, a nationwide effort to monitor the status of sea cucumbers in the wild, and studies on production, sea ranching and restocking are currently being undertaken (Bruckner 2006; Pagdilao 2009).

This study on species richness, size and density of sea cucumbers serves as a success indicator in managing the Tubbataha Reefs Natural Park and complements the nationwide monitoring of wild populations.

Materials and methods

Study site

The Tubbataha Reefs Natural Park is located in the middle of the Sulu Sea, Philippines. It lies at 8°43'–8°57'N, 119°48'–120°3'E, about 150 km southeast of Puerto Princesa City, Palawan and 130 km south of the municipality of Cagayancillo. The surveyed sites were outer reef slopes and walls. A total of 15 sites were surveyed (Fig. 1), six of which were reef walls: one each at North Atoll and Jessie Beazley Reef, and four at South Atoll. The reef slopes are composed of wide patches of sand habitats among soft and hard coral colonies, while the reef walls are characterised by sudden drop-offs with deep, narrow grooves extending towards the shallow reefs.

Species richness

Methods to document the species included wading on sandy-rubble flats around the Ranger Station during day and night low tide, snorkelling in shallow reef flats and scuba diving at deeper reef slopes and walls. The sea cucumbers were identified using

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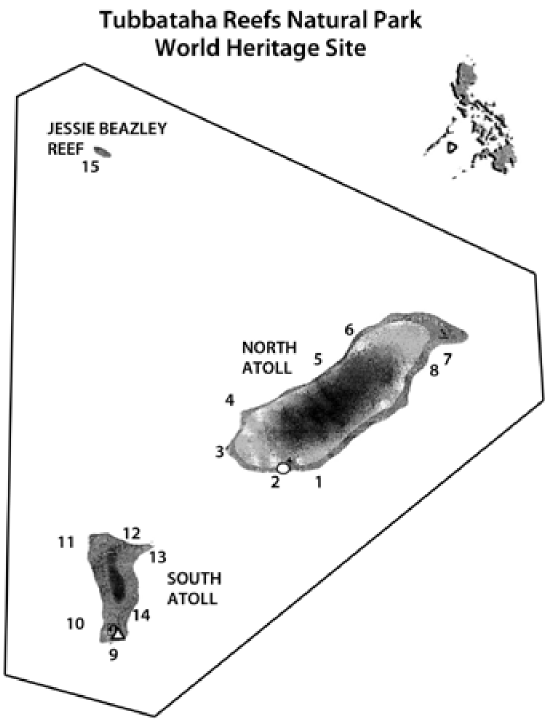

Figure 1. The 15 sampling sites in Tubbataha Reefs Natural Park.

various reference materials (Conand 1998; Schoppe 2000; Purcell et al. 2012; Kim et al. 2013).

Size

Sea cucumbers encountered close to the transect lines during the distance sampling were measured for undisturbed lengths (with a tape measure) to the nearest centimetre. The size of species encountered during the snorkelling and/or wading at the intertidal area was similarly measured.

Density

To estimate the density, distance sampling was conducted at the slope and drop-off areas in the outer part of the reef. Two scuba divers, one serving as guide, swam along the edge of the reef. The perpendicular distance of any sea cucumber species from the observer was recorded. The distance covered per dive was estimated using Garmin e Trex GPS. A total of 15 transect lines covering a distance of 11,909.16 m (Range: 370.15–1,094.35 m) were surveyed. Data were analysed using the software Distance 6.1 (Thomas et al. 2010).

Table 1. Species list of sea cucumbers in Tubbataha Reefs Natural Park.

No.	Species	North Atoll (NA)	South Atoll (SA)	Jessie Beazley Reef (JBR)
Family Holothuriidae				
1	*Actinopyga lecanora*	X		
2	*Actinopyga palauensis*	X		
3	*Actinopyga* sp. 1	X		
4	*Actinopyga* sp. 2	X		
5	*Bohadschia argus*	X	X	X
6	*Bohadschia koellikeri*	X		
7	*Bohadschia vitiensis*	X		
8	*Holothuria atra*	X	X	
9	*Holothuria fuscogilva*	X	X	
10	*Holothuria whitmaei*	X		
11	*Pearsonothuria graeffei*	X	X	X
Family Stichopodidae				
12	*Stichopus chloronotus*	X		
13	*Stichopus* sp.	X		
14	*Thelenota ananas*	X	X	X
15	*Thelenota anax*	X		
16	*Thelenota rubralineata*		X	X
Family Synaptidae				
17	*Euapta godeffroyi*	X		
18	*Synaptula* sp.	X		
Total		**17**	**6**	**4**

Results

Species composition

A total of 18 sea cucumber species belonging to eight genera and three families were recorded in the park (Table 1; Figs 2, 3 and 4). Eleven species (61.11%) belong to family Holothuriidae, five (27.28%) are under family Stichopodidae and two (11.11%) fall under family Synaptidae. The highest numbers of species were recorded at the North Atoll.

Size

Among the species sampled for total length, *S. chloronotus* and *H. atra* had the highest number of

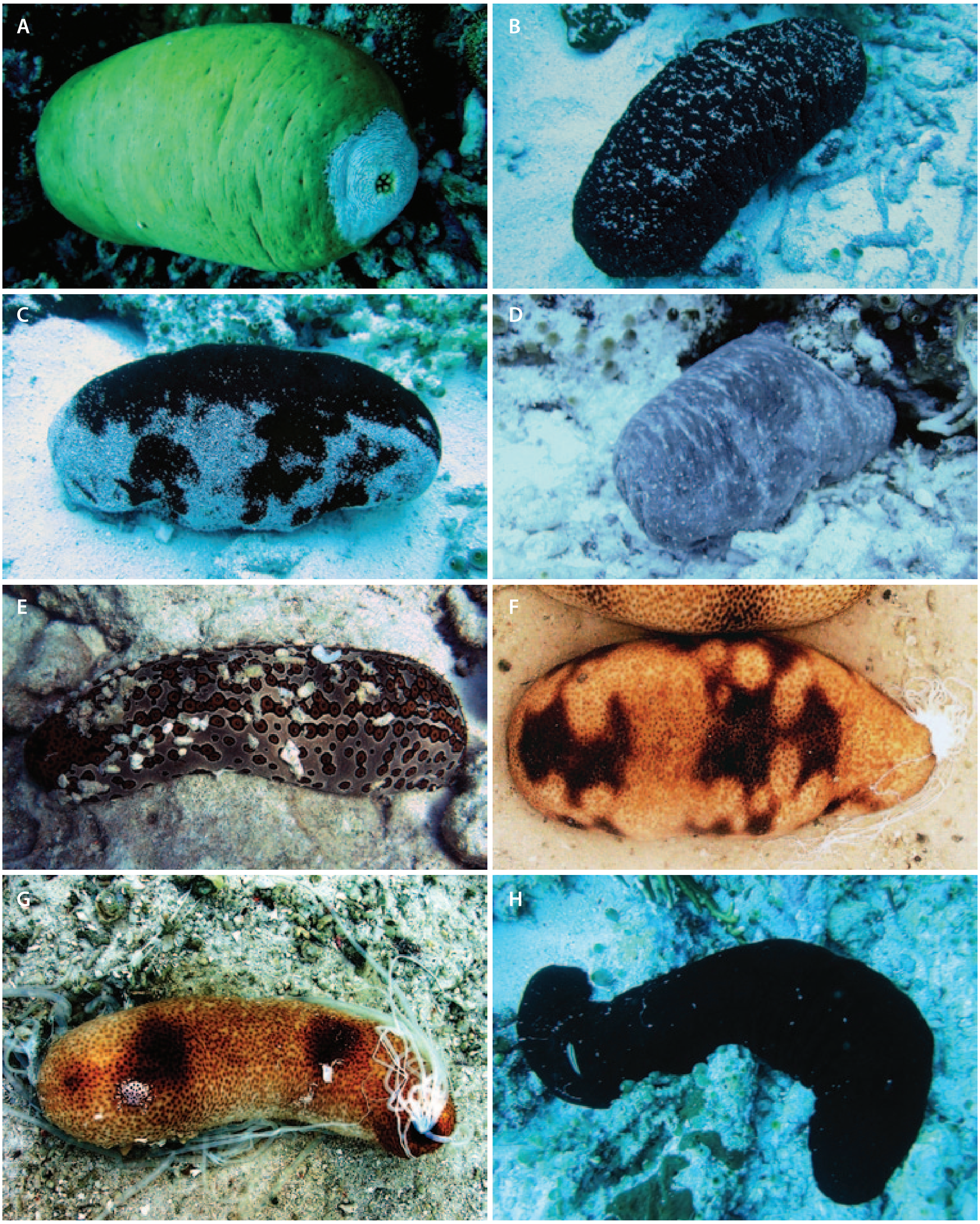

Figure 2. (A) *Actinopyga lecanora*; (B) *Actinopyga palauensis*; (C) *Actinopyga* sp. 1; (D) *Actinopyga* sp. 2; (E) *Bohadschia argus*; (F) *Bohadschia koellikeri*; (G) *Bohadschia vitiensis*; (H) *Holothuria atra*.

samples. Some species, such as *A. lecanora*, *B. koellikeri*, *B. vitiensis* and *T. rubralineata*, were quite rare so only one individual for each species was measured for total length (Table 2). The largest species were *H. atra* (100 cm), *T. ananas* (70 cm) and *T. anax* (60 cm). Among the species with length records, only *H. atra* and *S. chloronotus* were represented by small-sized individuals (min. length: 10 cm). Most of the other species were represented by large-sized individuals.

Density

The overall sea cucumber density in Tubbataha Reefs Natural Park was 41.93 ind. ha^{-1} (Table 3). The density pattern was relatively higher at the North than

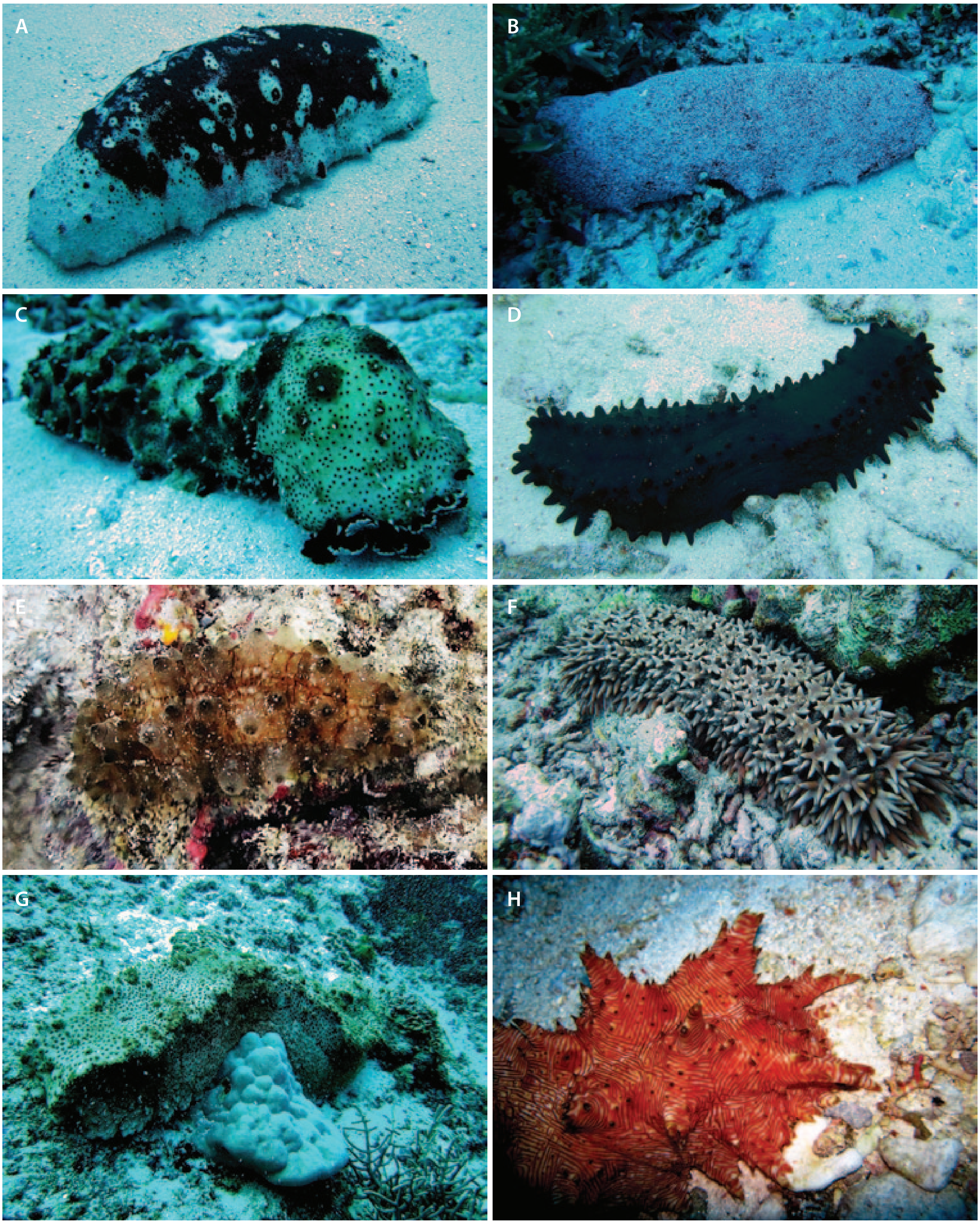

Figure 3. (A) *Holothuria fuscogilva*; (B) *Holothuria whitmaei*; (C) *Pearsonothuria graeffei*; (D) *Stichopus chloronotus*; (E) *Stichopus* sp.; (F) *Thelenota ananas*; (G) *Thelenota anax*; (H) *Thelenota rubralineata*.

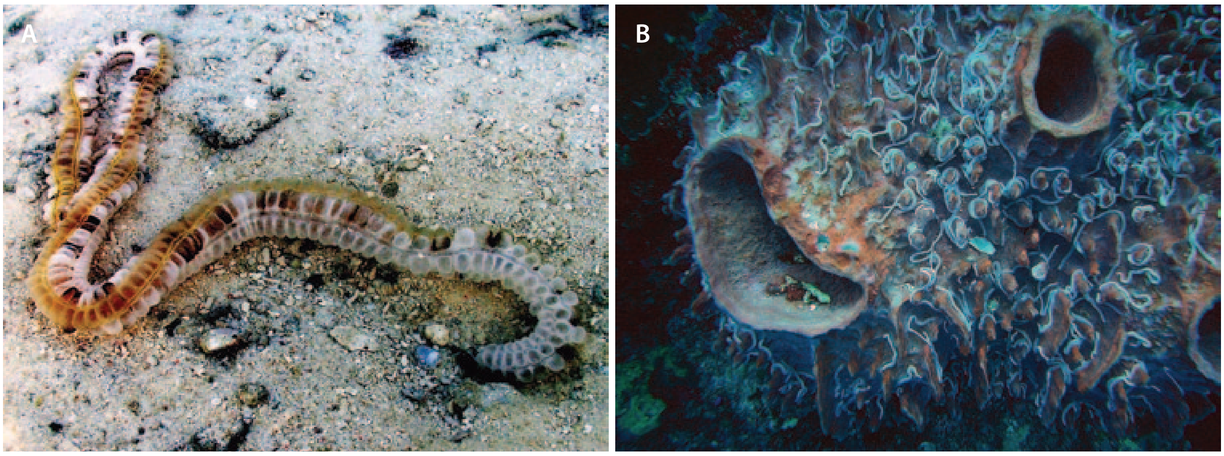

Figure 4. (A) *Euapta godeffroyi*; (B) *Synaptula* sp.

Table 2. Summary statistics for the total lengths of some sea cucumber species encountered in Tubbataha Reefs Natural Park.

Species	n	Mean length (cm)	Min. length (cm)	Max. length (cm)	Confidence level (95%)
Actinopyga lecanora	1		23.00		
Bohadschia argus	36	33.33	20.00	45.00	2.59
Bohadschia koellikeri	1		26.00		
Bohadschia vitiensis	1		24.00		
Holothuria atra	156	46.66	10.00	100.00	1.31
Holothuria fuscogilva	14	33.57	30.00	40.00	2.87
Pearsonothuria graeffei	19	33.53	30.00	45.00	2.62
Stichopus chloronotus	241	27.63	10.00	40.00	0.89
Thelenota ananas	90	53.20	40.00	70.00	1.54
Thelenota anax	2	60.00	60.00	60.00	
Thelenota rubralineata	1		50.00		
Total	**561**				

Table 3. Density (ind. ha^{-1}) of each sea cucumber species in Tubbataha Reefs Natural Park. The first three most abundant are shaded. NA = North Atoll; SA = South Atoll; JBR = Jessie Beazley Reef; LL = lower limit at 95% confidence level; UL = upper limit at 95% confidence level.

Species	NA		SA		JBR	TRNP	
	Density (ind. ha^{-1})	LL–UL	Density (ind. ha^{-1})	LL–UL	Density (ind. ha^{-1})	Density (ind. ha^{-1})	LL–UL
Bohadschia argus	7.24	5.02–10.44	0.46	0.12–1.81		4.20	2.64–6.67
Holothuria atra	16.73	9.59–29.14	4.38	1.52–12.45		9.65	5.42–17.18
Holothuria fuscogilva	1.04	0.24–4.46	0.39	0.07–2.06		0.71	0.21–2.33
Pearsonothuria graeffei	1.56	0.78–3.12	2.36	1.00–5.55	0.48	2.04	1.17–3.56
Stichopus chloronotus	42.30	24.82–72.05				22.91	12.63–41.55
Thelenota ananas	3.89	1.85–8.17	5.16	1.74–15.31	0.12	4.20	2.23–7.89
Thelenota anax	0.05	0.01–0.22				0.03	0.01–0.12
Thelenota rubralineata			0.46	0.10–2.15		0.19	0.04–0.81
Total	**70.27**	**46.37–106.48**	**10.21**	**4.11–25.37**	**0.24**	**41.93**	**27.15–64.74**

at the South Atoll and Jessie Beazley Reef (Table 3; Fig. 5). Densities at the reef slopes were much higher than at the reef walls (Fig. 5). At the North Atoll, *S. chloronotus*, *H. atra* and *B. argus* were the three most abundant species, while *T. ananas*, *H. atra* and *P. graeffei* were more common at the South Atoll. In Jessie Beazley Reef, only two individuals belonging to two species, *P. graeffei* and *T. ananas*, were encountered during the distance survey (Table 3).

Discussion

A number of reef assessments have been conducted in the park, yet only the works of Estacion et al. (1993) and Dolorosa and Jontila (2012) mention some sea cucumber species. Failure to note the number of sea cucumber species in previous studies could be related to abundance. Sea cucumbers are prone to over-exploitation and recover very slowly (Purcell et al. 2012). Prior to and even several years after its declaration as a national park in 1988, harvesting of marine resources remained uncontrolled (Arquiza and White 1999), which could have greatly reduced the sea cucumber populations. This could be why only two species were encountered by Estacion et al. (1993). In the Red Sea, Egypt, a drop in species richness of sea cucumbers was recorded after the fishing period (Hasan and Abd El-Rady 2012). Overfishing of sea cucumber is widespread, resulting in a long-term fishery closure in some countries (Uthicke 2004; Hasan 2005; Friedman et al. 2008; Kalaeb et al. 2008; Hasan and Abd El-Rady 2012; Purcell et al. 2013).

Most reef assessment studies in the park followed a permanent transect and mainly focused on coral cover and fish biomass (Ledesma et al. 2008). Only in 2005 were reef invertebrates included in the yearly monitoring, but this was limited to large gastropods and bivalves (Dolorosa and Schoppe 2005). In a 2008 survey, five species of sea cucumbers were reported as an offshoot of a survey on *Tectus* (*Trochus*) *niloticus* (Dolorosa and Jontila 2012). In the present study, 18 species were recorded, representing 33.96% of the 53 known species in Palawan (Jontila et al. 2014a). Nearly 90% of the sea cucumber species in the park are of high economic value and three species are in the IUCN Red List; *Actinopyga lecanora* and *Thelenota ananas* are listed as endangered, while *Bohadschia fuscogilva* is listed as vulnerable (Conand et al. 2014).

The maximum sizes of sea cucumbers in the park are close or even larger than their reported common and maximum lengths (Table 4). Extremely large *Holothuria atra* (measuring up to 100 cm) were encountered at the reef slope, while small individuals were common at the intertidal area within the Ranger Station. The abundance of large-size sea cucumbers suggests the possible absence of any form of exploitation, which could be attributed to the nature and depth of the habitats. Sampling sites far from the Ranger Station, where trochus were already depleted, still hold an abundance of sea cucumbers. In most cases, illegal fishers caught at the park were engaged in collecting fishery resources other than sea cucumbers. However, the rising sea cucumber price and demand in the world market (Bruckner 2006) may drive fishermen to engage in harvesting these species in the park. Measures to prevent any form of harvesting are needed because slow-growing, low-fecund and late-maturing sea cucumbers are prone to overexploitation (Bruckner 2006).

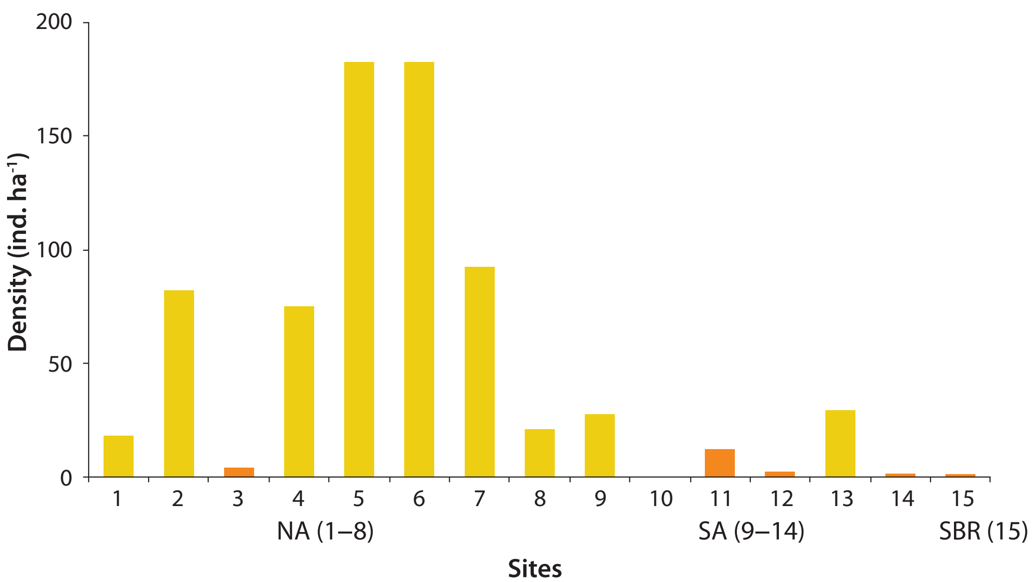

Figure 5. Density of sea cucumbers (ind. ha^{-1}) at each site. NA = North Atoll; SA = South Atoll; JBR = Jessie Beazley Reef. Sites 3, 10, 11, 12, 14 and 15 (orange bars) are reef walls. Other sites (yellow bars) are reef slopes.

Burrowing species, such as *B. koellikeri* and *B. vitiensis*, are difficult to find and only one of each species was encountered, partly buried in a sand flat surrounding the Ranger Station. One very small *Stichopus* sp. (~5 cm) was accidently found under a coral rock (Fig. 3E). Knowing the habitats of juvenile sea cucumbers essential in stock recruitment and density monitoring.

The high densities at the North compared with the South Atoll could be attributed to the sampling sites. Seven of the eight sites in the North Atoll were reef slopes, which appeared to be preferred to reef walls by many species (Fig. 5). Other factors could be the remoteness from the Ranger Station of the South Atoll and Jessie Beazley Reef. Populations of *Tectus* (*Trochus*) *niloticus* in sites far from the Ranger Station were severely affected by poaching (Dolorosa et al. 2010; Jontila et al. 2014b). The park has no record of apprehensions for sea cucumber poaching but we do not discount the possibility that poachers will collect any high value species, including sea cucumbers. Nevertheless, the present densities of some sea cucumbers species at the park are comparable with density records in other countries (Table 5). The exceptional density of *H. atra* in other reports could

Table 4. Common length and maximum length of sea cucumbers at TRNP compared with the reported data of Conand (1998).

Species	Common length (cm)		Maximum length (cm)	
	Conand (1998)	This study	Conand (1998)	This study
Actinopyga lecanora		23		
Bohadschia argus	36	33	60	45
Bohadschia koellikeri		26	40*	
Bohadschia vitiensis	32	24	40	
Holothuria atra	20	47	45	100
Holothuria fuscogilva	42	34	57	40
Pearsonothuria graeffei	35	34	45	45
Stichopus chloronotus	18	28	35	40
Thelenota ananas	45	53	80	70
Thelenota anax	55		80	60
Thelenota rubralineata			50*	50

* Kerr et al. (2006).

Table 5. Density (ind. ha^{-1} ±SE) in other localities compared with the records in Tubbataha Reefs Natural Park.

Species	Palau (Pakoa et al. 2009)	Eritrea (Kalaeb et al. 2008)	New Caledonia (Purcell et al. 2009)	Mauritius (Lampe-Randoo et al. 2014)	This study
Family Holothuriidae					
Actinopyga lecanora	1.5 ±1.1				
Actinopyga palauensis			>10		
Bohadschia argus	4.5 ±3.2		10–30		4.20
Bohadschia vitiensis	378.0 ±136.4			38	
Holothuria atra	3,770.5 ±187.3	295.0	100	424	9.65
Holothuria fuscogilva		3.0			0.71
Holothuria whitmaei			>10		
Pearsonothuria graeffei					2.04
Family Stichopodidae					
Stichopus chloronotus	6.8 ±3.5		10–100	96	22.91
Thelenota ananas		3.5	>10		4.20
Thelenota anax					0.03
Thelenota rubralineata					0.19

be habitat-related. There is an abundance of shallow water populations of small-sized *H. atra* within the Ranger Station, which could be comparable with the reports of Pakoa et al. (2009) but such densities require quantitative measurements.

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References

Arquiza Y.D. and White A.T. 1999. Tales from Tubbataha. 2nd edition. Makati City, Metro Manila, Philippines: The Bookmark, Inc. 190 p.

Bruckner A.W. 2006. Proceedings of the CITES workshop on the conservation of sea cucumbers in the families Holothuriidae and Stichopodidae. NOAA Technical Memorandum NMFSOPR 34, Silver Spring, MD. 244 p.

Conand C. 1998. Holothurians (Sea cucumbers, Class Holothuroidea). p. 1157–1190. In: Carpenter K.E. and Niem V.H. (eds). FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific. Volume 2. Cephalopods, crustaceans, holothurians and sharks. Rome, Italy: Food and Agriculture Organization of the United Nations. 709 p.

Conand C., Polidoro B., Mercier A., Gamboa R., Hamel J.F. and Purcell S. 2014. The IUCN Red List assessment of aspidochirotid sea cucumbers and its implications. SPC Beche-de-mer Information Bulletin 34:3–7.

Dolorosa R.G. and Schoppe S. 2005. Focal benthic molluscs (Mollusca: Bivalvia and Gastropoda) of selected sites in Tubbataha Reefs National Marine Park, Palawan, Philippines. Science Diliman 17(2):1–8.

Dolorosa R.G. and Jontila J.B.S. 2012. Notes on common macrobenthic reef invertebrates of Tubbataha Reefs Natural Park, Philippines. Science Diliman 24(2):1–11.

Dolorosa R.G., Songco A.M., Calderon V., Magbanua R. and Matillano J.A. 2010. Population structure and abundance of *Trochus niloticus* in Tubbataha Reefs Natural Park, Palawan, Philippines with notes on poaching effects. SPC *Trochus* Information Bulletin 15:17–23.

Estacion J.E., Palaganas V.P., Perez R.E. and Alava M.N.R. 1993. Benthic characteristics of islands and reefs in the Sulu Sea, Philippines. Silliman Journal 36(2):15–44.

Friedman K.S., Purcell S., Bell J. and Hair C. 2008. Sea cucumber fisheries: A manager's toolbox. ACIAR Monograph No. 132. 32 p.

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

Hasan M.H. and Abd El-Rady S.E.D.A. 2012. The effect of fishing pressure on the ecology of sea cucumber populations in the Gulf of Aqaba, Red Sea. SPC Beche-de-mer Information Bulletin 32:53–59.

Jontila J.B.S., Balisco R.A.T. and Matillano J.A. 2014a. The Sea cucumbers (Holothuroidea) of Palawan, Philippines. AACL Bioflux 7:194–206.

Jontila J.B.S., Gonzales B.J. and Dolorosa R.G. 2014b. Effects of poaching on topshell *Tectus niloticus* population of Tubbataha Reefs Natural Park, Palawan, Philippines. The Palawan Scientist 6:14–27.

Kalaeb T., Ghirmay D., Semere Y. and Yohannes F. 2008. Status and preliminary assessment of the sea cucumber fishery in Eritrea. SPC Beche-de-mer Information Bulletin 27:8–12.

Kerr A.M., Netchy K. and Gawel A.M. 2006. Survey of the shallow-water sea cucumbers of the central Philippines. A Report to the Municipalities of Negros Oriental, Cebu and Bohol, local Bantay Dagat groups, Coastal Conservation and Education Foundation, Inc., and Silliman University-Angelo King Center for Research and Environmental Management. University Of Guam Marine Laboratory. 56 p.

Kim S.W., Kerr A.M. and Paulay G. 2013. Colour, confusion, and crossing: Resolution of species problems in *Bohadschia* (Echinodermata: Holothuroidea). Zoological Journal of the Linnean Society 168(1):81–97.

Lampe-Ramdoo K., Moothien Pillay R. and Conand C. 2014. An assessment of holothurian diversity, abundance and distribution in the shallow lagoons of Mauritius. SPC Beche-de-mer Information Bulletin 34:17–24.

Ledesma M.C., Jontila J.B.S., Dygico M.P., Conales S., Songco A.M., Dolorosa R.G. and Calderon V. 2008. Tubbataha Reefs Natural Park: Research and monitoring report 2008. 65 p.

Pagdilao C. 2009. Saving the sea cucumbers. High prices, unregulated harvest, drive sea cucumbers to extinction. Special To The Manila Times. June 14, 2009. http://www.manilatimes.net/national/2009/june/14/yehey/top_stories/20090614top1.html

Pakoa K., Lasi F., Tardy E. and Friedman K. 2009. The status of sea cucumbers exploited by Palau's subsistence fishery. Noumea, New Caledonia: Secretariat of the Pacific Community. 44 p.

Purcell S.W., Gossuin H. and Agudo N.S. 2009. Status and management of the sea cucumber fishery of La Grande Terre, New Caledonia. Noumea, New Caledonia: WorldFish Center. 140 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, Italy: Food and Agriculture Organization of the United Nations. 223 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.

Schoppe S. 2000. A guide to the common shallow water sea stars, brittle stars, sea urchins, sea cucumbers and feather stars (Echinoderms) of the Philippines. Singapore Time Media Private Ltd. 144 p.

Thomas L., Buckland S.T., Rexstad E.A., Laake J.L., Strindberg S., Hedley S.L., Bishop J.R., Marques T.A. and Burnham K.P. 2010. Distance software: Design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology 47:5–14.

Uthicke S. 2004. Overfishing of holothurians: Lessons from the Great Barrier Reef. p. 163–171. In: Lovatelli A., Conand C., Purcell S., Uthicke S., Hamel J. and Mercier A. (eds). Advances in sea cucumber aquaculture and management. FAO Fisheries Technical Paper No. 463. Rome, Italy: Food and Agriculture Organization of the United Nations. 425 p.

Species list of Indonesian *trepang*

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Abstract

As is well known, *trepang* (beche-de-mer) is considered not only a delicacy but also as a traditional medicine. In official Indonesian export data, *trepang* is treated as a single species, even though in several national and international scientific publications it is evident that *trepang* from Indonesia includes multiple species. It is difficult to identify processed (dried) *trepang* and, since most *trepang* for export is in its dried form, it is easier to state that *trepang* is a single species. The current study aims to provide a species list of all the species included in Indonesian *trepang* which have ever been, and still are, fished for trade. The result puts in evidence 54 species, of which 33 have been taxonomically confirmed. There are some species that are traded but have not been previously documented.

Introduction

Indonesia is the largest *trepang*-producing country, according to Food and Agriculture Organization of the United Nations global statistics, with Hong Kong SAR (China) as the main importing country (Bruckner et al. 2003; Tuwo 2004; Choo 2008). As in other countries, Indonesian *trepang* has suffered from over exploitation, and unregulated fishing is considered the main cause (Bruckner et al. 2003; Tuwo 2004; Purwati and Yusron 2005; Choo 2008; Purwati et al. 2010; Purcell et al. 2011). It is thought that a huge exploitation has been occuring since the end of the seventeenth century, when Indonesian *trepang* fishermen started to go as far afield as northern Australia because there was no longer enough trepang in the waters of Maluku or Sunda to fulfil the demands of the Chinese market (Knaap and Sutherland 2004; Máñez and Ferse 2010).

Trepang accounts for only ±4.5% of the total number of sea cucumber species. Sixty-six species have been fished worldwide, with the majority from Indo-Pacific waters (Purcell et al. 2011; Conand and Byrne 1993). Purwati (2005) reports 26 species that have ever been, or are still being, traded in Indonesian waters. From another report, Choo (2008) lists 35 *trepang* species from Indonesia that entered the international markets. Both resources are compiled mostly from fishery reports, which do not include taxonomic information. Meanwhile, in export statistics published by the Ministry of Marine Affairs and Fisheries in 2011, *trepang* is still considered a single product (mono-species).

Indonesia is known as an area with a very high diversity of marine organisms, distributed in a total area of 5.2 million km^2. It is difficult to determine the main areas where particular species are found because fishermen are scattered over a vast area and protect their information about precise fishing locations (Tuwo 2004; Purwati 2005; Choo 2008). Furthermore, it is difficult to identify the *trepang* species that enter the market, partly because the local names for species differ from area to area, and because the *trepang* traded are in the form of processed products (dried or gutted and salted) which damage the taxonomic characteristics.

In order to list the trepang species traded in Indonesia, we started from four fish-landing locations that provided easy access. As these locations offered fresh and processed *trepang*, we evaluated whether the species of dried and gutted-salted ones could still be identified.

Methods

Between December 2011 and February 2013, we collected *trepang* samples from four locations (Fig. 1): Karimunjawa, northern Central Java (six fresh specimens), Situbondo, northern East Java (11 fresh specimens), Spermonde, South Sulawesi (nine salted specimens) and Ambon, Central Moluccas (eight dried specimens).

All samples were collected from either *trepang* divers/fishermen or collectors to ensure that those species were gathered for trade. The fresh samples

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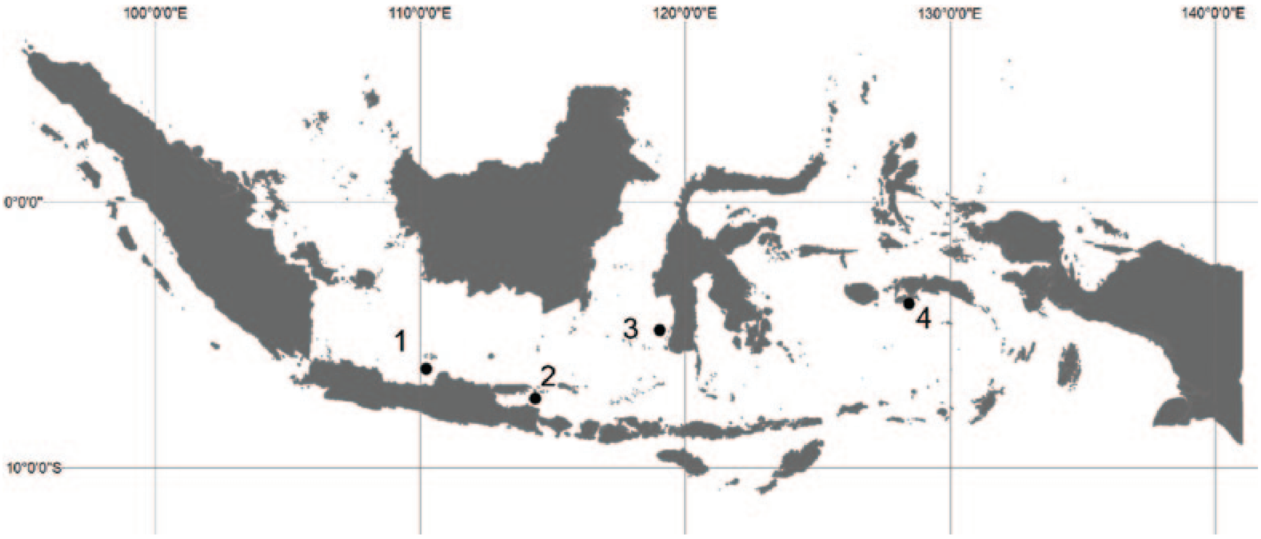

Figure 1. Locations where *trepang* specimens were collected from.
Study sites: (1) Karimunjawa; (2) Situbondo; (3) Spermonde; (4) Ambon.

were preserved in 96% alcohol for a week, then in 70% alcohol for long-term storage. The salted ones were rinsed in tap water to remove the salt and then preserved in the same way, and the dried samples were kept in plastic bags until identified, then preserved in 70% alcohol for long-term storage. All the samples were deposited in the Museum Zoological Bogoriense Indonesia.

Species identification was based on morphology, and ossicle types and composition. Ossicles were collected from the dorsal body wall, the ventral body wall, the dorsal papillae, the ventral tube feet, the tentacle, the collar, the anal papillae, the cuvierian tubules, the gonad, the rete mirabile, the longitudinal muscle, the cloacal wall and the cloacal retractor muscle. Small pieces of tissue from each sample were dipped in domestic bleach for several minutes. The ossicles were rinsed with tap water, followed by 70% alcohol before being identified under a compound microscope.

Results

From the studied areas, we identified 27 species of *trepang* (Table 1). The taxonomic accounts have been reported in Setyastuti (2013). This result added *trepang* species that have ever been, and/or are still being, fished in Indonesia, giving a total of 54 species (Table 2).

Discussion

Sea cucumber species in Indonesian trading

Karimunjawa is one of the *trepang* producing areas in Java. Purwati et al. (2010) successfully identified 18 species of *trepang* fished and traded in this area. From this study, we added two other species i.e. *Holothuria* (*Metriatyla*) cf. *lessoni* (Massin, Uthicke, Purcell, Rowe and Samyn, 2009) and *Stichopus* cf. *monotuberculatus* (Quoy and Gaimard, 1833).

Unlike other locations in this study, Situbondo has never been included as a research site for *trepang* or holothurian studies. Out of eight species from this area, three species (*Holothuria turriscelsa*, *H. excellens*, and *Stichopus noctivagus*) have been found only in Spermonde Island previously, as reported by Massin (1999).

Generally, fishermen may not be aware of the small differences in the appearance of *trepang* when they collect them. Consequently, many species that were not in market demand were fished. *Stichopus* cf. *monotuberculatus* was rarely reported as a traded species. Local fishermen called it teripang pace, the same name for *Stichopus vastus*, because they are similar in their external morphology. *Stichopus vastus* was more frequently reported as being traded than *S. quadrifasciatus*. This species was the most common species found in shallow water and easily distinguishable from its morphology, such as the reticulate black-brown "tiger" pattern covering the dorsal body wall (Massin et al. 2002). Choo (2008) mentions the presence of *S. quadrifasciatus* in her list and one of the origin countries is Indonesia, but Purcell et al. (2010) does not include it. Purwati et al. (2010) assumes that this situation is generated by insufficient volume or lack of regular supplies entering the market. In Indonesia, this species was reported from two locations: Lombok waters and Seribu Archipelago (Wirawati et al. 2007; Setyastuti 2011).

Table 1. Ossicles isolated from each body part of fresh and processed specimens. dbw = dorsal body wall; vbw = ventral body wall; dp = dorsal papillae; vtf = ventral tube feet; tent = tentacle; coll = collar; ap = anal papillae; ct = cuvierian tubulus; gon = gonad; rm = rete mirabile; lm = longitudinal muscle; cw = cloacal wall; crm = cloacal retractor muscle; P = present; A = absent; NA = not aplicable.

No.	Species	dbw	vbw	dp	vtf	tent	coll	ap	ct	gon	rm	rt	lm	cw	crm
Fresh specimens preserved in alcohol from Karimunjawa and Situbondo															
1	*Actinopyga lecanora* (Jaeger, 1835)	P	P	P	P	P	A	A	A	A	A	A	A	P	A
2	*Bohadschia* sp. 2	P	P	P	P	P	NA	P	NA	NA	A	P	A	P	A
3	*Holothuria* (*Halodeima*) *atra* (Jaeger, 1833)	P	P												
4	*Holothuria* (*Acanthotrapeza*) *coluber* (Semper, 1868)	P	P	P	P	P	NA	P	NA	NA	NA	P	A	A	A
5	*Holothuria* (*Halodeima*) *edulis* (Lesson, 1830)	P	P	P	P	P	NA	NA	NA	A	NA	P	A	A	A
6	*Holothuria* (*Platyperona*) *excellens* (Ludwig, 1875)	P	P	P	P	P	NA	NA	A	A	A	A	A	A	A
7	*Holothuria* (*Stauropora*) *fuscocinerea* (Jaeger, 1833)	P	P	P	P	P	P	NA	A	A	NA	P	A	P	P
8	*Holothuria* (*Metriatyla*) *lessoni* (Massin, Uthicke, Purcell, Rowe and Samyn, 2009)	P	P	P	P	P	NA	NA	NA	P	A	A	P	P	P
9	*Holothuria* (*Metriatyla*) *scabra* (Jaeger, 1833)	P	P	P	P	P	NA	NA	NA	NA	NA	NA	A	P	P
10	*Holothuria* (*Theelothuria*) *turriscelsa* (Cherbonnier, 1980)	P	P	P	P	P	P	NA	NA	A	A	A	A	A	A
11	*Stichopus monotuberculatus* (Quoy and Gaimard, 1833)	P	P	P	P	P	NA	NA	NA	NA	NA	P	A	P	A
12	*Stichopus noctivagus* (Cherbonnier, 1980)	P	P	P	P	P	NA	NA	NA	NA	NA	A	A	A	A
13	*Stichopus quadrifasciatus* (Massin, 1999)	P	P	P	P	P	A	P	NA	P	NA	A	A	P	P
Salt-processed specimens from Spermonde															
1	*Bohadschia* sp. 1	P	P	P	P	P	NA	P	NA	NA	NA	NA	A	A	A
2	*Bohadschia subrubra* (Quoy & Gaimard, 1833)	P	P	NA	P	P	NA	NA	NA	NA	NA	NA	NA	NA	NA
3	*Bohadschia vitiensis* (Semper, 1868)	P	P	P	P	P	NA	NA	NA	NA	NA	A	A	A	P
4	*Holothuria* (*Halodeima*) *edulis* (Lesson, 1830)	P	P	P	P	P	NA	NA	NA	NA	NA	NA	NA	NA	NA
5	*Holothuria* (*Microthele*) *nobilis* (Selenka, 1867)	P	P	P	P	P	NA	P	NA	NA	A	NA	A	A	A
6	*Pearsonothuria graeffei* (Semper, 1868)	P	P	P	P	P	NA	NA	NA	NA	NA	NA	P	P	P
7	*Stichopus pseudohorrens* (Cherbonnier, 1967)	P	P	P	P	NA	NA	NA	NA	NA	NA	NA	A	P	P
8	*Stichopus vastus* (Sluiter, 1887)	P	P	P	P	P	NA	NA	NA	NA	NA	NA	NA	NA	NA
9	*Thelenota anax* (Clark, 1921)	P	P	P	P	P	NA	NA	NA	NA	NA	NA	NA	A	A
Dried-processed specimens from Ambon															
1	*Bohadschia* sp. 3	P	P	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2	*Holothuria* (*Metriatyla*) cf. *albiventer* (Semper, 1868)	P	P	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3	*Holothuria* (*Microthele*) *fuscopunctata* (Jaeger, 1833)	P	P	NA	NA	P	NA	P	NA	NA	NA	NA	NA	NA	NA
4	*Holothuria* (*Semperothuria*) cf. *imitans* (Ludwig, 1875)	P	P	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5	*Holothuria* (*Microthele*) *nobilis* (Selenka, 1867)	P	P	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6	*Pearsonothuria graeffei* (Semper, 1868)	P	P	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7	*Stichopus chloronotus* (Brandt, 1835)	P	P	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
8	*Thelenota ananas* (Jaeger, 1833)	A	A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 2. List of all *trepang* species which have ever been, and / or are still being, fished and traded in Indonesia. Specimen condition was related to the specimen when it was identified. Other sources refer to [A] Purwati (2005); [B] Purwati (2006); [C] Choo (2008); [D] Máñez and Ferse (2010); [E] Purwati et al. (2010); [F] Setyastuti (2013). (*) not a valid name or needing taxonomic confirmation.

No.	Species	Specimen condition	Local names	World market names	Other sources
1	*Actinopyga bannwarthi*	Fresh	*Sepatu*	-	E
2	*Actinopyga caerula**	-	*Kossong*	-	D
3	*Actinopyga echinites**	-	*Kunyit, ladu-ladu, kapok / kapukbillala, bilado, kassi*	Deepwater redfish	A,B,C,D
4	*Actinopyga lecanora*	Fresh (E,F)	*Batu, balibi, hitam*	Stonefish	A,B,C,D,E,F
5	*Actinopyga mauritiana**	-	*Buntal, ballang ulu*	Surf redfish	A,B,C,D
6	*Actinopyga miliaris*	Fresh (E)	*Kapok / kapuk, lotong, gamet, sepatu, hitam*	Blackfish	A,B,C,D,E
7	*Bohadschia* sp. 1	Salted	*Bintik*	-	F
8	*Bohadschia* sp. 2	Fresh	*Pulut*	-	F
9	*Bohadschia* sp. 3	Dried	*Kawasa merah*	-	F
10	*Bohadschia argus**	-	*Ular mata, gamat bati, bintik, cempedak, patola*	Leopardfish / Tigerfish / Spottedfish	A,B,C,D
11	*Bohadschia marmorata**	-	*Kawasa, olok-olok, getah putih, pulut, benang, krido polos*	-	A,C,D
12	*Bohadschia similis**	-	*Karido getah bintik / laos*	-	B,C
13	*Bohadschia subrubra*	Fresh (E), Salted (F)	*Teripang bintik, kapok*	Leopardfish	E,F
14	*Bohadschia tenuissima**	-	*Karet*	-	A,C
15	*Bohadschia vitiensis*	Fresh (E), Salted (F)	*Olok-olok, gatta, gama, polos*	Brown sandfish	B,D,E,F
16	*Holothuria* cf. *albiventer*	Dried	*Kunyit*	-	F
17	*Holothuria atra*	Fresh (E,F)	*Lakling hitam / coklat, hitam, dara, keling, cera*	Lollyfish / Black *trepang*	A,B,C,D,E,F
18	*Holothuria coluber*	Fresh (E,F)	*Taikokong, talengko*	Snakefish	A,B,C,D,E,F
19	*Holothuria conusalba**	-	-	-	C
20	*Holothuria edulis*	Fresh (E,F) and Salted (F)	*Dada / cera / perut /l akling merah, takling, batu keling*	Pinkfish / Pink lollyfish / *Trepang* rose	A,C,D,E,F
21	*Holothuria excellens*	Fresh	*Hitam*	-	F
22	*Holothuria fuscocinerea*	Fresh (E,F)	*Coklat, lakling coklat*	-	E,F
23	*Holothuria fuscogilva**	-	*Susu putih, bissawa*	White teatfish	A,C,D
24	*Holothuria fuscopunctata*	Dried (F)	*Susu putih, kuning, kunyit,*	Elephant trunkfish	A,B,C,D,F
25	*Holothuria hilla**	-	*Batuna*	-	A,C,D
26	*Holothuria* cf. *imitans*	Dried	*Coklat*	-	F
27	*Holothuria impatiens*	Fresh (E)	*Pulut*	-	A,C,E
28	*Holothuria lessoni*	Fresh	*Ugai, gosok*	Golden sandfish	F

Table 2. List of all *trepang* species which have ever been, and / or are still being, fished and traded in Indonesia. Specimen condition was related to the specimen when it was identified. Other sources refer to [A] Purwati (2005); [B] Purwati (2006); [C] Choo (2008); [D] Máñez and Ferse (2010); [E] Purwati et al. (2010); [F] Setyastuti (2013). (*) not a valid name or needing taxonomic confirmation *(cont.)*.

No.	Species	Specimen condition	Local names	World market names	Other sources
29	*Holothuria leucospilota*	Fresh (E)	*Getah, cera, jepun, keling, talengko*	-	A,C,D,E
30	*Holothuria nobilis*	Salted and Dried (F)	*Koro, cera hitam*	Black teatfish	A,B,D,F
31	*Holothuria ocellata**	-	*Kacang goreng*	-	A,C
32	*Holothuria pardalis**	-	-	-	C
33	*Holothuria perficax**	-	-	Tiger spotted *trepang*	A,C
34	*Holothuria rigida**	-	*Kebo, puti*		C,D
35	*Holothuria scabra*	Fresh (E,F)	*Gosok, pasir, buang kulit, putih, kamboa*	Sandfish	A,B,C,D,E,F
36	*Holothuria scabra versicolor**	-	-	-	C
37	*Holothuria similis**	-	*Krido, krido bintik*	Chalkfish / Whitefish	A,C
38	*Holothuria turriscelsa*	Fresh	*Hitam*	-	F
39	*Holothuria vagabunda**	-	-	-	C
40	*Holothuria vatiensis**	-	-	-	C
41	*Holothuria whitmaei**	-	-	-	C
42	*Pearsonothuria graeffei*	Fresh (E), Salted and Dried (F)	*Bintik merah, gombyok, sutra, cera duri, gemuk, bati, donga*	Flowerfish / Blackspotted sea cucumber	A,B,C,D,E,F
43	*Stichopus chloronotus*	Fresh (E), Dried (F)	*Jepung, japon, jepun,*	Greenfish / Squarefish	A,B,C,D,E,F
44	*Stichopus herrmanni*	Fresh (E)	*Gamet emas, gamet kacang, taikongkong*	Curryfish	B,C,D,E
45	*Stichopus horrens*	Fresh (E)	*Kacang goreng, taikongkong, kacang, susu, rengget*	Dragonfish	A,B,C,D,E
46	*Stichopus monotuberculatus*	Fresh	*Gamet pace*	-	F
47	*Stichopus noctivagus*	Fresh	*Gamat*	-	F
48	*Stichopus pseudohorrens*	Salted	*Teripang duri*	-	F
49	*Stichopus quadrifasciatus*	Fresh	*Gamat*	-	C,F
50	*Stichopus variegatus**	-	*Gamet, kasur, taikokong, anjing, kapok, gama*	Curryfish / Yellow meat	A,D
51	*Stichopus vastus*	Fresh (E,F), Salted (F)	*TKK, gamet, gamet pace, kacang goreng*	Curryfish	C,E,F
52	*Thelenota ananas*	Fresh (F)	*Nanas / nenas,*	Prickly redfish / Plum flower *trepang*	A,B,C,D,F
53	*Thelenota anax*	Fresh (E), Salted (F)	*Donga, duyung, babi*	Amberfish	A,B,C,D,E,F
54	*Thelenota rubralineata**	-	*Bati*	-	D

Stichopus pseudohorrens has *hitherto* been documented only in Kupang waters. This *trepang* species is easily misidentified as *teripang nanas* (or *Thelenota ananas*) due to its similar body size and enlarged papillae (Wirawati and Purwati 2012). Only two publications (Purcell et al. 2010, 2012) reported this species being traded internationally. A similar case of misidentification occurred between *A. bannwarthi* and *A. miliaris*. *A. bannwarthi* has been documented once in Timor in 2007 (Purwati et al. 2008).

Species that have never been traded but are being fished in the studied locations were: *Actinopyga bannwarthi*, *H. turriscelsa*, *H. excellens*, *H.* cf. *albiventer*, *H.* cf. *imitans* and *Stichopus noctivagus*. From a taxonomical point of view, this was the second report on the presence of *Holothuria turriscelsa*, *H. excellens* and *Stichopus noctivagus* in Indonesia, after their first one from Spermonde by Massin (1999). Both *Holothuria excellens* and *H. turriscelsa* were potentially misidentified as *teripang hitam* (or *Holothuria atra*) due to its body shape and colour. However, *H. excellens* is not black but dark purple and it has longer tube feet than the *H. atra* collected from Karimunjawa. Morphologically *H. turriscelsa* is definitely different from *H. atra* because it possesses yellow tentacles, and substantively this is much closer to *H. coluber*.

Condition of the processed trepang

Since the *trepang* used for trade is mostly in dried form, species recognition is getting more difficult due to processing procedures that alter the colour and shape and damage the ossicles (Uthicke et al. 2010; Purwati et al. 2010). Although most of the processed specimens were still intact, they were not in as good shape as the fresh ones. Salted specimens were more identifiable than dried ones, as the body wall, several internal organs and the ossicles remained. There were several that could be identified from the body appearance alone. These included *Thelenota ananas* (large-sized with large papillae), *Stichopus chloronotus* (medium-sized, dark green, papillae in three distinctive rows), and *Holothuria edulis* (medium-sized, pink on the ventral side).

All the dried specimens collected from Ambon were identifiable using morphology and ossicle examination of the body wall (Table 1). Two specimens, *H.* cf. *albiventer* and *H.* cf. *imitans*, could not be identified with certainty to species level because some morphology and ossicles characteristics were lost during processing.

Conclusion

Fifty-four sea cucumber species that have ever been, and/or are still being, fished in Indonesia have been recognised as *trepang*. Of these, 33 species have been taxonomically confirmed, including 12 species that had rarely, or never, reportedly been traded either in local or international markets (*Actinopyga bannwarthi*, *Bohadshia subrubra*, *Holothuria lessoni*, *H.* cf. *albiventer*, *H.* cf. *imitans*, *H. turriscelsa*, *H. excellens*, *H. fuscocinerea*, *Stichopus noctivagus*, *S. pseudohorrens*, *S. monotuberculatus*, *S. quadrifasciatus*). It is still possible to identify processed specimens, salted and dried, since their defining species characteristics, such as ossicles of the body walls and several internal organs, remain.

Focusing on taxonomic study, it will be necessary to collect more samples from an extended area to provide more accurate data on the *trepang* species involved in trade. Molecular studies that have been developed to support species identification could be applied to identify processed trepang available in the marketplace.

References

Bruckner A.W., Johnson K.A. and Field J.D. 2003. Conservation strategies for sea cucumbers: Can a CITES appendix II listing promote sustainable International trade? SPC Beche-de-mer Information Bulletin 18:24–33.

Choo P.S. 2008. Population status, fisheries and trade of sea cucumbers in Asia. p. 81–118. In: Toral-Granda V., Lovatelli A. and Vasconcellos M. (eds). Sea cucumbers: A global review of fisheries and trade. FAO Fisheries and Aquaculture Technical Paper No. 516. Rome, Italy: Food and Agriculture Organization of the United Nations. 317 p.

Conand C. and Byrne M. 1993. A review of recent developments in the world of sea cucumber fisheries. Marine Fisheries Review 55:1–13.

Knaap G. and Sutherland H. 2004. Monsoon traders: Ships, skippers and commodities in eighteenth-Century Makassar. Leiden, The Netherlands: KITLV Press. 269 p.

Máñez K.S. and Ferse S.C.A. 2010. The history of Makassan *trepang* fishing and trade. PloS ONE 5(6): e11346. doi:10.1371/journal.pone.0011346

Massin C. 1999. Reef-dwelling Holothuroidea (Echinodermata) of the Spermonde Archipelago (South-West Sulawesi, Indonesia). Zoologische verhandelingen Vol. 329. Leiden, Netherlands: National Museum of Natural History. 144 p.

Massin C., Zulfigar Y., Tan Shau Hwai A. and Rizal Boss S.Z. 2002. The genus *Stichopus* (Echinodermata: Holothuroidea) from the Johor marine park (Malaysia) with the description of two new species. Bulletin de l'institut royal des sciences naturelles de Belgique 72:73–99.

Purcell S.W., Lovatelli A., Vasconcellos M. and Ye Y. 2010. Managing sea cucumber fisheries with an ecosystem approach. FAO Fisheries and Aquaculture Technical Paper No. 520. Rome, Italy: Food and Agriculture Organization of the United Nations. 171 p.

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 14(1):34–59.

Purcell S.W., Samyn Y. and Conand C. 2012. Commercially important sea cucumbers of the world. FAO Species Catalogue for Fishery Purpose No. 6. Rome, Italy: Food and Agriculture Organization of the United Nations. 150 p.

Purwati P. 2005. Teripang Indonesia: Komposisi jenis dan sejarah perikanan. Oseana 30(2):11–18.

Purwati P. 2006. Souvenir from West Lombok, eastern Indonesia. SPC Beche-de-mer Information Bulletin 23:26–28.

Purwati P. and Yusron E. 2005. Teripang Indonesia, biota yang terancam. Prosiding Pertemuan Ilmiah Tahunan ISOI-2005. Surabaya, 5–6 July 2005: 57–64.

Purwati P., Wirawati I. and Hendriks D. 2008. Timun laut anggota ordo Aspidochirotida (Echinodermata, Holothuroidea) koleksi Pusat Penelitian Oseanografi LIPI Jakarta: katalog / penyusun, Pradina Purwati, Ismiliana Wirawati, Dominggus Hendriks. Jakarta, Indonesia: Pusat Penelitian Oseanografi, Lembaga Ilmu Pengetahuan Indonesia. 61 p.

Purwati P., Hartati R. and Widianingsih. 2010. Eighteen sea cucumber species fished in Karimunjawa Island, Java Sea. Marine Research in Indonesia 35(2):23–30.

Setyastuti A. 2011. Sea cucumbers (Echinodermata: Holothuroidea) of Tikus Island, Seribu Archipelago. Oseanologi dan Limnologi di Indonesia 37(2):211–234.

Setyastuti A. 2013. Taxonomy study on trepang collected from Karimunjawa, Situbondo, Spermonde and Ambon. Thesis. Bogor, Indonesia: Bogor Agricultural University. 121 p.

Tuwo A. 2004. Status of sea cucumber fisheries and farming in Indonesia. p. 49–55. In: Lovatelli A., Conand C., Purcell S., Uthicke S., Hamel J.-F. and Mercier A. (eds). Advances in sea cucumber aquaculture and management. FAO Fisheries Technical Paper No. 463. Rome, Italy: Food and Agriculture Organization of the United Nations. 425 p.

Uthicke S., Byrne M. and Conand C. 2010. Genetic barcoding of commercial beche-de-mer species (Echinodermata: Holothuroidea). Molecular Ecology Resources 10(4):634–646.

Wirawati I. and Purwati P. 2012. Rarely reported species of Indonesian sea cucumbers. Marine Resources Indonesia 37(1):9–23.

Wirawati I., Setyastuti A. and Purwati P. 2007. Timun laut Anggota Famili Stichopodidae (Aspidochirotida, Holothuroidea, Echinodermata) Koleksi Puslit Oseanografi LIPI, Jakarta. Oseanologi dan Limnologi Di Indonesia 33(3):355–380.

Field observations of sea cucumbers in the north of Baa atoll, Maldives

Frédéric Ducarme[1,*]

Abstract

This report describes the results of a sea cucumber survey that was conducted on the coral reefs of the islands north of Baa atoll for two months in 2014. The main result of this survey is the scarcity of sea cucumbers — and echinoderms in general — in Baa atoll, along with poor diversity, largely dominated by the Holothuriidae *Pearsonothuria graeffei*, followed by several Stichopodidae. This study increases the number of holothurian species recorded in the Maldives to around 25, depending on determination of ambiguous observations, and 18 for Baa atoll alone.

Introduction

The Republic of Maldives is known by sea cucumbers specialists for its recent yet spectacular beche-de-mer fishery, which began only around 1985 but led to dramatic over-exploitation as early as 1990 (Joseph 1992), with the population collapse of most of the high value species (James and Manikfan 1994), leading to a tightening of exports, along with feeble regulations (FAO 2013). For years, very little information has been available about the diversity and abundance of sea cucumbers in Maldives, although recent studies have shed some light on the region (Muthiga 2008).

This part of the UNESCO Biosphere Reserve of Baa atoll is quite an isolated region and has been poorly covered by biological studies (Jimenez et al. 2012). It was not covered by the main scientific survey for marine invertebrates of this atoll (Andréfouët 2012). Nevertheless, this region has some characteristics that make it stand out from general studies of the Maldives and Baa atoll, including its echinoderm populations.

The present study describes the result of a sea cucumber survey that was conducted on the coral reefs of the islands in the north of Baa atoll for two months in 2014. Only one of the island reefs surveyed was an inhabited island, Landaa Giraavaru, which is a resort island (built in 2006). Three similar surveys were conducted in three different sites in Malé atoll as a control, which led to observations consistent with results from Muthiga (2008), indicating that the difference of results with former studies is not due to a methodological bias.

Materials and methods

The survey of distribution and abundance of holothurians was carried out in 13 sites off nine islands, all located in the north-east part of Baa atoll in July–September 2014 (Fig. 1). Habitats were described using a hierarchy of coral cover (from 0 for no coral cover to 5 for >90% of cover, as in Jimenez et al. 2012), as well as for damaged coral and sand. Rugosity was also reported in a similar scale (from 1 for a flat surface to 5 for highly rugose 3D architecture, as in Jimenez et al. 2012), habitat richness (1 for homogenous habitat to 5 for highly heterogenous) and hydrodynamics (from 1 for quiet water motion to 5 for medium current, which constitutes the maximum in this rather calm region).

At each location, 45-minute searches were made along a visual transect parallel to the reef crest, using scuba or snorkel, depending on depth. Some sites were surveyed several times, at different hours of the day and night, in order to avoid sampling bias. A total of 45 surveys were done, including nine night surveys and 11 dives deeper than 10 m. All surveys were carried out by examining the benthos, searching under crevices and rocks on the reef, and identifying and recording all sea cucumbers encountered. Pictures of each newly encountered species were taken for identification confirmation (Fig. 2). Occurrence was calculated as a percentage of the number of sites where each species was recorded (one site corresponding to 7.5%).

Most of the islands of this region are very small, surrounded by narrow reef flats without a lagoon, followed by very steep reef edges, going straight

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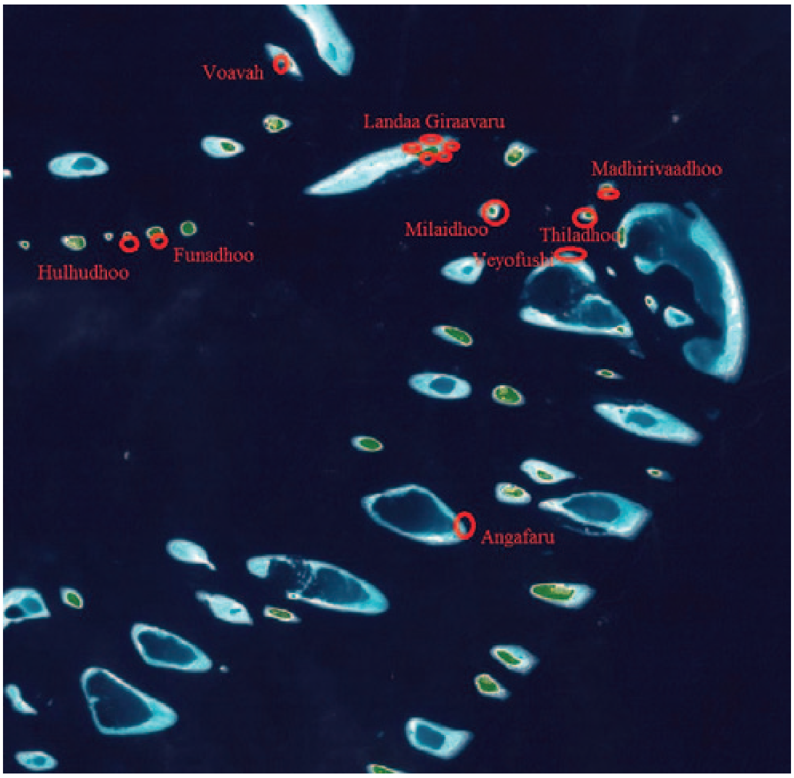

Figure 1. Location of sampling stations (north-east part of Baa atoll), with an indication of Baa atoll position relative to the Maldives.

down to a depth of about 30 metres (Kench 2012). The current can be steady, allowing important populations of sessile filter-feeding animals such as crinoids to develop; though wave action is moderate in this part of the atoll (Kench 2012).

Results

Study site description

The characteristics of the sites, including the benthic cover of the main ecological components of the substrate, are reported in Table 1. The benthic cover is largely dominated by live coral (more than 50%, often up to 80%), followed by dead coral more or less covered by turf algae and sand in some sites. No seagrass bed or mangrove was observed, and fleshy algae were also very rare. Rugosity, habitat richness and hydrodynamics were highly heterogenous, allowing quite a wide variety of ecological niches.

Aspidochirotid holothurians abundance and diversity

Seven species of aspidochirotid sea cucumbers were encountered during the survey (Table 2), including one species probably unidentified and one species not recorded in former studies (*Stichopus* cf. *horrens*). Seven more species were reported by colleagues and locals (from pictures or specimens) in the area but were not observed in the surveys. They are therefore listed as "reported" in Table 3. Among the species recorded in this survey, none was of high commercial value, and only three were reported as commercially exploited in the Maldives: *S. chloronotus*, *H. atra* and *T. anax* (Joseph 1992), despite the fact that all of them are considered edible and are fished in some regions (Purcell et al. 2012). Among the seven species recorded, five were stichopodids and two holothurids. The total number of individual sea cucumbers encountered at all the sites was 308 within a total search period of 33 hours. The overall density was 6.8 individuals per 45-minute search. The density of sea cucumbers was highest at Thiladhoo where the mean was 14.25 individuals per search.

The density of observations was very variable, ranging from 0 to 20 individuals per 45-minute search. *Pearsonothuria graeffei* was by far the most abundant species, accounting for 291 observations out of 308 (= 94.5%), and present in all sites but one (a site without live corals). It was followed by *Stichopus chloronotus* (2.3% of observations, recorded in three sites, corresponding to 23%). More individuals were found on live coral substrate (especially the most abundant species), but softer bottoms provided more diverse species. Sites with a high live coral cover (and important relief) provided important populations of *P. graeffei*, whereas *S. chloronotus* was observed in more simple sites with a less complex coral landscape and more algal turf. *H. atra* was observed only once, on a sandy reef flat with abundant detritic material (coming from coral but also partly human activities). Big stichopodids, such as *T. anax*, *S. herrmanni* and *S.* cf. *horrens*, were observed on large sandy patches in open reefs, but never on sandy detritic reef flats. Nearly all of the observations were made at snorkelling depths (1–7 m), and deeper dives showed a fast decrease of observations, and no additional species. Night surveys tended to find less abundance but a higher level of diversity, some species being observed mostly at night, especially the big stichopodids.

An unknown species (Fig. 2G) was observed three times at the same site, Landaa Giraavaru south, involving at least two different specimens. One specimen was collected and is currently under study at the National Museum of Natural History: it is a large (20–30 cm), robust species of stichopodid

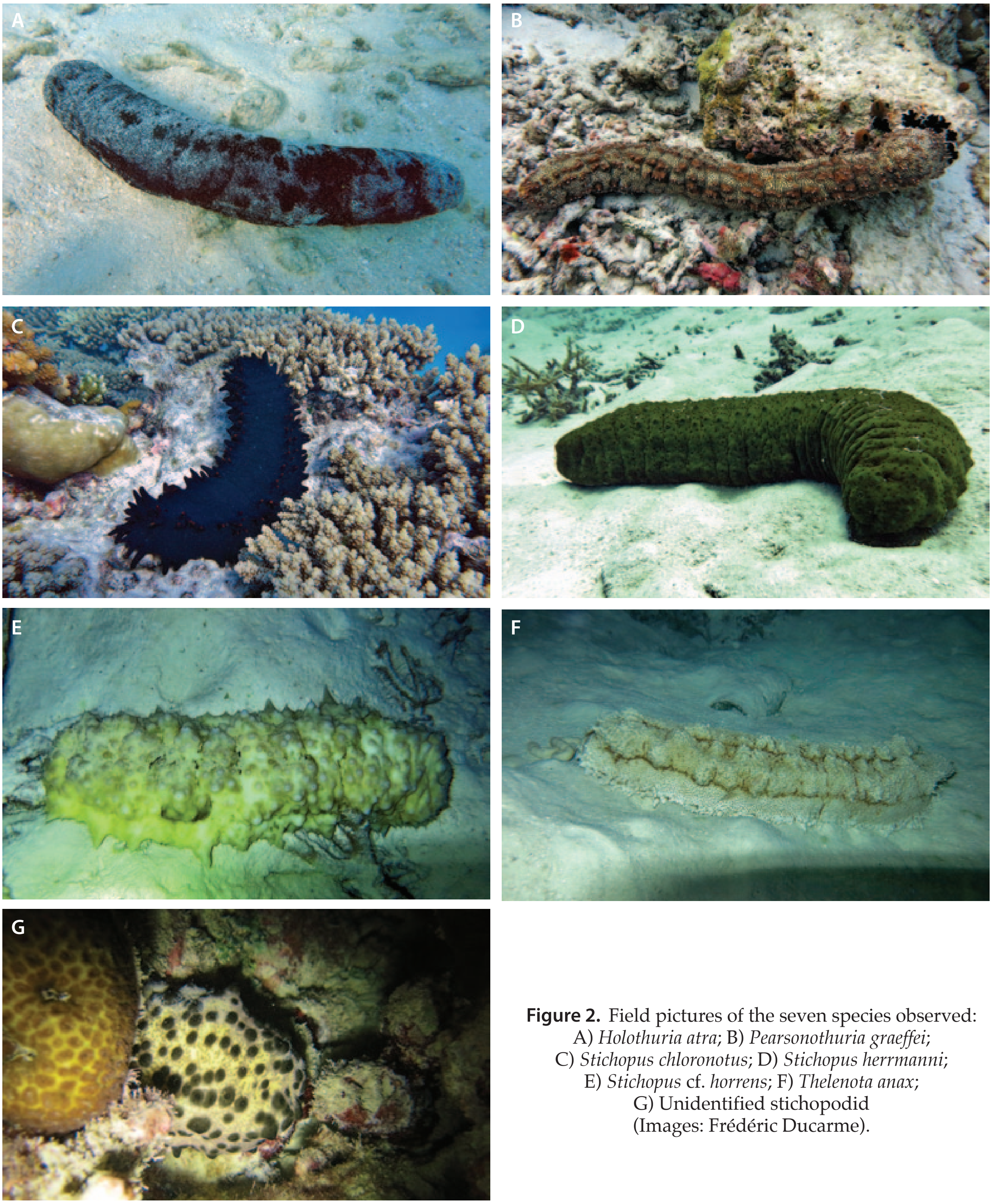

Figure 2. Field pictures of the seven species observed: A) *Holothuria atra*; B) *Pearsonothuria graeffei*; C) *Stichopus chloronotus*; D) *Stichopus herrmanni*; E) *Stichopus* cf. *horrens*; F) *Thelenota anax*; G) Unidentified stichopodid (Images: Frédéric Ducarme).

sea cucumber, with light greenish skin spotted with large dark spots.

Overall echinoderm diversity in the study sites

The study sites showed a strikingly scarce population of echinoderms compared to data from other atolls of the Maldives (field observations and Muthiga [2008]). The most abundant class was Asteroidea, with a large population of *Linckia multifora* and *Culcita schmideliana* (consistent with Andréfouët 2012), followed by, in order of abundance, *Fromia indica*, *Linckia guildingi*, *Choriaster granulatus*, *Fromia nodosa*, *Gomophia egyptiaca* and *Fromia nodosa*; big specimens of *Mithrodia clavigera* and *Leiaster* cf. *speciosus* were also observed at night (both new records for this area). *Acanthaster planci*, though reported earlier (Andréfouët 2012), was not observed in Baa (but individuals were observed during control surveys in Kuda Huraa, east of Malé atoll). The second

Table 1. Characteristics of the survey sites and diversity of holothurians. Observed live coral cover, rugosity (3D complexity), habitat richness and hydrodynamics of sampling stations, in relation to the number of species observed.

Survey site	Live coral	Turf and damaged coral	Sand	Rugosity	Habitat richness	Hydrodynamics	Number of surveys	Diversity of sea cucumbers
Angafaru	2	2	1	1	3	1	1	1
Funadhoo	5	1	0	4	4	3	1	1
Hulhudhoo	5	1	0	4	4	3	3	1
Landaa south	4	2	1	5	4	2	15	5
Landaa east	2	2	1	2	2	4	3	4
Landaa north	0	3	3	1	1	2	1	0
Landaa NE	3	2	2	3	3	3	1	1
Landaa SE	2	2	2	2	4	2	1	2
Madhirivaadhoo	4	2	1	4	3	2	4	1
Milhadhoo	3	3	1	3	4	2	6	2
Thiladhoo	4	2	1	4	4	3	4	1
Veyofushi	2	1	3	3	3	3	1	1
Voavah	5	1	2	5	5	1	3	1

Table 2. Abundance of each holothurian species in the survey sites and occurrence (number of sites with presence / total number of sites).

	Angafaru	Funadhoo	Hulhudhoo	Landaa south	Landaa east	Landaa north	Landaa NE	Landaa SE	Madhirivaadhoo	Milhadhoo	Thiladhoo	Veyofushi	Voavah	Total abundance	Occurrence (%)
Pearsonothuria graeffei	7	3	10	90	21		5	6	30	50	57	5	7	291	92.0
Stichopus chloronotus				1	1					5				7	23.0
Holothuria atra					1									1	7.5
Thelenota anax				1				1						2	15.0
Stichopus herrmanni					2									2	7.5
Stichopus cf. *horrens*				2										2	7.5
Unidentified sp.				3										3	7.5

most abundant class was *Crinoidea*, represented by at least six different morphotypes including probable *Lamprometra*, *Himerometra*, *Comanthus*, *Oxycomanthus*, *Stephanometra* and *Commissia* sp. *Echinoidea* were surprisingly cryptic, with hardly any observation during the day, except burrowing species like *Echinostrephus molaris* (the most abundant species) and scarce, small specimens of *Echinometra mathaei*. Nevertheless, large populations of *Heterocentrotus mamillatus* (both white-red and purple morphs) and *Phyllacanthus imperialis* were observed at night. Other observations included very scarce and small *Diadema savignyi* and *Echinothrix diadema*, along with stranded tests of *Fibularia* sp. (quite common on beaches), *Metalia sternalis* and *Clypeaster humilis*. *Ophiuroidea* were extremely rare and cryptic, represented only by scarce observations of Ophiothrichidae.

Discussion

The main result of this survey is the scarcity of sea cucumbers — and echinoderms in general — in Baa atoll, along with poor diversity, largely dominated by the holothuroid *Pearsonothuria graeffei*, followed by several stichopodids. The number of species by survey as well as the overall abundance were both strikingly weaker than what was observed in Malé atoll, and recorded by Muthiga (2008) (Table 3). Such a result is consistent with the overall rarity of benthic organisms noted by Andréfouët (2012) for this atoll, where most of the species were seen only once. In this survey, stichopodid sea cucumbers were better represented than expected, given previous work, whereas holothuroids showed less diversity, though they dominate the Maldivian assemblage in most of the other surveys. This result, therefore, differs from previous studies for Baa atoll (Andréfouët 2012), as well as Malé atoll (Muthiga 2008), Laamu atoll (Reichenbach 1999) and Maldives (Joseph 1992; James and Manikfan 1994), which were clearly dominated by *Holothuria*, *Actinopyga* and *Bohadschia* (Table 3). The dominance of *P. graeffei* is consistent with Andréfouët 2012, but more pronounced in our study with occurrence accounting for 92%, compared to 53.5% in the previous study. The fact that we recorded *Stichopus chloronotus* as the second most abundant species (seven observations in three sites) was surprising, given the fact that this species was not even recorded by Andréfouët 2012 (Table 3). This leads to a total of 18 recorded species for Baa atoll for both studies, including eleven holothurids, six stichopodids and one synaptid.

Two individuals of *Stichopus* cf. *horrens* were observed, rather big, uniformly clear and highly warty individuals (Fig. 2E). These constitute the first record of this species in Baa atoll, and it was absent from the most recent studies (Muthiga 2008; Andréfouët 2012). As the taxonomy of this group and its relation with morphology is still debated (Byrne et al. 2010), exact determination of the species could not be made. The external features of these animals possibly suggest a new morph, subspecies or even species, and further work could concentrate on this animal. *Actinopyga caerulea* is also a new record for the region.

This scarcity of sea cucumbers could be partly explained by the ecosystem characteristics — small islands with little vegetation and no mangrove, no true lagoon, and no seagrass bed — all ecosystems that are used to shelter an important part of the holothurian

Table 3. Comparison of the present results with previous inventories. Four species were reported by locals (picture or specimen) in the area but were not observed during the surveys.

	Present study (Baa atoll)	Andréfouët (2012) (Baa atoll)	Muthiga (2008) (Malé atoll)	Reichenbach (1999) (Malé & Laamu atolls)	James (1994) (Maldives)	Joseph (1992) (Maldives)
Holothuria atra	*	*	*		*	*
Pearsonothuria graeffei	*	*	*			
Stichopus chloronotus	*		*		*	*
Stichopus herrmanni	*			*		
Stichopus cf. *horrens*	*					
Thelenota anax	*	*	*	*	*	
Unidentified sp.	*					
Actinopyga lecanora	Reported	*	*		*	*
Actinopyga mauritiana		*	*	*	*	*
Bohadschia argus		*				
Bohadschia marmorata		*			*	*
Holothuria edulis	Reported	*	*	*		
Holothuria fuscogilva		*		*		
Thelenota ananas	Reported	*	*	*	*	
Synaptula sp.	Reported	*				
Actinopyga caerulea	Reported					
Actinopyga echinites				*	*	
Actinopyga miliaris	Reported		*	*	*	
Bohadschia atra			*			
Bohadschia vitiensis			*			
Holothuria fuscopunctata	Reported			*	*	*
Holothuria hilla			*			
Holothuria leucospilota			*			*
Holothuria nobilis			*		*	*
Synapta maculata						*

biodiversity. Even fleshy algae were very rare as well, which is consistent with the almost complete absence of green turtle, compared to a high population of hawksbill turtle. The sites at Hulhudhoo, Voavah and Thiladhoo had the highest hard coral cover (Table 1), and Landaa Giraavaru east had the lowest (sand and rubble bed). This is significantly higher than is reported for most Maldivian reefs (Muthiga 2008).

This trend can also be related to the relative scarcity of diurnal benthic invertebrates, which might be linked to a high level of predation, as suggested by the rarity and cryptic behaviour of most benthic animals, and the evidence of predation on big and strong benthic invertebrates (especially *H. mamillatus*).

However, human exploitation could also be a cause of this low diversity, and explain in part the absence of high value species, such as *Thelenota ananas* (the main target of fishermen in Maldives, according to James and Manikfan [1994] and FAO [2013]), which is known in the region but could not be found in this survey. This could suggest a high level of fishing, even on uninhabited island reefs in a weakly populated UNESCO Biosphere Reserve. According to field-gathered information, sea cucumber processing documented by FAO (Joseph 1992) in Hithaadhoo and Thulhaadhoo is no longer in activity, but little information could be gathered on site about current fishing. Nevertheless, illegal fishing is known to occur throughout all the Maldivian area (Ahmed et al. 1996; FAO 2013).

This study increases the number of holothurian species recorded in Maldives to around 25, depending on determination of ambiguous observations, and 18 for Baa atoll alone.

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References

Ahmed H., Mohamed S. and Saleem M. 1996. Exploitation of reef resources: Beche-de-mer, reef sharks, giant clams, lobsters and others. p. 137–167. In: Nickerson D.J. and Maniku M.H. (eds). Workshop on Integrated Reef Resources Management in the Maldives, Bay of Bengal Programme. 16–20 March 1996. Madras, India: Food and Agriculture Organization of the United Nations.

Andréfouët S. 2012. Biodiversity, resources, and conservation of Baa atoll (Republic of Maldives): A UNESCO Man and Biosphere Reserve. Atoll Research Bulletin 590.

Byrne M., Rowe F. and Uthicke S. 2010. Molecular taxonomy, phylogeny and evolution in the family Stichopodidae (Aspidochirotida: Holothuroidea) based on COI and 16S mitochondrial DNA. Molecular Phylogenetics and Evolution 56(3):1068–81.

FAO. 2013. Report on the FAO Workshop on sea cucumber fisheries: An ecosystem approach to management in the Indian Ocean (SCEAM Indian Ocean), Mazizini, Zanzibar, the United Republic of Tanzania, 12–16 November 2012. FAO Fisheries and Aquaculture Report. No. 1038. ood and Agriculture Organization of the United Nations. 92 p.

James D.B. and Manikfan M.A. 1994. Some remarks on the present status of beche-de-mer industry of Maldives and its lesson for the Lakshadweep. Bulletin of the Center for Marine Fishery Resources Institute 46:101–105.

Jimenez H., Bigot L., Bourmaud C., Chabanet P., Gravier-Bonnet N., Hamel and Andréfouët S. 2012. Multi-taxa coral reef community structure in relation to habitats in the Baa Atoll Man and Biosphere UNESCO Reserve (Maldives), and implications for its conservation. Journal of Sea Research 72:77–86.

Joseph L. 1992. Review of the beche-de-mer (Sea Cucumber) Fishery in the Maldives. Bay of Bengal Working Paper Vol. 79. 34 p.

Kench P.S. 2012. The geomorphology of Maa (south Maalhosmadulu) atoll and its reef islands. Biodiversity, Resources, and Conservation of Baa Atoll (Republic of Maldives): A UNESCO Man and Biosphere Reserve, 590, 1–30.

Muthiga N. 2008. Field observations of sea cucumbers at North Male Atoll in the Maldives. SPC Beche-de-Mer Information Bulletin 27:33–37.

Purcell S.S.W., Samyn Y. and Conand C. 2012. Commercially important sea cucumbers of the world. FAO Species Catalogue for Fishery Purposes No. 6. Rome, Italy: Food and Agriculture Organization of the United Nations. 223 p.

Reichenbach N. 1999. Ecology and fishery biology of *Holothuria fuscogilva* (Echinodermata: Holothuroidea) in the Maldives, Indian Ocean. Bulletin of Marine Science 64(1):103–113.

Spawning induction and larval rearing of the sea cucumber *Holothuria scabra* in Malaysia

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Abstract

The sea cucumber *Holothuria scabra* was induced to spawn by the methods of thermal and algal stimulation. Thermal stimulation proved to be the better method. The larvae were given a mix of microalgal diet, the concentration of which was based on the larval growth. Doliolaria larvae appeared 11 days after fertilisation, and then became pentactula 18 days after fertilisation. A survival rate of 4.2% was recorded from three successful spawning.

Keywords: *Holothuria scabra*, spawning method, survival rate, thermal induction.

Introduction

The processed beche-de-mer of *Holothuria scabra* is a source of income and food for the coastal communities of eastern Malaysia. However, severe overfishing has led to a significant decrease in the natural sea cucumber population. This continuous over-exploitation is likely to have a huge impact on the ecosystem and marine environment as a whole (Conand 2004). Research into the feasibility of restocking and stock enhancement of tropical sea cucumber is being conducted in many tropical countries (Purcell et al. 2011, 2014; Eriksson et al. 2014; Watanabe et al. 2014). There is also an urgent need for restocking and stock enhancement in Malaysia. This paper focuses on breeding and cultivation of *H. scabra*, a high-value, widely distributed species and currently the only tropical species that can be mass produced in hatcheries. This is the first report of breeding by induced spawning of *H. scabra* and larval rearing in Malaysia.

Materials and methods

Broodstock collection

Healthy *H. scabra* weighing between 450 and 750 g were collected from the wild by divers in April 2012. Broodstock collected from the nearby coastal area were carefully transported to the hatchery in tubs of fresh seawater, while broodstock collected from far away were packed in polythene bags supplied with oxygen and fresh seawater. At the hatchery, the broodstock were placed in 10 m^3 flow-through tanks filled with sandy substratum. There were about 30 to 40 animals per tank. They were fed with algae, seaweed and mud and the substratum was changed every two weeks.

Induced spawning

We used two methods to induce spawning: thermal stimulation and algal stimulation. Thermal stimulation was found to be the better method and was used thereafter.

For thermal stimulation, 30 to 40 sea cucumbers were gently washed, cleansed and prepared for spawning. The temperature of the spawning tank was raised by 3–5°C from the ambient temperature of 27–28°C to induce spawning. The males released their sperm 30 minutes after spawning induction for two hours and then, after one hour, the females released their eggs.

For algal stimulation, 100 g of dried *Spirulina* was mixed with seawater and dissolved in a one-litre spawning tank. Additional dried *Spirulina* was added if the concentration was still insufficient to induce spawning. Thirty to 40 sea cucumbers were introduced into the tank and left for an hour to spawn. Once the spawning was over, the broodstock were put back in the broodstock tanks.

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Three spawning trials were conducted using each of the spawning induction methods. After each successful spawning, the eggs were collected, washed in 75-µm sieves, and counted using a hemacytometer.

Larval rearing

The larvae were stocked in a 1,000 L larval rearing tank with a stocking density of 200 to 250 larvae per litre. The tank was filled with 1 µm UV sterilised seawater at a temperature between 26 and 30°C. Salinity was maintained between 32 and 36 ppt, and pH between 8.0 and 8.2. The larvae were checked every day for changes in shape, size and stage, as well for the presence of bacteria and predators.

The auricularia larvae were fed with microalgae, and the algal concentration in the rearing tanks was maintained at 20,000–35,000 cells mL^{-1}, depending on the growth stages. A microalgae diet consists of *Isochrysis galbana*, *Pavlova lutheri*, *Chaetoceros muelleri*, *Nitzschia acicularis* and *Navicula* sp.

Continuous aeration was provided to the tanks and the water was changed every day by flow through. A 75-µm sieve was placed inside the tank to prevent the larvae from flowing out. The bottom of the tanks was siphoned out every day to clear any sediment. The doliolaria stage began 11 days after larval stocking. The larvae were transferred into juvenile rearing tanks filled with settlement plates covered with *Spirulina* sheets. After seven days, the doliolaria transformed into pentactula and actively fed on benthic diatoms, dead algae, seagrass, seaweed powder and *Spirulina*. They were harvested once they reached an average length of 15 mm.

Results

Results from Table 1 and Figure 1 show that thermal induction was the more effective method, producing a total of 1,073,000 eggs from three spawning trials, while induced spawning via the algal induction method was successful only in one trial out of the three, producing 120,000 eggs.

Table 1. Number of eggs produced from different types of spawning method of *Holothuria scabra*.

Spawning method	Date	No. of broodstock	No. of eggs
Thermal induction	28-05-2012	30	154,000
Thermal induction	01-06-2012	30	385,000
Thermal induction	25-07-2012	30	534,000
Algal induction	28-05-2012	30	0
Algal induction	01-06-2012	30	0
Algal induction	25-07-2012	30	120,000

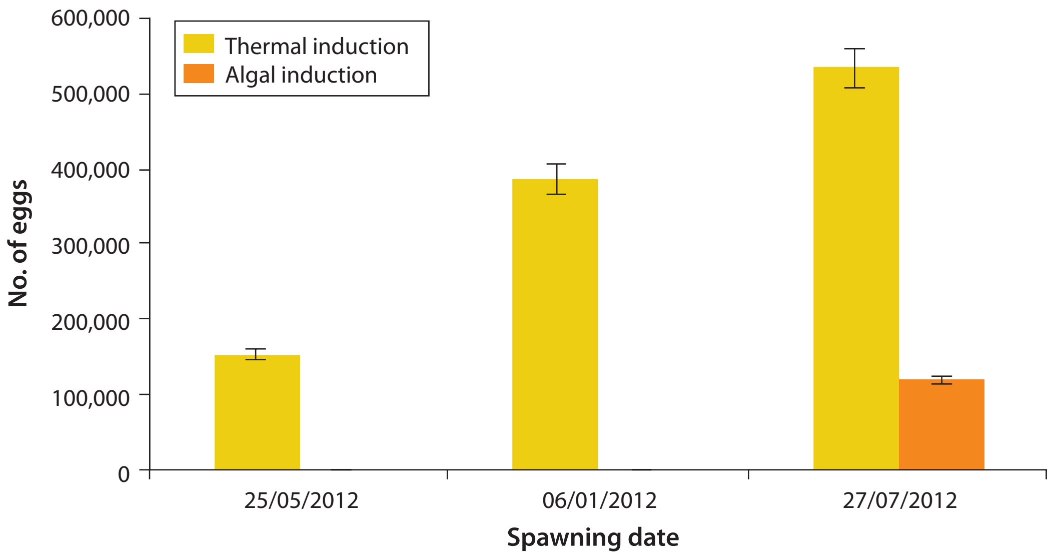

Figure 1. Number of eggs produced from different spawning method of *Holothuria scabra*.

The percentage of larval hatch was calculated on the appearance of auricularia larvae, approximately 48 hours after fertilisation. From the three spawning trials, 92% ±2.9 of auricularia larvae hatched. Auricularia is the start of the feeding stage, and during this stage the larvae were fed with 20,000 cells mL^{-1} of microalgae. The feed was subsequently increased by the larval demand. Auricularia sizes range from about 425 to 450 μm. Middle auricularia were bigger, with a size range between 750 and 950 μm (Fig. 2).

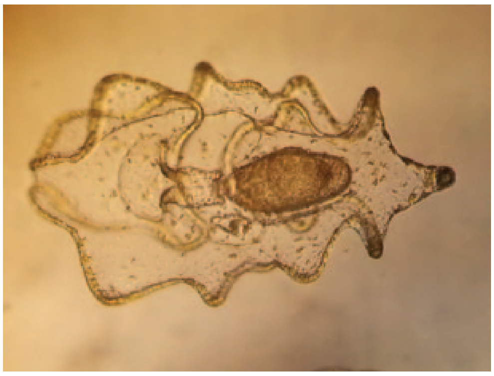

Figure 2. Auricularia larva of *Holothuria scabra*.

After 11 days, about 38 ±12.9% auricularia larvae metamorphosed into the non-feeding stage, doliolaria — A very active non-feeding, fast moving larva between 450 and 650 μm (Fig. 3).

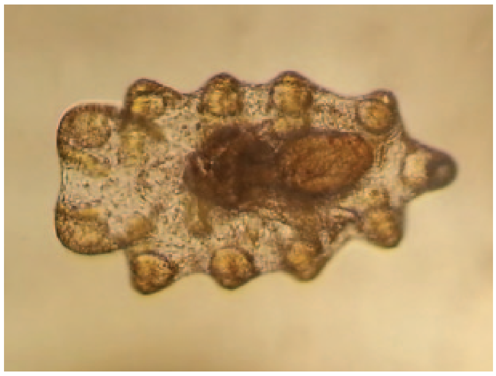

Figure 3. Doliolaria larva of *Holothuria scabra*.

Doliolaria transformed into creeping stage pentactula on the 18th day. They can be seen on the settlement plates, on the bottom and on the wall of the tanks as they search for suitable substratum to settle on. The pentactula larvae size ranges from 350 to 750 μm. The survival rate of *H. scabra* larvae was 4.2% ±0.5 (Fig. 4).

Discussion

Restocking, reseeding or stock enhancement is seen as a way of rebuilding after the depletion of the wild stock of sea cucumbers. Many countries have started their own stock enhancement programme by doing research into the feasibility of tropical sea cucumber breeding (Purcell et al. 2011, 2014; Eriksson et al. 2014; Watanabe et. al. 2014). Successful

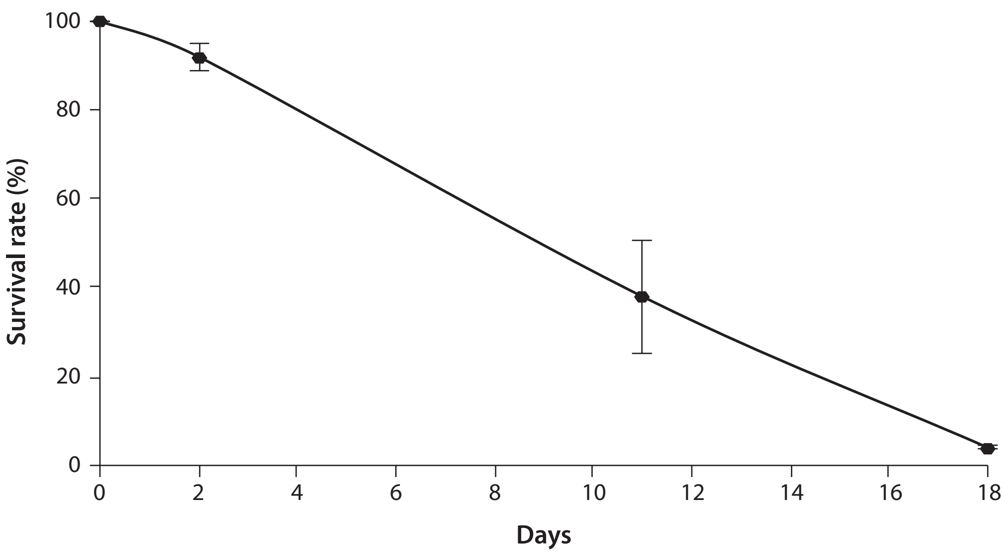

Figure 4. Survival rate of *Holothuria scabra* larvae.

breeding by induced spawning has been widely reported and most of the authors claim that thermal induction is the best method for sea cucumber spawning (Battaglene 1999; Battaglene et al. 2002; Laxminarayana 2005; Ivy and Giraspy 2006; Eeckhaut et al. 2012). In this study, two methods were compared and thermal induction gave a better result than algal stimulation. While thermal induction was effective on most sea cucumber species, it is less effective on *Holothuria fuscogilva* (Battaglene et al. 2002).

There are other methods for induced spawning, such as powerful water jets on drying individuals (James 1996; Liu et al. 2004; Wang and Yuan 2004) and blended gonad as stimulant (Battaglene 1999). *Stichopus* sp. (curry fish) was induced to spawn by open-air drying followed by flow-through seawater stimulation.

Successful spawning and larval rearing of several species of sea cucumber have been reported in various studies (Battaglene et al. 2002; Chen 2003; Laxminarayana 2005; Giraspy and Ivy 2005; Ivy and Giraspy 2006; Dabbagh et al. 2011). However, the only tropical species that can be mass-produced in hatcheries is *H. scabra* (Battaglene and Bell 1999). *H. scabra* culture started in 1988 in India for farming purposes, although the possibility for stock enhancement was suggested (James et al. 1988, 1994; James 1996). This species appears capable of spawning all year long without the influence of lunar periodicity (Ong Che and Gomez 1985; Conand 1993). They are dioecious, highly fecund and are broadcast spawners. The life cycle of cultured *H. scabra* starts with the appearance of early auricularia 48 hours after fertilisation of the eggs, followed by mid and late auricularia. Eleven days after fertilisation, the larvae morph into the non-feeding state of doliolaria. Then the first appearance of pentactula larvae is observed 18 days after fertilisation. The larval growth characteristics vary from species to species. For example, *Holothuria atra* and *Bohadschia marmorata* take 20 days to reach pentactula stage (Laxminarayana 2005) while *H. lessoni* take 19 days (Ivy and Giraspy 2006).

The survival rate of *H. scabra* from this study was 4.2% ±0.5. The poor survival rate of tropical sea cucumber species has been reported by Purcell et al. (2012). Ivy and Giraspy (2006) reported that the survival rate for *H. scabra versicolor* was 1.12% in 2004 and 4.53% in 2005. The survival rates for *B. marmorata* and *H. atra* were 12.5% and 6.4% respectively (Laxminarayana 2005). A few studies suggest that survival rate and algal concentration are related. A good survival rate of *H. lessoni* was obtained with algal concentration 4 x 10^4 cells mL^{-1} (Ivy and Giraspy 2006) while *Holothuria spinifera* had the highest survival rate at algal concentration of between 2 and 3 x 10^4 cells mL^{-1} (Asha and Muthiah 2002).

Decline in the percentage of the survival rate occurs during the metamorphosis stage in our study. From 92% hatched larvae, only 38% of auricularia larvae morphed into doliolaria. The rate further declined to 4.2% when they transformed into pentactula larvae. In this experiment, the mortality rate was up to 96%, starting from when the eggs were fertilised to the formation of the pentactula larvae. Battaglene (1999) reported that the highest mortality occurred at the first feeding and settlement. This also may be due to the food demands and the induction of the larval metamorphosis. The presence of bacteria and predators in the tank also affects the mortality and survival rate. Furthermore, it may also relate to the anatomy and physiology of the larvae of the sea cucumber species.

Acknowledgements

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References

Asha P.S. and Muthiah P. 2002. Spawning and larval rearing of sea cucumber *Holothuria* (*Theelothuria*) *spinifera* Theel. SPC Beche-de-mer Information Bulletin 16:11–15.

Battaglene S.C. 1999. Culture of the tropical sea cucumbers for the purpose of stock restoration and enhancement. Naga, the ICLARM Quarterly 22(4):4–11.

Battaglene S.C. and Bell J.D. 1999. Potential of the tropical Indo-Pacific sea cucumber, *Holothuria scabra*, for stock enhancement. p. 478–490. In: Howell B.R., Moskness E. and Svasand E. (eds). Stock enhancement and sea ranching. Oxford, United Kingdom: Blackwell Science. 606 p.

Battaglene S.C., Seymour T.E., Ramofafia C. and Lane I. 2002. Spawning induction of three tropical sea cucumbers, *Holothuria scabra*, *Holothuria fuscogilva* and *Actinopyga mauritiana*. Aquaculture 207:29–47.

Chen J. 2003. Overview of sea cucumber farming and sea ranching practices in China. SPC Beche-de-mer Information Bulletin 18:18–23.

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

Conand C. 2004. Present status of world sea cucumber resources and utilization: An international overview. p. 13–23. In: Lovatelli A., Conand C., Purcell S., Uthicke S., Hamel J.-F. and Mercier A. (eds). Advances in sea cucumber aquaculture and management. FAO Fisheries Technical Paper. No. 463. Rome, Italy: Food and Agriculture Organization of the United Nations. 425 p.

Dabbagh A., Sedaghat A.R., Rameshi H. and Kamrani E. 2011. Breeding and larval rearing of the sea cucumber *Holothuria leukospilota*, Brandt (*Holothuria vegabunda*, Selenka) from the Northern Persian Gulf, Iran. SPC Beche-de-mer Information Bulletin 31:35–38.

Eeckhaut I., Lavitra T., Léonet A., Jangoux M. and Rasolofonirina R. 2012. In vitro fertilization: A simple, efficient method for obtaining sea cucumber larvae year round. p. 40–49. In: Hair C.A., Pickering T.D. and Mills D.J. (eds). Asia-Pacific tropical sea cucumber aquaculture. Proceedings of an international symposium held in Noumea, New Caledonia. ACIAR Proceedings No. 136. Canberra, Australia: Australian Centre for International Agricultural Research. 209 p.

Eriksson H., Torre-Castro M., Purcell S.W. and Olsson P. 2014. Lessons for resource conservation from two contrasting small-scale fisheries. Ambio. doi:10.1007/s13280-014-0552-5.

Giraspy D.A.B. and Ivy G. 2005. Australia's first commercial sea cucumber and sea ranching project in Hervey Bay, Queensland, Australia. SPC Beche-de-mer Information Bulletin 21:29–32.

Ivy G. and Giraspy D.A.B. 2006. Development of large-scale hatchery production techniques for the commercially important sea cucumber *Holothuria scabra* var. *versicolor* (Conand, 1986) in Queensland, Australia. SPC Beche-de-mer Information Bulletin 24:28–34.

James D.B. 1996. Culture of sea cucumber. p. 120–126. In: Rengarajan K. (ed.). Artificial reefs and sea farming technologies. Bulletin of The Central Marine Fisheries Research Institute, Vol. 48.

James D.B., Rajapandian M.E., Baskar B.K. and Gopinath C.P. 1988. Successful induced spawning and rearing of holothurian, *Holothuria* (*Meriatyla*) *scabra*, Jaegar at Tuticorin. Marine Fisheries Information Service, Technical and Extension Service 87:30–33.

James D.B., Gandhi A.D., Palaniswamy N. and Rodrigo J.X. 1994. Hatchery techniques and culture of the sea cucumber *Holothuria scabra*. Cochin, India: Central Marine Fisheries Research Institute, Special publication. No. 57.

Laxminarayana A. 2005. Induced spawning and larval rearing of the sea cucumbers, *Bohadschia marmorata* and *Holothuria atra*, in Mauritius. SPC Beche-de-mer Information Bulletin 22:48–52.

Liu X., Zhu G., Zhao Q., Wang L. and Gu B. X. 2004. Studies on hatchery techniques of the sea cucumber *Apostichopus japonicus*. p. 287–296. In: Lovatelli A., Conand C., Purcell S., Uthicke S., Hamel J.-F. and Mercier A. (eds). Advances in Sea Cucumber Aquaculture and Management. FAO Fisheries Technical Paper. No. 463. Rome, Italy: Food and Agriculture Organization of the United Nations. 425 p.

Ong Che R.G. and Gomez E.D. 1985. Reproductive periodicity of *Holothuria scabra* Jaeger at Calatagan, Batangas, Philippines. Asian Marine Biology 2:21–29.

Purcell S.W., Mercier A., Conand C., Hamel J., 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.

Purcell S.W., Hair C.A. and Mills D.J. 2012. Sea cucumber culture, farming and sea ranching in the tropics: Progress, problems and opportunities. Aquaculture 368/369:68–81.

Purcell S. W., Lovatelli A. and Pakoa K. 2014. Constraints and solutions for managing Pacific Island sea cucumber fisheries with an ecosystem approach. Marine Policy 45:240–250.

Wang R. and Yuan C. 2004. Breeding and culture of the sea cucumber, *Apostichopus japonicus*, Lio, 2004. p. 277–286. In: Lovatelli A., Conand C., Purcell S., Uthicke S., Hamel J.-F. and Mercier A. (eds). Advances in Sea Cucumber Aquaculture and Management. FAO Fisheries Technical Paper. No. 463. Rome, Italy: Food and Agriculture Organization of the United Nations. 425 p.

Watanabe S., Sumbing J.G. and Lebata-Ramos M.J.H. 2014. Growth pattern of the tropical sea cucumber, *Holothuria scabra*, under captivity. Japan Agricultural Research Quarterly 48(4):457–464.

Effect of nurseries and size of released *Holothuria scabra* juveniles on their survival and growth

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Abstract

When 15-g juveniles of *Holothuria scabra* are transferred into sea pens for farming in Madagascar, there is high mortality during the two first months of rearing, which is principally due to predation by the crab *Thalamita crenata*. The use of nurseries (covered pens) is thought to be the best way of protecting those juveniles against predation. An experiment was carried out in Tampolove, a sea cucumber farming site where there is a very low density of predators. The purpose of the experiment was to see how the use of nurseries and the size at which juveniles are released into them affected their survival and growth.

For this experiment, eight nurseries and eight sea pens, all 16 m², were constructed and four size groups of juveniles were tested: 0–5 g, 5–10 g, 10–15 g and 15–20 g. The rearing density was 3 ind. m^{-2}. After three months, the average survival rates were between 78.00 and 83.75%, which suggests that the size of released juveniles did not affect the survival rate. Also, the use of a nursery did not significantly increase the survival rates; they were 87.50% and 78.88% respectively for juveniles reared in nurseries and in sea pens.

This experiment showed that the use of nurseries is not necessary in farming sites with a low density of predators, and that juveniles less than 5 g can be released in these sites.

Introduction

Mesh enclosures in the sea or in earthen ponds are one solution for scaling up production of juvenile sandfish because the cost of mesh and water exchange are relatively low (Juinio-Meñez et al. 2012; Purcell et al. 2012; Purcell and Agudo 2013). Pitt and Duy (2004) conducted the pioneering work of growing sandfish juveniles in mesh enclosures in earthen ponds. This nursery system involved two steps: small juveniles of a few mm body length from hatchery tanks are grown in the fine-mesh enclosures to about 20 mm body length (almost 1 g body weight), then transferred to coarse-mesh enclosures of 1 mm mesh and grown to a competent size for stocking into ponds or into the sea.

Tsiresy et al. (2011) were the first to use sea nurseries (mesh-covered sea pens) ensuring the first months of *Holothuria scabra* juveniles development in SW Madagascar after being transferred from earthen ponds. The *H. scabra* juveniles are transferred into nurseries at a weight of 15 g. The first assays with nurseries were made at Sarodrano and Andrevo, two villages close to Toliara, which suffer the greatest losses of juveniles. The introduction of nurseries made it possible to significantly restrict losses in the first month. The idea behind these nurseries was to physically prevent crabs *Thalamita crenata* (the biggest predator of sandfish juveniles in the region, Lavitra et al. [2009]) from approaching juveniles during the first weeks of growth in the sea. With this new system, 15 days after stocking, the observed survival rates were 79% for Sarodrano and 70% for Andrevo. Unfortunately, these positive results led farmers to neglect crab culling, both in nurseries and in the rest of the pens, so losses after the first few days were huge.

Juinio-Meñez et al. (2012) tested different enclosure systems in the Philippines for rearing sandfish juveniles starting at 4–10 mm over 1–2 months. They found poor survival (18%) of juveniles in enclosures set on the sea bed, better rates in floating enclosures (12–44%) and the best rates in enclosures in earthen ponds (57–73%). Purcell and Agudo (2013) in New Caledonia used coarse-mesh sea enclosures gathered at the top and attached to the benthos but the

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system did not appear to be a viable nursery system; the slow growth rates of sandfish juveniles that they measured would stifle production of juveniles for stocking programmes.

At present, results of the tests involving nurseries are conflicting. In the present study, we investigate the effects of: (i) the use of sea nurseries; and (ii) the size of released juveniles on the survival and growth of *H. scabra* juvenile in Tampolove, a farming site on the northwest coast of Toliara (Madagascar) where the predator crabs *T. crenata* are rare.

Materials and methods

Construction of pens and nurseries

The construction of pens and nurseries was carried out during low tide in the spring. The pens were constructed with plastic nets fixed to wooden stakes placed at 50 cm intervals and buried to a depth of 25 cm to prevent the escape of juveniles (Fig. 1A). A nursery is a pen covered on top by a local fishing net (Fig. 1B). For this experiment eight pens and eight nurseries were constructed and installed in Tampolove village. Each pen/nursery had a surface area of 16 m^2 (4 x 4 m) and was 50 cm high.

Juveniles

Holothuria scabra juveniles were offered by the MHSA Company (Madagascar Holothurie Société Anonyme) and four different sizes were tested: 0–5 g; 5–10 g; 10–15 g and 15–20 g. The rearing density was 3 ind. m^{-2}, which was equivalent to 48 juveniles per pen/nursery.

Measurements

This experiment was conducted over a three-month period (June to September 2012). To get the growth rate, the juveniles were weighed monthly at night, since they burrow under the sediment during the day. The survival rate was recorded at the end of each month by counting the number of live specimens.

Data analysis

All samples presented a normal distribution of the data and homogeneity of variances after running the Kolmogorov-Smirnov and Levene tests. Therefore, a two-way ANOVA was used to analyse the data. The statistical analysis was performed using SYSTAT v12 Software.

Results

Survival

After three months of rearing, the average survival rates were 83.75% ±6.18, 88.00% ±13.88, 78.00% ±17.49 and 83.00% ±13.63 for the four size classes respectively (juveniles released in nurseries and pens combined; Fig. 2). The statistical analysis showed that the release size of the *H. scabra* juveniles did not affect their survival ($P = 0.7640$). Also, the use of a nursery did not increase the survival rates ($P = 0.226$). They were 87.50% ±11.42 and 78.88% ±12.87 respectively for juveniles reared in a nursery and in a pen (all sizes combined; Fig. 2).

Growth

A slightly exponential growth was observed during the three months of the experiment for the four size classes of *H. scabra* juveniles: 0–5 g, 5–10 g, 10–15 g, and 15–20 g (Fig. 3). Because the juveniles released at the beginning of the experiment were of different sizes, their average weights were also different after three months ($P = 0.0001$). They were 35.25 g ±4.14, 48.80 g ±3.80, 58.32 g ±5.72 and 62.99 g ±4.02 for the four size classes respectively (Fig. 4).

Figure 1. Experimental enclosures constructed on a seagrass bed.
A: Uncovered pen; B: nursery (pen covered by fishing net).

No significant difference was observed for *H. scabra* juveniles reared in nurseries (51.66 g ±13.39) compared to those reared in pens (51.01 g ±10.59) ($P = 0.794$).

Discussion

In sea cucumber aquaculture developed in Madagascar, *H. scabra* juveniles of 2 cm are reared on sandy-muddy substrates in earthen ponds until they reach a length of 6–8 cm (about 15 g) (Eeckhaut et al. 2008; Lavitra 2008). Once the individuals reach this size, they are placed in sea pens. Below this size, predators such as crabs and fish could attack them (Battaglene 1999; Lavitra 2008; Eeckhaut et al. 2008). Thus, the use of covered pens (nurseries) was suggested for the first months of the transfer (Tsiresy et al. 2011) in order to protect the newly delivered

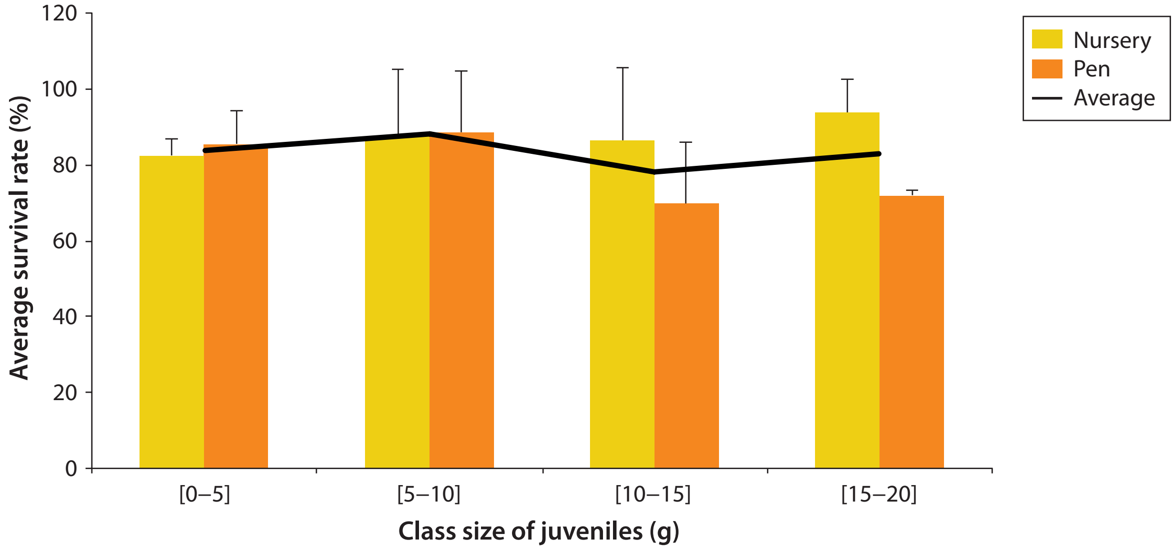

Figure 2. Average survival rates of *Holothuria scabra* juveniles of different sizes in pen and nursery after three months of rearing.

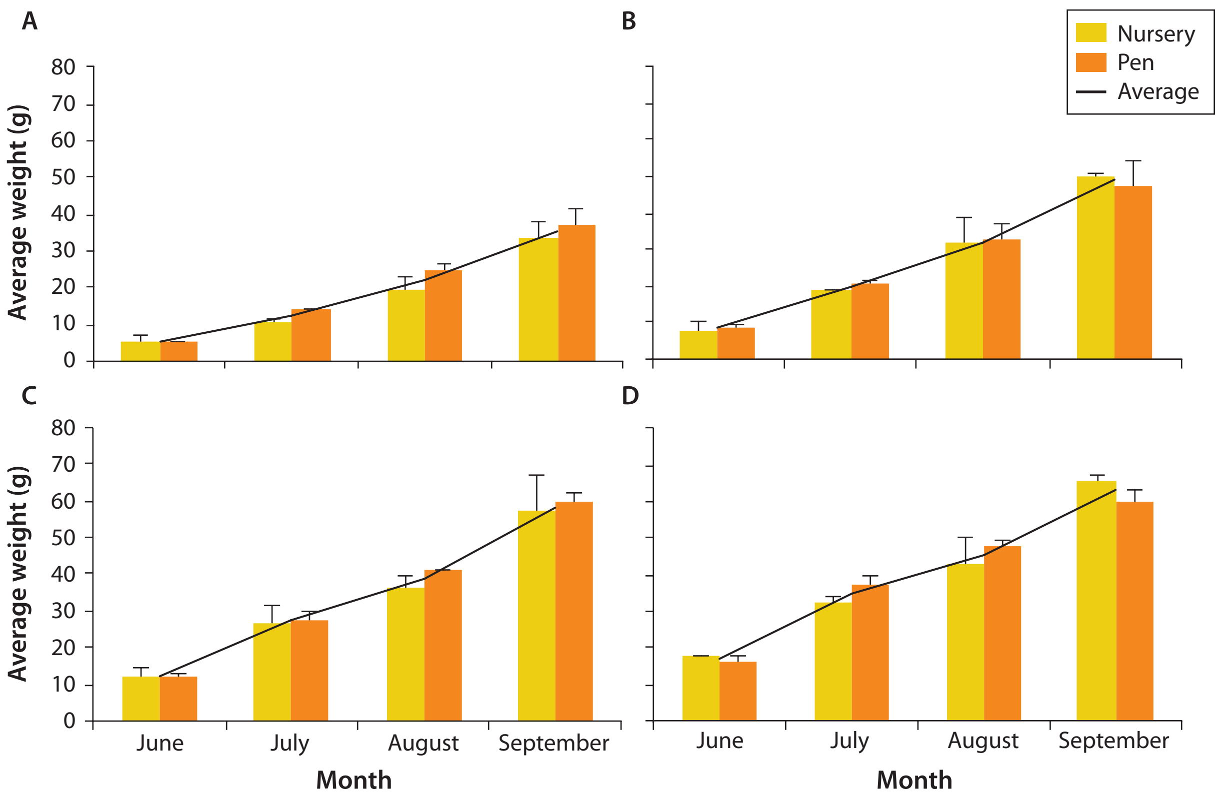

Figure 3. Average growth of *Holothuria scabra* juveniles during three months of rearing in pens and nurseries. The initial measure was taken in June. A: Size release 0–5 g; B: 5–10 g; C: 10–15 g; and D: 15–20 g.

juveniles. Our experiment showed that the use of nurseries was not necessary in Tampolove, as the survival of *H. scabra* juveniles reared in normal sea pens and in nurseries did not differ significantly, nor did their growth. Also, this experiment showed that the size of released juveniles did not affect their survival, which suggests that *H. scabra* juveniles of less than 5 g could be released directly into sea pens in some regions where the density of predators, like the crabs *T. crenata* in SW of Madagascar, is low. This new data mean that the time necessary for *H. scabra* juveniles to grow to the appropriate size of 15 g in external tanks — two to three months — can be reduced to only one month if juveniles are reared in appropriate sea sites without predators. From this experiment, we would suggest that the presence of predators is one of the most important factors that should be considered before choosing: (i) a sea cucumber farming site; (ii) the type of enclosure; and (iii) the size of released juveniles.

Acknowledgments

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References

Battaglene S.C. 1999. Culture of the tropical sea cucumbers for the purpose of stock restoration and enhancement. Naga, the ICLARM Quarterly 22(4):4–11.

Eeckhaut I., Lavitra T., Rasolofonirina R., Rabenevanana M.W., Gestin P.G. and Jangoux M. 2008. Madagascar Holothurie SA: The first trade company based on sea cucumber aquaculture in Madagascar. SPC Beche-de-mer Information Bulletin 28:22–23.

Juinio-Meñez M.A., de Peralta G.M., Dumalan R.J.P., Edullantes C.M. and Catbagan T.O. 2012. Ocean nursery systems for scaling up juvenile sandfish (*Holothuria scabra*) production: Ensuring opportunities for small fishers. p. 57–62. In: Hair C., Pickering T. and Mills D. (eds). Asia-Pacific Tropical Sea Cucumber Aquaculture. ACIAR Proceedings No. 136. Canberra, Australia: Australian Center for International Agricultural Research. 210 p.

Lavitra T. 2008. Caractérisation, contrôle et optimisation des processus impliqués dans le développement postmétamorphique de l'holothurie comestible *Holothuria scabra* (Jaeger, 1833) (Holothuroïdea: Echinodermata). Thèse de Doctorat, Université de Mons-Hainaut, Belgique. 166 p.

Lavitra T., Rasolofonirina R., Jangoux M. and Eeckhaut I. 2009. Problems related to the farming of *Holothuria scabra* (Jaeger, 1833). SPC Beche-de-mer Information Bulletin 29:20–30.

Pitt R. and Duy N.D.Q. 2004. Breeding and rearing of the sea cucumber *Holothuria scabra* in Viet Nam. p. 333–346. In: Lovatelli A., Conand C., Purcell S., Uthicke S., Hamel J.-F. and Mercier A. (eds). Advances in Sea Cucumber Aquaculture and Management. FAO Fisheries Technical Paper No. 463. Rome, Italy: Food and Agriculture Organization of the United Nations. 425 p.

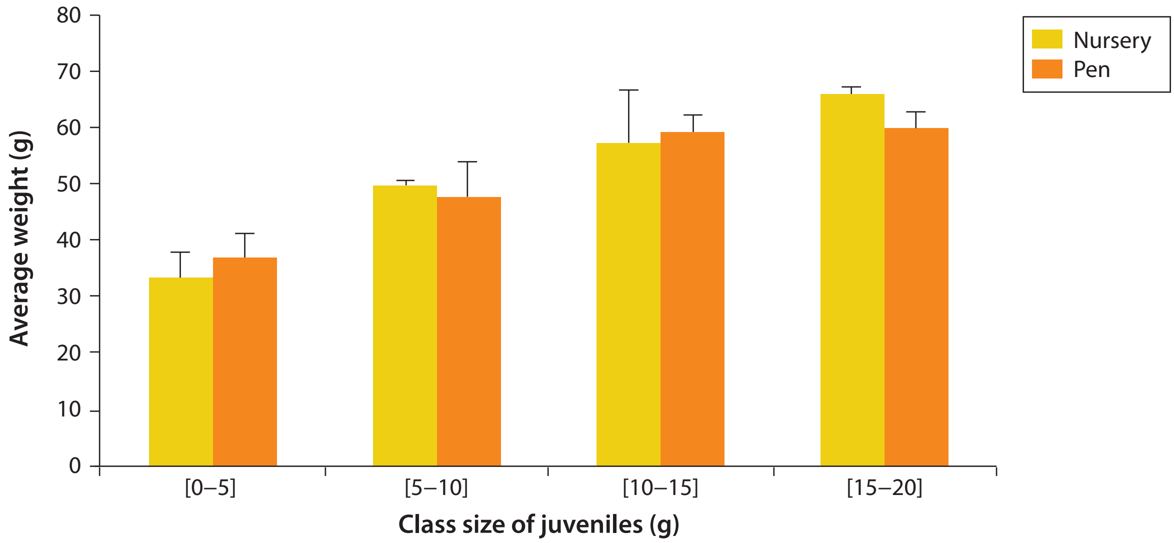

Figure 4. Average weight of *Holothuria scabra* juveniles of different sizes in pens and nurseries after three months of rearing.

Purcell S.W., Hair C. and Mills D. 2012. Sea cucumber culture, farming and sea ranching in the tropics: Progress, problems and opportunities. Aquaculture 368:68–81.

Purcell S.W. and Agudo N.S. 2013. Optimisation of mesh enclosures for nursery rearing of juvenile sea cucumbers. PLoS ONE 8(5): e64103. doi:10.1371/journal.pone.0064103.

Tsiresy G., Pascal B. and Plotieau T. 2011. An assessment of *Holothuria scabra* growth in marine micro-farms in Southwestern Madagascar. SPC Beche-de-mer Information Bulletin 31:17–22.

Baseline assessment of virgin biomass of sea cucumbers in Old Providence and Santa Catalina, Western Caribbean

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Abstract

In this paper we report the result of an independent baseline fishery survey conducted in the islands of Old Providence and Santa Catalina, Colombia, in 2014, with the objective of characterising spatially explicit abundance and distribution of the sea cucumber communities.

We included local artisanal fishers in the planning and data collection parts of this survey. Our results showed very limited diversity of sea cucumbers, with *Holothuria mexicana* being the most abundant. There were higher densities of *H. mexicana* in the sand and rubble habitat than in the seagrass and bioturbated areas. We found aggregation sites for sea cucumbers where density was an order of magnitude higher; this habitat was a narrow band between seagrass and sand and rubble. Total population size was considered too low to sustain a fishery, and mariculture experiments with sea cucumbers in the region should carefully consider the number of organisms taken when establishing breeding protocols.

Key words: Coral reefs, sea cucumber, artisanal fishing, beche-de-mer, ecosystem services.

Introduction

Sea cucumber fisheries in Colombia started about a decade ago, but has been mostly illegal, and to date it is still unregulated and unreported (Toral-Granda 2008; Rodriguez et al. 2013). While the main species exploited in the Colombian Caribbean include *Isostichopus badionotus*, *Stichopus herrmanni* and *Stichopus variegatus* (Rodriguez et al. 2013), reports for the wider Caribbean include up to six species (Toral-Granda 2008). Initially, the fishery was done with middlemen hiring fishers to collect as many sea cucumbers as possible but, as densities dropped, this activity shifted towards an "on-demand" activity, with fishers making about 3 USD kg^{-1} (Rodriguez et al. 2013). The unregulated nature of this fishery, coupled with the lack of knowledge of the resource, has resulted in concerns about the state of the resource. Since market demand for sea cucumber is still growing, some authors suggest mariculture of sea cucumbers instead of harvesting the wild population, as a way to establish alternative sources of income for fishers, reusing abandoned aquaculture facilities, and establishing conservation programmes (Rodriguez et al. 2013).

Inhabitants of the islands of Old Providence and Santa Catalina, located in the western Caribbean 180 miles off Central America, are closely linked to sea. Most of them are fishers either full or part time. The recent decline in landings, due to overexploitation of their marine resources, has made the local fishing community consider alternatives to fishing. With perceived high prices of sea cucumbers in Asian markets, some are looking at sea cucumber farming as one of their options. Since sea cucumbers are susceptible to overfishing (Toral-Granda 2008), the community showed an interest in mariculture. This study was conducted to assess the baseline wild stock of sea cucumbers available for mariculture around the islands of Old Providence and Santa Catalina, working in collaboration with local fishers.

Methods

Sampling area

The archipelago of San Andres, Old Providence and Santa Catalina is located in the western Caribbean between 13°17'N and 81°22'W, 190 km from

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the Middle America continental shelf, and 720 km away from the Colombian mainland (Geister 1992). Old Providence and Santa Catalina (OPSC) are located 80 km north of San Andres; Old Providence is the second largest island in the archipelago with a land area of 17 km^2, while Santa Catalina is a small satellite island located 150 m to the north of Old Providence. The two islands are joined by a floating footbridge. OPSC have 32 km of coral reef formations that run north to southeast. Within its barrier reef there are multiple patch reefs, sand flats and seagrass areas (Gómez-López et al. 2012) (Fig. 1).

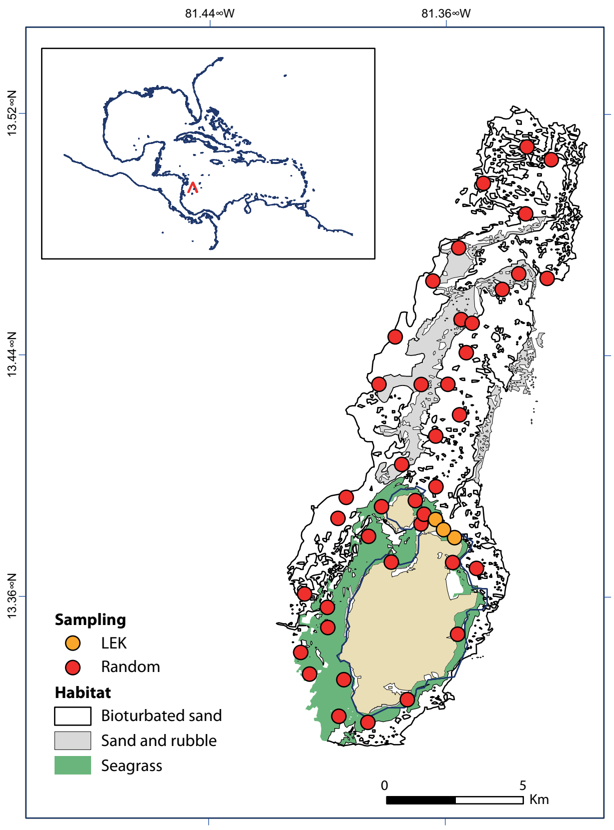

Figure 1. Location of Old Providence Island, and sampling points around the island. Inset map: World Vector Shoreline of the Gulf of Mexico and Caribbean Sea region. Source: National Imagery and Mapping Agency (formerly U.S. Defense Mapping Agency).

Survey design and community involvement

This study was a community-led effort; fishers were included in all the stages and we adopted a collaborative, rather than cooperative approach (Yochum et al. 2011).

Nine species of sea cucumbers have been recorded by Borrero-Pérez et al. (2012) in the region (Table 1). They are distributed mainly in biodisturbed sand, sand and rubble, and seagrass habitats. Using habitat maps obtained from the local environmental agency, CORALINA, we focused on surveying these habitats by means of a stratified random sampling design. The baseline stock assessment included a total of 40 sampling sites that were distributed among the identified habitat strata using the Sampling Design Tool available for the ArcGIS software (Menza and Finnen 2007). In addition, we surveyed aggregation sites, since sea cucumbers are known to aggregate in favourable habitats (Shiell and Knot 2010; Young and Chia 1982). It is important to survey these aggregation sites when estimating total population size, since a high proportion of the individuals could reside within them. However, these sites are usually a combination of multiple environmental factors and thus have a low probability of being included in randomly designed surveys. We therefore used fishers' local ecological knowledge (LEK) to identify three such high-density sampling sites, which will be referred to as LEK sites henceforth (Fig. 1).

Table 1. Sea cucumber species reported for the island of Old Providence (Borrero-Perez et al. 2012).

Species
Actinopyga agassizii
Holothuria (Cystipus) cubana
Holothuria (Halodeima) floridana
Holothuria (Halodeima) grisea
Holothuria (Halodeima) mexicana
Holothuria (Thymiosycia) thomasi
Isostichopus badionotus

Survey method

The diversity and abundance of sea cucumbers in OPSC were estimated by means of underwater visual transect surveys. At each sampling site, a pair of divers swam a twenty-minute two-metre wide belt transect in a random direction, while ensuring that they remained within the same habitat. The sampling depth was limited to 20 metres for logistics and safety reasons. For each transect, the surveyors recorded the species of sea cucumber found, and measured the total length and diameter to the nearest centimetre, using a fiberglass seamstress tape. Transect length was calculated from a towed Global Positioning System (GPS) unit, which was set to track mode and had the Wide Area Augmentation System (WASS) feature turned on to increase accuracy. Inter-observer variability was addressed by conducting training sessions where sampling methodology and species identification were explained. Since surveyors included local fishers, extra care was taken to ensure that all observers understood the limits of the sampling area and did not count cucumbers outside of the transect.

Size comparison

Significant differences in the mean length and width of sea cucumbers found in random and LEK sites were assessed by means of ANOVA, followed by Tukey's HSD test.

Density calculation and population size estimate

We used the model selection method to estimate the density of sea cucumbers because it allowed us to account for the cucumbers' clumped distribution (Campagna and Hand 1999). We created a set of generalised linear models assuming four distributions: normal, Poisson, negative binomial, and zero-inflated. Additionally, we tested for the influence of sampling habitat strata on density. This resulted in a total of eight models (Table 2).

Model selection was based on the Akaike information criterion (AIC), which calculates the log likelihood of the model, while penalising for the number of parameters (Akaike 1973). The best explaining model was chosen, based on the fewest parameters within two units of the lowest AIC score (Burnham and Anderson 2002). Additionally, we used the likelihood ratio test for the competing best-fit models to test for significant differences. We used this approach for the randomly located and LEK sites.

Total population size was calculated by multiplying the resulting estimated density for each habitat with the area size of said habitat. These were obtained from the benthic habitat maps for LEK sites. The total area was calculated by delineating the habitat area from a geo-referenced digitised aerial photograph using ArcGIS 10.2.

All of the statistical analyses were done using the open source software R (R Development Core Team 2009); plotting was done with the package ggplot2 (Wickham 2009); data manipulation was done with the package reshape2 (Wickham 2007); the generalised linear model in the negative binomial distribution was fitted, using package pscl (Jackman et al. 2012); and the likelihood ratio test was conducted using the package lmtest (Hothorn et al. 2010).

Results

Although nine species of sea cucumbers have been described for OPSC (Borrero-Pérez et al. 2012; Table 1), we found only two in our baseline survey. *Holothuria mexicana* was the most common species, followed by occasional sighting of *Holothuria thomasi*. Overall density was low, as we counted a total of 82 sea cucumbers. For randomly placed transects (n = 40), we counted 43 sea cucumbers (41 *H. mexicana* and 2 *H. thomasi*), and 39 *H. mexicana* in LEK transects (n = 3). Due to the low abundance of *H. thomasi*, we focused all further analyses on *H. mexicana*.

Size distribution

The length of *H. mexicana* in OPSC ranged between 15.0 and 46.5 cm, with a mean of 29.66 cm ±0.75 SE, while the width ranged between 2 and 15 cm, with a mean of 8.25 cm ±0.23 SE. There were significant differences in the length of sea cucumbers between habitats ($P < 0.01$), where sand and rubble habitat and bioturbated sand habitat had significantly larger individuals than LEK and seagrass habitat ($P < 0.05$ under Tukey HSD test) (Fig. 2).

Baseline stock assessment

Model selection showed model 7 (negative binomial distribution accounting for habitat) to be the most parsimonious model, with the lowest AIC score (Table 2). The density for each habitat strata, estimated using model 7, is as listed: sand and rubble had the highest density with 6.38 ind. hr^{-1} ±3.01 SE, followed by seagrass with 1.56 ind. hr^{-1} ±0.66 SE, and bioturbated sand with 1.47 ind. hr^{-1} ±0.63

Table 2. Model types testing for habitat effects and distributions. df = degree of freedom; AIC = Akaike information criterion.

Model	Habitat Effect	Distribution	df	AIC score
1	No	Normal	2	245.94
2	No	Poisson	1	274.86
3	No	Negative Binomial	2	151.55
4	No	Zero-Inflated Normal	2	210.52
5	Yes	Normal	5	210.91
6	Yes	Poisson	4	153.86
7	Yes	Negative Binomial	5	136.96
8	Yes	Zero-Inflated Normal	8	137.54

SE (Table 3). The sand and rubble habitat showed higher density (but not significant) compared to the other two habitats (Table 3).

Aggregation site assessment

Aggregation sites — so-called "good sites" by fishers — were consistently found between seagrass and sand and rubble, close to the shore on the eastern side of Old Providence Island (Fig. 1). The width of this specific habitat was narrow, ranging from three to six metres, and consisted of only 0.3% of the area of OPSC (Table 3).

Best-fit model showed that data from LEK sites were in negative binomial distribution. The estimated density was significantly higher by an order of magnitude than in the randomly selected sites, with a mean density of 32.99 ind. ha^{-1} ±10.22 SE (Fig. 3).

Total population size in OPSC

The total estimated density for each habitat was calculated as the estimated density per habitat strata multiplied by the area. The population size for each habitat is as follows: 7,550 ±3,558 SE individuals for

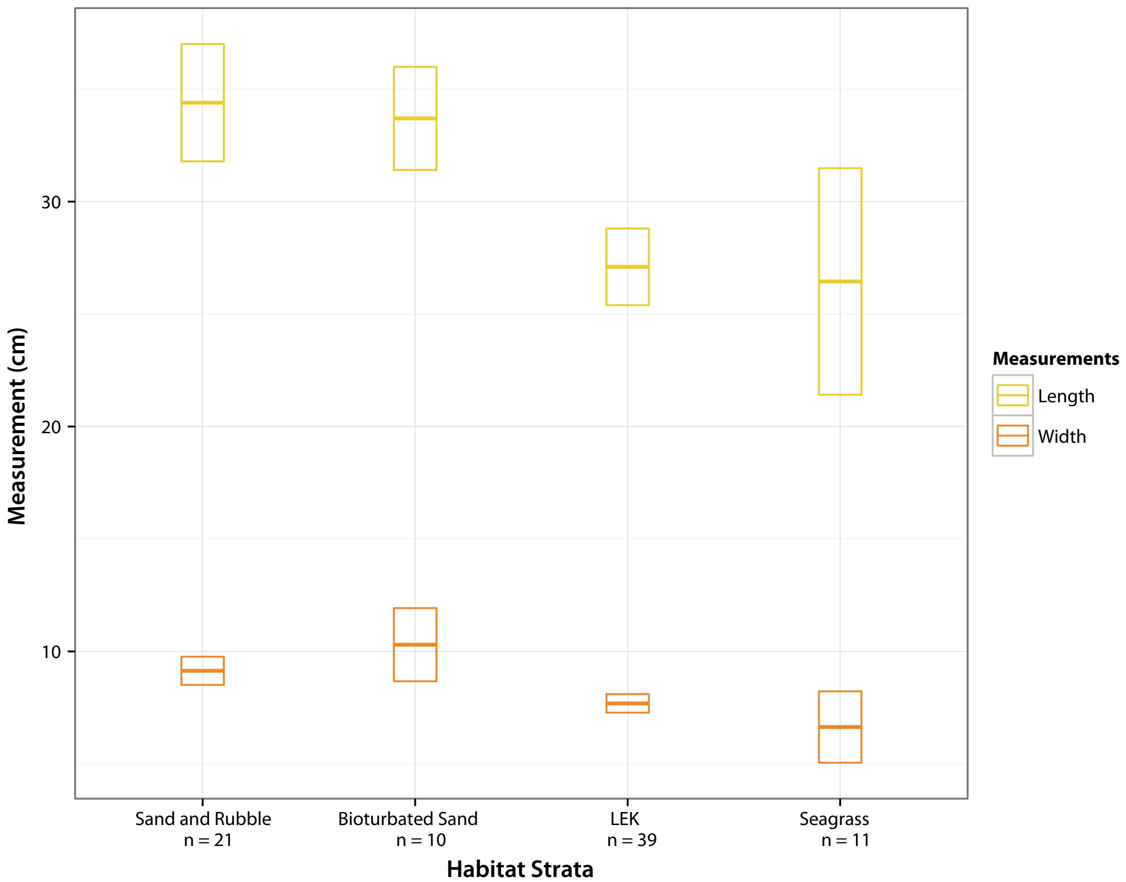

Figure 2. Length and width (in cm) of *Holothuria mexicana* for each habitat strata. Box outline marks the boundary of 95% confidence interval. Sample sizes for each habitat strata are noted at the bottom.

Table 3. Information of each habitat type surveyed. Information includes: number of transects, estimated density with 95% confidence interval (CI), area size of each habitat strata, and estimated population size. Information on aggregation site (marked as LEK) is also included.

Habitat	n	Density (ind. ha^{-1})	95% CI	Area (ha)	Population size
LEK	3	32.99	17.97–60.56	29.59	976
Sand and rubble	8	6.38	2.53–16.07	1,183.14	7,550
Seagrass	16	1.56	0.68–3.59	1,563.78	2,444
Bioturbated sand	16	1.47	0.63–3.43	5,405.30	7,928

the sand and rubble habitat; 2,444 ±1,037 SE individuals for seagrass habitat; 7,928 ±3,431 SE individuals for the bioturbated sand habitat; and 976 ±302 SE for the LEK (aggregation) sites (Table 3). Therefore, total estimated number of sea cucumbers for OPSC was 18,898, with a 95% confidence interval of 7,994–44,959. The confidence interval was calculated by accounting for the standard error of each habitat strata.

Discussion

Distribution of *H. mexicana* in OPSC was very patchy, with clear aggregation sites located on the northern side of the island of Old Providence on a very narrow fringe habitat between seagrass, and sand and rubble. The density of *H. mexicana* was low, even when accounting for its negative binomial distribution, compared to other sites in the Caribbean (Table 4). From the density and size difference between habitat strata (Figs 2 and 3), we can infer that younger *H. mexicana* likely occur in seagrass areas (hence the significantly smaller sized individuals in LEK and seagrass strata), but no actual juveniles were found during the survey.

The total estimated abundance of sea cucumbers in OPSC (both in species richness and stock size) indicates that commercial wild fishery activities are not feasible. In fisheries, as a rule of thumb, 20% virgin biomass is often used as a reference point to ensure sustainable exploitation (Restrepo et al. 1998). Furthermore, for sea cucumbers there is evidence that exploitation values as low as 5% virgin biomass have resulted in over-exploitation (Uthicke 2004). If we apply this to our estimated current population size, only 944 sea cucumbers should be harvested each year for a fishery to be sustainable. This low number would not ensure the economic sustainability of a wild fishery.

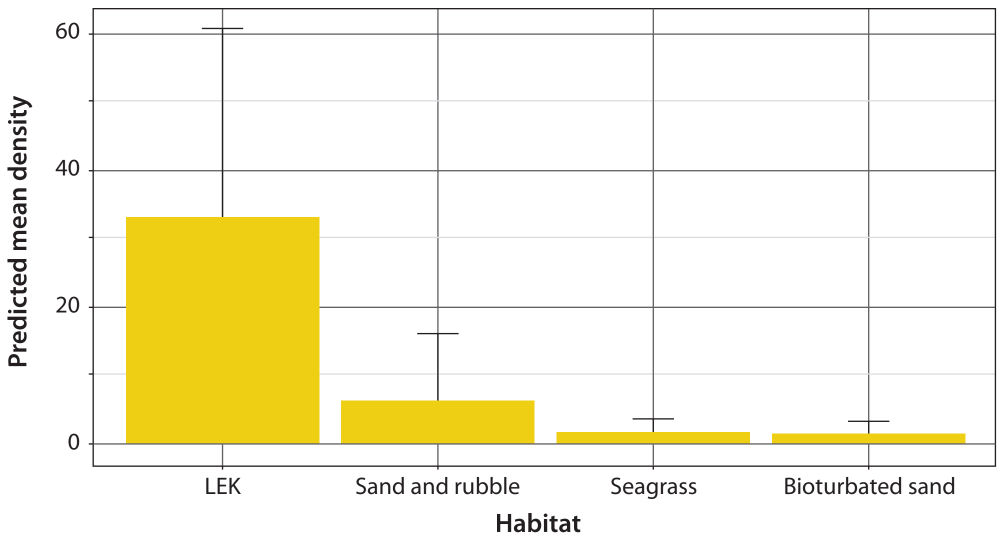

Figure 3. Estimated density of *Holothuria mexicana* for each survey strata in the islands of Old Providencia and Santa Catalina.

Table 4. Density estimates of *Holothuria mexicana* for several locations in the Caribbean.

Country	Year	Abundance (ind. ha^{-1})	Reference
Panama, Bocas del Toro	2000	161.8	Guzman and Guevara (2002)
Venezuela, Isla de Cubagua	2008	7.7	Trigliafico et al. (2011)
Jamaica	1981	70	Hammond (1981)
Venezuela	1998	110–210	Rodríguez-Milliet and Pauls (1998)
Venezuela	1999	13,500	Bitter (1999)
Venezuela, Isla de Cubagua	1987	7,000–9,400	Sambrano (1987)
Venezuela	1988	1,400–19,700	Bitter (1988)
Venezuela	1997	9,400	Conde (1997)
Cuba	2006	0–17,000	Alfonso-Hernandez (2006)

This low population could, however, sustain capture of individuals to be used as parent stock in mariculture. In this activity, adult wild sea cucumbers are harvested and conditioned in tanks to collect viable eggs, which is determinant (Morgan 2000). However, the survival rate of a sea cucumber's planktonic larvae is very low, with estimates of as little of one individual from its cohort surviving to the juvenile stage (Purcell et al. 2012). This results in a negative relationship between larvae stocking density and survival to settlement (Battaglene and Bell 2004). Furthermore, this low larval survivorship is followed by a high predation rate among juveniles by carnivorous fish, birds, turtles, sea stars, crabs, gastropods and other invertebrates (Dance et al. 2003; Francour 1997). This is a problem when a pen is built in open water, where it is difficult to avoid these predators (Purcell et al. 2012). Consequently, obtaining a large enough brood stock to ensure adequate supply of larvae for mariculture could result in a reduction of larvae for the wild population. Therefore, decisions on the number of adult individuals taken from the field should be made with great care. Additionally, aggregation sites with much larger densities (Fig. 3) have a higher risk of being targeted, once market demand is present, due to ease of catch compared to searching time. Nonetheless, depleting these high density sites can have detrimental effects on the overall sea cucumber population of OPSC, possibly causing an Allee effect (Uthicke 2004), and this should be taken into special consideration when opening a fishery.

With an ever-increasing market demand for beche-de-mer, it is inevitable for a sea cucumber fishery to be considered an alternative source of income. However, it is important to understand the local stock status when considering this option. Based on our results, we propose the recommendations listed below.

- A wild fishery of *H. mexicana* in the islands of OPSC should not be considered.
- Mariculture activities that capture *H. mexicana* from the field should limit their annual harvest to no more than 944 individuals.
- Should mariculture be considered, mechanisms are needed to prevent poaching of wild stock and selling them as farmed.
- Aggregation areas could be a source of broodstock, but they should not be depleted. Instead, collection could be done in low-density areas, while protecting these aggregation sites in order to ensure adequate larval supply.

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We would like to show our great appreciation to the local fishermen of Old Providence and Santa Catalina who participated in all aspects of this project and greatly improved it by sharing their knowledge with us. We also thank the staff at the Fish and Farm Coop and the Sony dive shop, especially Rosana Torres and June Marie Mow. We thank CORALINA for providing logistic support. We thank Julio Andrade for field help, and Laura Rodriguez for help in the surveys and literature review. This project is the result of the government-run initiative Plan San Andres, and was funded through the program Fase I de un Proyecto de Ciencia, Tecnología e Innovación para el desarrollo de técnicas de cultivo de especies marinas a escala de laboratorio y de planta piloto con fines comerciales, cooperation agreement No. 9677-20-822-2013 between Fish and Farm Cooperative Enterprise and Unidad nacional para la gestion del riesgo de desastres — Fondo nacional de gestion del riesgo de desastres, Presidencia de la Republica.

References

Akaike H. 1973. Information theory as an extension of the maximum likelihood principle. p. 267–281. In: Petrov B.N. and Csaki F. (eds). Second International Symposium on Information Theory. Budapest, Hungary: Akademiai Kiado.

Alfonso-Hernandez I. 2006. National Report Cuba. p. 141–144. In: Bruckner A.W. (ed.). Proceedings of the CITES workshop on the conservation of sea cucumbers in the families Holothuriidae and Stichopodidae. 1–3 March 2004. Silver Spring, United States of America: NOAA Technical Memorandum NMFS-OPR 34. 244 p.

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.L. (eds). Case Studies in Marine Ranching. FAO Fisheries Technical Paper No. 429. Rome, Italy: Food and Agriculture Organization from the United Nations. 213 p.

Bitter R.S. 1988. Análisis multivariado de la comunidad asociada a *Thalassia testudinum* en el Parque Nacional Morrocoy. PhD. Thesis. Caracas, Venezuela: Universidad Central de Venezuela. 153 p.

Bitter R.S. 1999. Benthic communities associated to *Thalassia testudinum* (Hydrocharitaceae) at three localities of Morrocoy Nacional Park, Venezuela. Revista de Biologia Tropical 47:443–452.

Borrero-Pérez G.H., Benavides-Serrato M. and Diaz-Sanches C.M. 2012. Equinodermos del Caribe colombiano II: Echinoidea y Holothuroidea. Santa Marta, Colombia: Instituto de Investigaciones Marinas y Costeras. 252 p.

Burnham K.P. and Anderson D.R. 2002. Model selection and multimodel inference: A practical information-theoretic approach. 2nd Edition. New York, United States of America: Springer-Verlag. 488 p.

Campagna S. and Hand C.M. 1999. Density estimates of giant red sea cucumber (*Parastichopus Californicus*) populations, by dive survey, in the Gulf Islands and Jervis Inlet Areas, British Columbia, Canada, in November 1997 and January 1998. Nanaimo, Canada: Fisheries and Oceans Canada, Science Branch, Pacific Region, Pacific Biological Station. 53 p.

Conde J.E. 1997. Après les bébés phoques, les concombres de mer. La Recherche 304:61–64.

Dance S.K., Lane I. and Bell J.D. 2003. Variation in short-term survival of cultured sandfish (*Holothuria scabra*) released in mangrove-seagrass and coral reef flat habitats in Solomon Islands. Aquaculture 220:495–505.

Francour P. 1997. Predation on holothurians: A literature review. Invertebrate Biology 116:52–60.

Geister B.J. 1992. Modern reef development and Cenozoic evolution of an oceanic island / ref. complex: Isla de Providencia (western Caribbean Sea, Colombia). Erlangen 27:1–70.

Gómez-López D.I., Segura-Quintero C., Sierra-Correa P.C. and Garay-Tinoco J. 2012. Atlas de la Reserva de Biósfera Seaflower. Archipiélago de San Andrés, Providencia y Santa Catalina. Instituto de Investigaciones Marinas y Costeras "José Benito Vives De Andréis" -INVEMAR- y Corporación para el Desarrollo Sostenible del Archipiélago de San Andrés, Providencia y Santa Catalina -CORALINA-, Santa Marta, Colombia. 180 p.

Guzman H.M. and Guevara C.A. 2002. Population structure, distribution, and abundance of three commercial species of sea cucumber (Echinodermata) in Panama. Caribbean Journal of Science 38(3–4):230–238.

Hammond L.S. 1981. An analysis of grain size modification in biogenic carbonate sediments by deposit-feeding holothurians and echinoids (Echinodermata). Limnology and Oceanography 26(5):898–906.

Hothorn T., Zeileis A., Millo G. and Mitchell D. 2010. Package 'lmtest'. Testing Linear Regression Models.

Jackman S., Zeileis C.M., Fearon J., Jackman M.S. and MCMCpack S. 2012. Package 'pscl'. Standford University, United States of America: Political Science Computational Laboratory.

Menza C. and Finnen E. 2007. Manual for the sampling design tool for ArcGIS. NOAA Center for Coastal Marine Monitoring.

Morgan A.D. 2000. Induction of spawning in the sea cucumber *Holothuria scabra* (Echinodermata: Holothuroidea). Journal of the World Aquaculture Society 31:186–194.

Purcell S.W., Hair C.A. and Mills D.J. 2012. Sea cucumber culture, farming and sea ranching in the tropics: Progress, problems and opportunities. Aquaculture 368–369:68–81.

R Development Core Team. 2009. R: A language and environment for statistical computing. Vienna, Austria: The R Foundation for Statistical Computing. 409 p.

Restrepo V.R., Thompson G.G., Mace P.M., Gabriel W.L., Low L.L., MacCall A.D., Methot R.D., Powers J.E., Taylor B.L., Wade P.R. and Witzig J.F. 1998. Technical guidance on the use of precautionary approaches to implementing national standard 1 of the Magnuson-Stevens fishery conservation and management act. NOAA Technical Memorandum NMFS-F/SPO 31. United States of America: National Oceanic and Atmospheric Administration. 54 p.

Rodriguez F.A., Vergara W. and Agudelo-Martinez V. 2013. First insight into Colombian Caribbean sea cucumbers and sea cucumber fishery. SPC Beche-de-mer Information Bulletin 33:9–13.

Rodríguez-Milliet E. and Pauls S.M. 1998. Sea cucumbers fisheries in Venezuela. p. 513–516. In: Mooi R. and Telford M. (eds). Echinoderms. Proceedings of the Ninth International Echinoderm Conference, San Francisco, August 1996. San Fransisco, United States of America: Balkema. 923 p.

Sambrano A. 1987. Actividad sedimentivora de *Isostichopus badionotus* e *Holothuria mexicana* (Echinodermata: Holothuroidea) en bajos de Thalassia. Trabajo Especial de Grado. Caracas, Venezuela: Universidad Simon Bolívar. 131 p.

Shiell G.R. and Knott B. 2010. Aggregations and temporal changes in the activity and bioturbation contribution of the sea cucumber *Holothuria whitmaei* (Echinodermata: Holothuroidea). Marine Ecology Progress Series 415:127–139.

Toral-Granda V. 2008. Population status, fisheries and trade of sea cucumbers in Latin America and the Caribbean. p. 213–229. In: Toral-Granda V., Lovatelli A. and Vasconcellos M. (eds). Sea cucumbers: A global review of fisheries and trade. FAO Fisheries and Aquaculture Technical Paper No. 516. Rome, Italy: Food and Agriculture Organization from the United Nations. 317 p.

Tagliafico A., Rangel M.S. and Rago N. 2011. Distribución y densidad de dos especies de holoturoideos en la isla de Cubagua, Venezuela. Revista de Biología Tropical 59(2):843–852.

Uthicke S. 2004. Overfishing of holothurians: Lessons from the Great Barrier Reef. p. 163–172. In: Lovatelli A., Conand C, Purcell S., Uthicke S., Hamel J.-F. and Mercier A. (eds). Advances in Sea Cucumber Aquaculture and Management. FAO Fisheries Technical Paper No. 463. Rome, Italy: Food and Agriculture Organization from the United Nations. 425 p.

Wickham H. 2007. Reshaping data with the reshape package. Journal of Statistical Software: 21(12):1–20.

Wickham H. 2009. ggplot2: Elegant graphics for data analysis. New York, United States of America: Springer-Verlag. 213 p.

Yochum N., Starr R.M. and Wendt D.E. 2011. Utilizing fishermen knowledge and expertise: Keys to success for collaborative fisheries research. Fisheries 36:593–605.

Young C.M. and Chia F.S. 1982. Factors controlling spatial distribution of the sea cucumber *Psolus chitonoides*: Settling and post settling behaviour. Marine Biology 69:195–205.

Advances on spontaneous captive breeding and culture conditions of Caribbean sea cucumber *Stichopus* sp.

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Abstract

The sea cucumber *Stichopus* sp. is a species that inhabits the Colombian Caribbean, and little is known about their reproductive behaviour under controlled laboratory conditions. During 2012 and 2013, from July to October, spontaneous spawning and spermiation events took place in the Aquaculture Laboratory of the Universidad del Magdalena (Santa Marta, Colombia). The mean number of fertilised eggs was 48.4 x 10^6, which developed up to the late auricularia stage. In this study, handling conditions, water quality and limitations associated with reproduction and larval culture are described.

Key words: reproduction, moon phase, ovocyte, *Stichopus*.

Introduction

In Asian countries there is controlled production of sea cucumbers for restocking programmes, conservation strategies and the production of natural health products (Sicuro and Levine 2011). In contrast, in South American countries, studies on the culture of species with commercial importance are emerging (Guzman et al. 2003; Guisado et al. 2012; Rodríguez et al. 2013; Zacarías-Soto et al. 2013). In Colombia, little is known about the sea cucumber species, their biology, taxonomy, population dynamics, fisheries management and culture (Caycedo 1978; Borrero-Pérez et al. 2004; Rodríguez et al. 2013).

It has been found that spawning of sea cucumbers is possible by natural means under controlled conditions. On this subject, several authors report successful results in this process (Sicuro and Levine 2011; Soliman et al. 2013; Zacarías-Soto et al. 2013), while others have obtained eggs by artificial means such as hormones, chemicals, thermal stimulation, *in vitro* fertilisation and photoperiod methods or through controlled food supply (Ong Che and Gomez 1985; Hamel et al. 1993; Conand and Byrne 1993; Morgan 2000; Ramofafia et al. 2000; Fajardo-León et al. 2008; Eeckhaut et al. 2012). That is why the environment and chemicals are considered determining factors for the controlled reproduction of these marine organisms. In addition, the influence of moon phases has been demonstrated by several authors where environmental variables do not produce a response in organisms acclimated in controlled environments (Mercier et al. 2000; Hamel et al. 2001; Battaglene et al. 2002; Asha and Muthiah 2008; Hu et al. 2013).

In spite of the wide existing documentation, information about the reproductive behaviour and spawning methods of Caribbean holothuroids is scarce. This study provides a brief description of the reproduction and larval development of *Stichopus* sp. native of the Colombian Caribbean Sea, with notes on the problems associated through the success of the culture.

Materials and methods

Collection of animals

During their reproductive season (July to October), in 2012 and 2013, two hundred *Stichopus* sp. were purchased from local artisanal fishermen in Rodadero bay in Santa Marta, Colombia (11°13'22,73"N–74°13´32,59"O). The sea cucumbers were rapidly brought to the Aquaculture Laboratory of the Universidad del Magdalena in 20-L plastic tanks filled with seawater. There they were weighed using an analytical scale Ohaus (0.001 g), and their total length was measured with a standard measuring board (in mm). After that, the sea cucumbers were slowly allowed to acclimatise to a 550-L tank filled with ambient seawater (temperature 26°C; pH 7.8) maintained at the Aquaculture Laboratory.

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Broodstock management

After acclimatisation in the laboratory, the animals were randomly separated and put into six circular 550-L plastic tanks at a density of 0.1 ind. L^{-1}, distributed in a recirculation system. The tanks were filled with sterilised seawater, equipped with a biological filter, and aerated by air stones. Laboratory water temperature was maintained at 26.68°C (±0.79 SD). The sea cucumbers were exposed to a 12-h light-dark photoperiod using overhead fluorescent lights. Faeces were siphoned every day and water salinity was adjusted when needed (Fig. 1).

Figure 1. *Stichopus* sp. broodstock.

Eggs and larvae management

The broodstock was constantly monitored to observe reproductive behaviour, such as elevation of the anterior end, prominent gonopore or body wall erection.

Once the presence of gametes in the culture tanks was observed, these were removed by siphoning and a replacement of 80% of water of the breeding tanks was done. The fertilised eggs were washed with filtered seawater and sterilised, and then selected with a mesh of 60 microns. To estimate the total number of eggs, samples were withdrawn using a 1-mL aliquot. After that, they were incubated in a 50-L aquarium with soft aeration at room temperature (26°C). During the first two days of embryonic development, samples were taken every 30 minutes to monitor the morphological changes by light microscopy observations (Carl Zeiss, Modelo Primo Star), and photographic records were made with a video camera and digital photography (Axiocam ERC 5S).

Feeding practices

Broodstock

Broodstock were fed from the third day of arrival to the laboratory as follows: in 2012, a microalgae powder (5 g per 100 L of powder of *Spirulina* (Artemia-International®) was given; while in 2013, a mixture of marine sediment (previously washed and dried) was used with *Spirulina* powder at a rate of 0.5 g per 100 g of sediment.

Larvae

Two larval feeding protocols were tested. During the 2012 spawning season, powdered algal product, *Spirulina* (Artemia-International®) was used; while in 2013 the larvae were supplied with live algae (*Chlorella* sp.) at a concentration of 5,000 cells mL^{-1}.

Monitoring of the culture conditions

In 2012, water quality parameters were checked daily with a multiparameter Handy Lab: temperature of 25.14°C ±2.02, pH 6.96 ±0.13, salinity 36.4 g L^{-1} ±0.27, and dissolved oxygen 6.40 mg L^{-1} ±0.16. In 2013, water quality parameters were modified in order to ensure better larvae survival: temperature of 28.51°C ±0.17, pH 8.18 ±0.07, salinity 36.96 g L^{-1} ±0.42, and dissolved oxygen 5.56 mg L^{-1} ±0.28. The photoperiod consisted of 12 hours of light and 12 hours of dawn. Aeration was supplied by blowers (Hitachi Iced Serie G).

During incubation and to avoid the appearance of parasites, a daily siphoning of the aquarium was carried out. In addition, 30% of seawater was replaced until the blastula stage was reached and after the start of the auricularia stage, 20% daily seawater exchange was implemented.

Results and discussion

Sea cucumber spawning

From July to October 2012 and from August to October 2013, sixteen spontaneous spawning and sperm releases were presented. Reproductive events occurred within two weeks of the arrival of the sea cucumbers to the laboratory, during the hours of night and dawn. Individuals showed normal behaviour during this time. Sea cucumbers scrolled through the walls of the tanks with a prominent and noticeable genital pore (Fig. 2). Some authors have identified the animal behaviour and the condition of the genital pore as reproductive indicators of species such as *Holothuria scabra*, *Actinopyga mauritiana* and *Stichopus* sp. (Ramofafia et al. 2003; Hu et al. 2010). Since females and males were in the same tank, fertilisation occurred in a free form and subsequent quantification enabled a total average production of 48.4 x 10^6 fertilised oocytes.

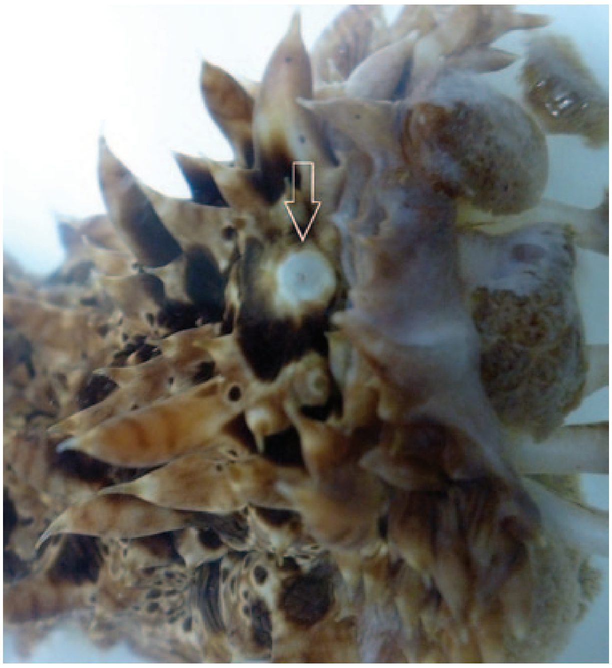

Figure 2. Mature adult with prominent genital pore (arrow).

In this study, the new moon seemed to exert a great influence over the sea cucumber reproduction. The greater reproductive peak occurred in September 2012, during the new moon phase (Table 1). In this period, during three consecutive days, natural spawning took placed (Fig. 3). These events recorded the largest number of fertilised oocytes by month (17.1 x 10^6). The reproductive behaviour of this species is similar to that reported for *Isostichopus badionotus*, showing reproductive peaks from July to November, as described by various authors (Guzman et al. 2003; Foglietta et al. 2004; Zacarias-Soto et al. 2013).

Some studies have established that the lunar cycle has a major role in the reproduction of species such as *Stichopus* sp., *H. scabra*, *I. fuscus* and *I. badionotus*, enabling the prediction of reproductive events based on lunar periodicity (Babcock et al. 1992; Mercier et al. 2000). Thus, their influence is possibly related to endogenous rhythms of each species. *Stichopus* sp. spawning occurs between the first and second night after the new moon from May to August, both in captivity and in the wild. It has also been referenced in species such as *A. japonicus*, *H. scabra*, *I. fuscus*, *Polycheira rufescens*, *Pearsonothuria graeffei*, *S. herrmanni* (Kubota and Tomari 1998; Morgan 2000; Hamel et al. 2002, 2003; Mercier et al. 2007; Hu et al. 2013; Soliman et al. 2013), and in the wild, *B. argus*, *Euapta godeffroyi*, *S. chloronotus* and *H. tubulosa* (Babcock et al. 1992; Andrade et al. 2008). Although spawning presented in this study was associated with the moon phase, it is necessary to evaluate a longer period to confirm whether this is a species reproductive pattern, as the moon phases have been associated to the reproduction and may vary among species.

Table 1. Production of fertilised eggs of *Stichopus* sp. under laboratory conditions.

Moon phase	Spawning date	Fertilised eggs x10^6
Third quarter	Jul-10-2012	1.2
New moon	Aug-20-2012	4.0
	Sept-17-2012	12.3
	Sept-18-2012	2.1
	Sept-20-2012	3.3
Menguante	Oct-10-2012	5.3
New moon	Aug-6-2013	2.4
	Aug-7-2013	1.5
	Aug-8-2013	1.7
	Aug-9-2013	1.8
	Sept-5-2013	2.1
	Sept-6-2013	1.8
	Sept-7-2013	3.2
	Oct-5-2013	3.0
	Oct-6-2013	1.2
	Oct-7-2013	1.5

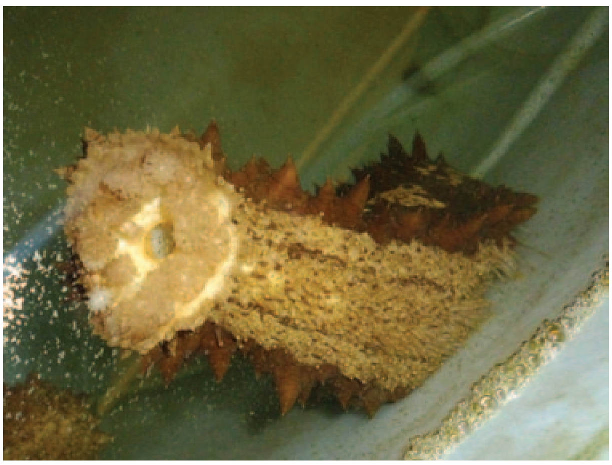

Figure 3. *Stichopus* sp. female spawning.

Larviculture

Embryonic development of *Stichopus* sp. is shown in Figure 4 and Table 2. In 2012, once the larvae reached the early auricularia stage, they did not continue the metamorphosis and, after a month, 100% mortality was recorded. In addition, during this period, the larvae did not change the stage. In 2013, ten days after fertilisation, the larvae successfully developed until late auricularia (Fig. 4) but an infestation of copepods and protozoa caused 100% mortality. Thus, during larval rearing, mortality, possibly associated with the water quality management, was recorded. The occurrence of protozoan parasites during sea cucumber larviculture is a common problem that has been documented by several authors (Purcell and Eeckhaut 2005; Raison 2008; Hu et al. 2010, 2013). Becker et al. (2009) reported that these microorganisms appear after the hatching period and once the larvae start feeding, they feed on the

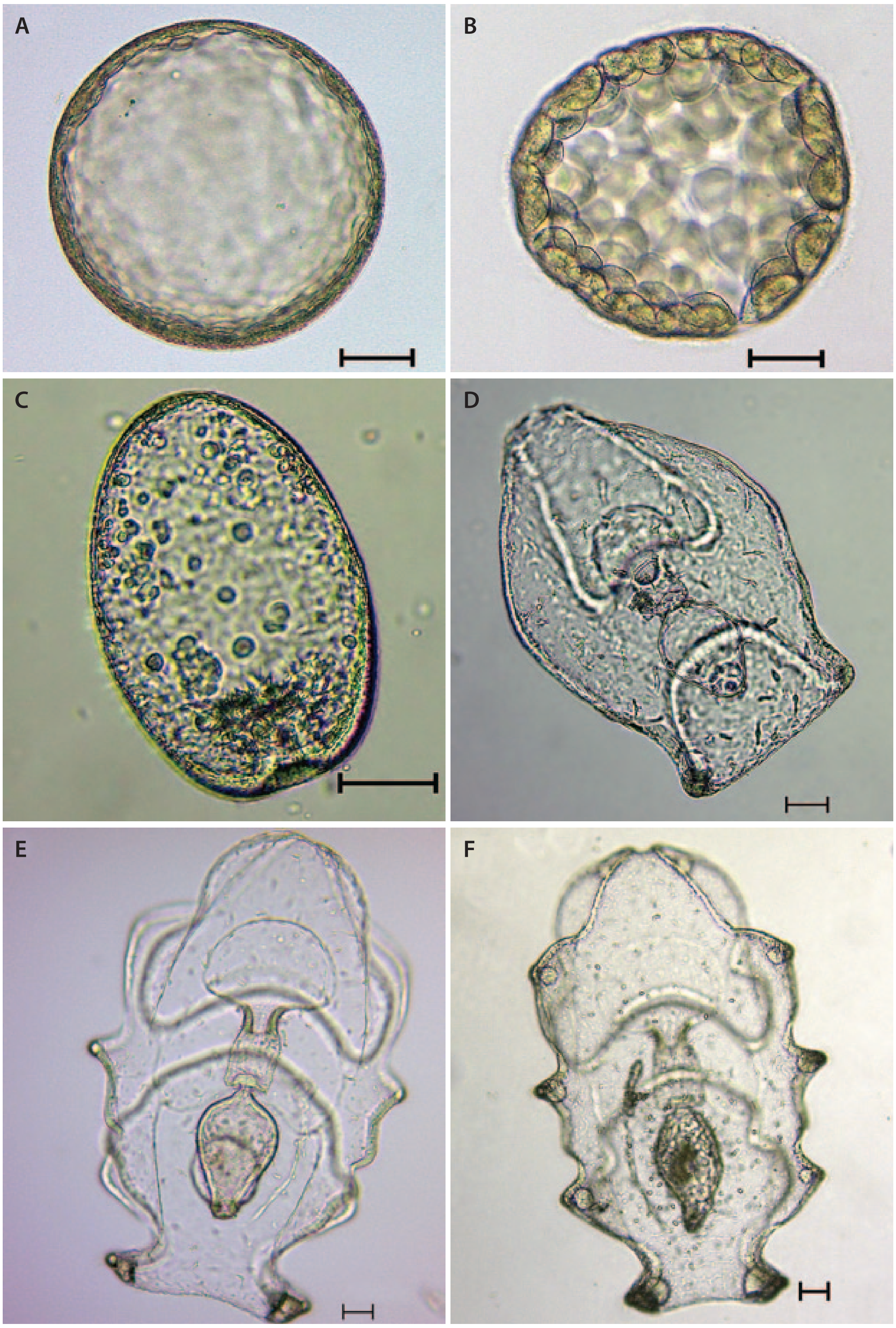

Figure 4. Embryonic and larval development of *Stichopus* sp. Embryonic phases: A) Fertilised egg; B) Blastula; C) Gastrula. Planktonic larval phases: D) Early auricularia; E) Mid auricularia; F) Late auricularia (Scale bar 20 μm).

Table 2. Characterisation of embryonic development of *Stichopus* sp.

Stages	Characteristics	Size (µm)	Time
Fertilised egg	Spherical.	138.02–175.05	0
Blastula	Spherical. It has a cover of cilia that keeps it in constant rotary motion around its axis.	262.72–302.79	4–5 (h)
Gastrula	Invagination of the vegetal pole. Appearance of the rudiments of the digestive tract.	287.40–356.30	8–10 (h)
Early auricularia	Elongation of the larva. Presence of oral cilia, intestine and cloaca.	425.30–476.50	30–40 (h)
Mid auricularia	Larger larvae with larger fold sides and better differentiated and developed digestive tract.	609.28–788.83	50–60 (h)
Late auricularia	Accumulation of hyaline spheres and development and axohidroceloma.	787.59–1,087.66	21–23 (d)

gut contents and tissues, causing shrinkage and rupture of the intestinal wall, killing the larvae within one to three days. Two preventive actions in *I. fuscus* culture are a decrease in water temperature and increased aeration, but low temperatures and strong agitation generate an adverse effect, which is noticeable in the delay or interruption of larval development (Becker et al. 2009; Mercier et al. 2012). Further to this, in Japan and India, chemical treatments are implemented to remove copepods in hatcheries (James 1994; Ito 1995; Yanagisawa 1998; Ito and Kitamura 1997). As stated by Batagglene and Bell (2004), Trichlorphon or Dipterex are used to control copepod infestation. In this study, sterilisation and filtering of seawater were insufficient to control the problem. Therefore, tests must be performed with different doses of Trichlorfon / Dipterex to find out the optimal concentration required for controlling copepod infestation.

Several authors have noted that larval development is directly related to water quality management as temperature, pH, or salinity. In addition, the quantity and quality of the food supply are key factors in the success of hatchery sea cucumber. As noted by James (1994), Ramofafia et al. (1995), and Battaglene (1999), who studied holothuroids (*H. scabra*, *A. echinites* and *H. atra* respectively), optimal water temperature for tropical sea cucumber larvae is between 27 and 30°C, values which are within the range of the larvae cultured in this study. Authors such as Hamel and Mercier (1996) or Asha and Muthiah (2005) state that a pH of 7.8 to 8.0, is an appropriate value for optimal larval growth in *C. frondosa* and *H. spinifera*; in our study, and in 2012, this factor remained below the optimal range suggested by other authors. In this study, it was not possible to determine whether this factor directly influenced the development and survival of larvae, although in 2013, pH value remained constant (8.18), and culture conditions were improved. Additionally, salinity is also an important factor for larval development of sea cucumbers as the larvae cannot tolerate values below 32 g L^{-1}; such values can cause deformities and high mortality, as has happened in species such as *H. spinifera*, *A. echinites* and *A. japonicus* (Chen and Chian 1990; Asha and Muthiah 2002; Kashenko 2002). In this study, salinity did not have any effect on the larvae; this parameter remained constant and optimal for both hatchery periods (2012 and 2013).

In this study, larval development was influenced by temperature and food supply: during the first spawning, obtained between July and September 2012, larval development stopped at early auricularia, and larval sizes were inferior to all of those achieved in 2013 (August–October). That year, live microalgae (*Chlorella* sp.) supply and higher temperature (28°C) resulted in improved conditions for larval culture and advanced the development of the larvae until late auricularia stage. The sizes of the larvae are shown in Figure 5.

Becker et al. (2009), state that growing larvae need to be fed with abundant and high quality live microalgae, especially during the auricularia stage. In case of failure in this requirement, larvae growth and metamorphosis are significantly delayed for long periods, as happened in the first year of our study. Some authors have suggested the use of some algae of the genus *Spirulina* for food in the early stages (Agudo 2006; Zacarías-Soto et al. 2013) but this is only useful during pentactula or juvenile stages because they are benthic (the added *Spirulina* falls to the bottom of the tank). Therefore, in 2013, *Chlorella* sp. was cultured and added as feed during the auricularia stage. As reported by Xilin (1986), Asha (2004) or Asha and Muthiah (2006), its use mixed with other algae (such as *Dunaliella euchlaia*, *Chaetoceros gracilis*, *C. muelleri*, *Isochrysis galbana*, *Nanochloropsis salina*, *Dicrateria zhanjiangensis*, *Pavlova lutheri* and *Tetraselmis chuii*) is a key factor during this stage of culture development.

In 2013, we established that food was ingested by the larvae due to the green gut colouration (Fig. 6). At day ten of the culture, these larvae reached a

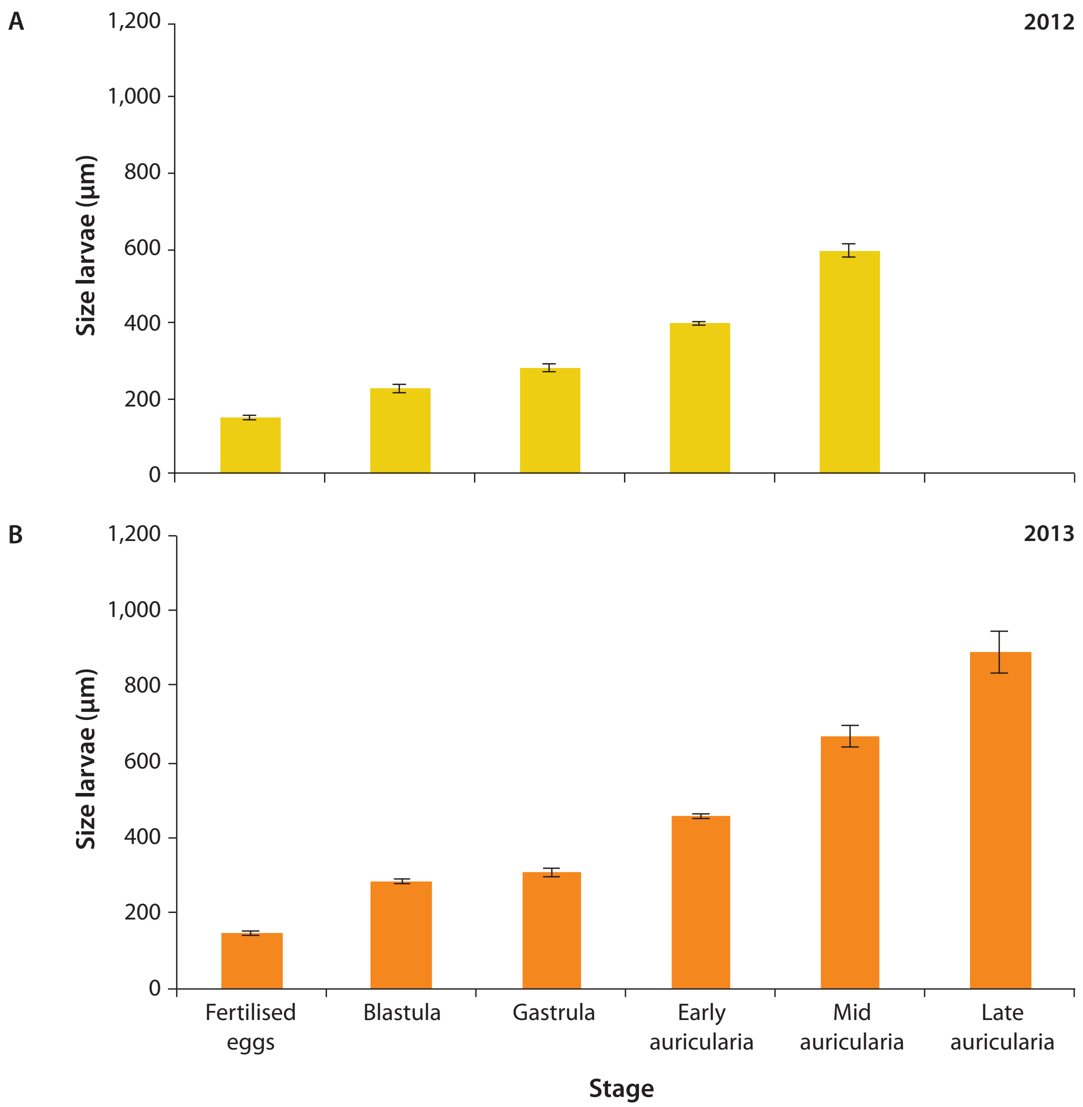

Figure 5. Larvae sizes in each of the reproductive periods under culture conditions: A) 2012: Temperature 26°C and feeding with *Spirulina* powder; B) 2013: Temperature 28°C and feeding with *Chlorella* sp. at a density of 5,000 cells mL^{-1}.

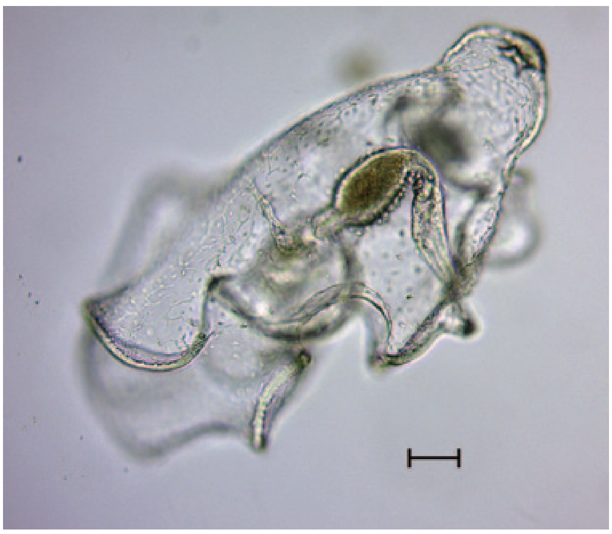

Figure 6. Late auricularia feeding microalgae (*Chlorella* sp.). Note green gut. Scale bar 20 µm.

maximum size of 888.71 µm ±106.71, when development stopped due to new copepod infestation that stopped the larval cycle and as well larvae metamorphosis.

Conclusion

Stichopus sp. reproduction is feasible under laboratory conditions since the species is easy handling and adapts to captivity. In addition, their spawning is continuous from July to November. Our findings will provide the basis for their reproduction under laboratory conditions and in turn promote the development of other related larval feeding studies to optimise sea cucumber production and survival and guarantee larvae requirements for growth and metamorphosis.

Acknowledgments

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References

Agudo N. 2006. Sandfish hatchery techniques. Australian Centre for International Agricultural Research, Secretariat of the Pacific Community and the World Fish Center, Noumea. 44 p.

Andrade Á.A., Machado L.F., Barreiros J.P., Paulay G. and Cardigos F. 2008. In situ observation of sexual reproduction of *Holothuria tubulosa* (Gmelin, 1788) (Echinodermata: Holothuroidea) in the Azores (NE Atlantic). SPC Beche-de-mer Information Bulletin 27:43–45.

Asha P.S. 2004. Effect of feed concentrations on larval growth, survival and development of *Holothuria* (*Theelothuria*) *spinifera* Theel. Journal of the Marine Biological Association of India 46(1):80–86.

Asha P.S. and Muthiah P. 2002. Spawning and larval rearing of the sea cucumber *Holothuria* (*Theelothuria*) *spinifera* Theel. SPC Beche-de-mer Information Bulletin 16:11–15.

Asha P.S. and Muthiah P. 2005. Effects of temperature, salinity and pH on larval growth, survival and development of the sea cucumber *Holothuria spinifera* Theel. Aquaculture 250:823–829.

Asha P.S. and Muthiah P. 2006. Effects of single and combined microalgae on larval growth, development and survival of the commercial sea cucumber *Holothuria spinifera* Theel. Aquaculture Research 37(2):113–118.

Asha P.S. and Muthiah P. 2008. Reproductive biology of the commercial sea cucumber *Holothuria spinifera* (Echinodermata: Holothuroidea) from Tuticorin, Tamil Nadu, India. Aquaculture International 16:231–242.

Babcock R., Mundy C., Kessing J. and Oliver J. 1992. Predictable and unpredictable spawning events: *In situ* behavioural data from free-spawning coral reef invertebrates. Invertebrates Reproduction and Development 22:210–228.

Battaglene S.C. 1999. Culture of the tropical sea cucumbers for the purpose of stock restoration and enhancement. Naga, the ICLARM Quarterly 22(4):4–11.

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). Marine Ranching. FAO Fishery Technical Paper No. 429. Rome, Italy: Food and Agriculture Organization of the United Nations. 213 p.

Battaglene S.C., Seymour E.J., Ramofafia C. and Lane I. 2002. Spawning induction of three tropical sea cucumbers *Holothuria scabra*, *Holothuria fuscogilva* and *Actinopyga mauritiana*. Aquaculture 207:29–47.

Becker P., Eeckhaut I., Ycaza R.H., Mercier A. and Hamel J.-F. 2009. Protozoan disease in larval culture of the edible sea cucumber *Isostichopus fuscus*. p. 571–573. In: Harris L.G., Bottger S.A., Walker C.W. and Lesser M.P. (eds). Echinoderms. London, United Kingdom: CRC Press.

Borrero-Pérez G., Benavides-Serrato M., Solano O. and Navas R. 2004. Holothuroideos (Echinodermata: Holothuroidea) recolectados en el talud continental superior del Caribe Colombiano. Boletín del Instituto Oceanográfico de Venezuela, Universidad de Oriente 42(1,2):68–85.

Caycedo I.E. 1978. Holothuroidea (Echinodermata) de aguas someras en la Costa Norte de Colombia. Anales del Instituto de Investigaciones Marinas de Punta Betín 10:149–198.

Chen C.P. and Chian C.S. 1990. Short note on the larval development of the sea cucumber *Actinopyga echinites* (Echinodermata: Holothuroidea). Bulletin of the Institute of Zoology Academia Sinica 29:127–133.

Conand C. and Byrne M. 1993. A review of recent developments in the world sea cucumber fisheries. Marine Fisheries Review 55(4):1–13.

Eeckhaut I., Lavitra T., Léonet A., Jangoux M. and Rasolofonirina R. 2012. *In vitro* fertilisation: A simple, efficient method for obtaining sea cucumber larvae year round. Asia-Pacific tropical sea cucumber aquaculture 136:40–49.

Fajardo-León M.C., Suárez-Higuera M.C.L., Del Valle-Manríquez A. and Hernández-López A. 2008. Biología reproductiva del pepino de mar *Parastichopus parvimensis* (Echinodermata: Holothuroidea) de Isla Natividad y Bahía Tortugas, Baja California Sur, México. Ciencias Marinas 34(002):165–177.

Foglietta L.M., Camejo M.I., Gallardo L. and Herrera F.C. 2004. A maturity index for holothurians exhibiting asynchronous development of gonad tubules. Journal of Experimental Marine Biology and Ecology 303:19–30.

Guisado C., Carrasco S.A., Díaz-Guisado D., Maltrain R. and Rojas H. 2012. Embryonic development, larval morphology and juvenile growth of the sea cucumber *Athyonidium chilensis* (Holothuroidea: Dendrochirotida). Revista de Biología Marina y Oceanografía 47(1):65–73.

Guzmán H., Guevara C. and Hernández I. 2003. Reproductive cycle of two commercial species of sea cucumber (Echinodermata: Holothuroidea) from Caribbean Panama. Marine Biology 142(2):271–279.

Hamel J.-F. and Mercier A. 1996. Early development, settlement, growth, and spatial distribution of the sea cucumber *Cucumaria frondosa* (Echinodermata: Holothuroidea). Canadian Journal of Fisheries and Aquatic Sciences 53(2):253–271.

Hamel J.-F., Himmelman J.H. and Dufresne L. 1993. Gametogenesis and spawning of the sea cucumber *Psolus fabricii* (Duben and Koren). Biological Bulletin 184:125–143.

Hamel J.-F., Conand C., Pawson D.L. and Mercier A. 2001. The sea cucumber *Holothuria scabra* (Holothuroidea: Echinodermata): Its biology and exploitation as beche-de-mer. Advances in Marine Biology 41:129–233.

Hamel J.-F., Pawson D.L., Conand C. and Mercier A. 2002. The sea cucumber *Holothuria scabra* (Holothuroidea: Echinodermata): Its biology and its exploitation as beche-de-mer. Advanced Marine Biology 41:131–233.

Hamel J.-F., Hidalgo R.Y. and Mercier A. 2003. Larval development and juvenile growth of the Galapagos sea cucumber *Isostichopus fuscus*. SPC Beche-de-Mer Information Bulletin 18:3–8.

Hu C., Xu Y., Wen J., Zhang L., Fan S. and Su T. 2010. Larval development and juvenile growth of the sea cucumber *Stichopus* sp. (Curry fish). Aquaculture 300(1):73–79.

Hu C., Li H., Xia J., Zhang L., Luo P., Fan S. and Wen J. 2013. Spawning, larval development and juvenile growth of the sea cucumber *Stichopus horrens*. Aquaculture 404:47–54.

Ito S. 1995. Studies on the technical development of the mass production for sea cucumber juvenile, *Stichopus japonicus*. Hatchery Manual. Saga, Japan: Saga Prefectual Sea Farming Center. 87 p.

Ito S. and Kitamura H. 1997. Induction of larval metamorphosis in the sea cucumber *Stichopus japonicus* by periphitic diatoms. Hydrobiologia 358:281–284.

James D.B. 1994. Seed production in sea cucumbers. Aquaculture International 1(9):15–26.

Kashenko S.D. 2002. Reactions of the larvae of the sea cucumber *Apostichopus japonicus* to sharp desalination of surface water. A laboratory study. SPC Beche de Mer Information Bulletin 15:11–15.

Kubota T. and Tomari M. 1998. Reproduction in the apodid sea cucumber *Polycheira rufescens*: Semilunar spawning rhythm and sex change. Journal of the Marine Biological Association of the United Kingdom 78(01):249–267.

Mercier A., Battaglene S.C. and Hamel J.-F. 2000. Periodic movement, recruitment and size-related distribution of the sea cucumber *Holothuria scabra* in Solomon Islands. Hydrobiologia 440:81–100.

Mercier A., Ycaza R.H. and Hamel J.-F. 2007. Long-term study of gamete release in a broadcast-spawning holothurian: Predictable lunar and dial periodicities. Marine Ecology Progress Series 329:179–189.

Mercier A, Ycaza R.H., Espinoza R, Haro V.M.A and Hamel J.-F. 2012. Hatchery experience and useful lessons from *Isostichopus fuscus* in Ecuador and Mexico. ACIARSPC Asia-Pacific tropical sea cucumber aquaculture symposium 136:79–90.

Morgan A.D. 2000. Induction of spawning in the sea cucumber *Holothuria scabra* (Echinodermata: Holothuroidea). Journal of the World Aquaculture Society 31:186–194.

Ong Che R.G. and Gomez E.D. 1985. Reproductive periodicity of *Holothuria scabra* Jaeger at Calatagan, Batangas, Philippines. Asian Marine Biology 2:21–29.

Purcell S.W. and Eeckhaut I. 2005. An external check for disease and health of hatchery-produced sea cucumbers. SPC Beche-de-mer Information Bulletin 22:34–38.

Raison C.M. 2008. Advances in sea cucumber aquaculture and prospects for commercial culture of *Holothuria scabra*. CAB Reviews 3(82):1–15.

Ramofafia C., Gervis M. and Bell J. 1995. Spawning and early larval rearing of *Holothuria atra*. SPC Beche-de-Mer Information Bulletin 7:2–6.

Ramofafia C., Battaglene S.C., Bell J.D. and Byrne M. 2000. Reproductive biology of the commercial sea cucumber *Holothuria fuscogilva* in the Solomon Islands. Marine Biology 136:1045–1056.

Ramofafia C., Byrne M. and Battaglene C. 2003. Reproduction of the commercial sea cucumber *Holothuria scabra* (Echinodermata: Holothuroidea) in the Solomon Islands. Marine Biology 142(2):281–288.

Rodríguez A., Vergara W. and Agudelo V. 2013. First insight into Colombian Caribbean sea cucumbers and sea cucumber fishery. SPC Beche-de-Mer Information Bulletin 33:9–13.

Sicuro B. and Levine J. 2011. Sea cucumber in the Mediterranean: A potential species for aquaculture in the Mediterranean. Reviews in Fisheries Science 19(3):299–304.

Soliman T., Yamazaki Y., Niiyama H. and Tsunoda K. 2013. Spontaneous captive breeding and larval development in the green and red variants of the Japanese sea cucumber *Apostichopus japonicus* (Selenka, 1867). Aquaculture Research 44(5):738–746.

Xilin S. 1986. Advances and prospects of sea cucumber (*Apostichopus japonicus*) aquaculture in China. SPC Beche-de-Mer Information Bulletin 19:16.

Yanagisawa T. 1998. Aspects of the biology and culture of the sea cucumber. p. 292–308. In: De Silva S.S. (ed.). Tropical Mariculture. London, United Kingdom: Academic Press. 487 p.

Zacarías-Soto M., Olvera-Novoa M.A., Pensamiento-Villarauz S. and Sánchez-Tapia I. 2013. Spawning and larval development of the four-sided sea cucumber, *Isostichopus badionotus* (Selenka, 1867), under controlled conditions. Journal of the World Aquaculture Society 44(5):694–705.

About lesser known beche-de-mer markets

Chantal Conand[1,*]

Introduction

In the tropical Pacific, much attention has been given recently (Purcell et al. 2010; Purcell 2014a,b), following previous work (Conand 1979, 1990; Skewes et al. 2004), to beche-de-mer in the Indo-Pacific region. This contribution follows short observations already presented in SPC beche-de-mer information bulletins from other countries.

It appears that, in several markets, the traditional products coming from tropical Indo-Pacific species are no longer dominant and specific identification of the dry products needs special attention. It is therefore recommended that processors and scientists, in new beche-de-mer producing countries, develop small research projects on the changes in length and weight of the species during the different phases of processing. A few specimens per category of size (small, medium, large) would be necessary to establish the regression model for each species. Providing photos at the different stages would also be helpful.

Reports

1. Democratic People's Republic of Korea, market of Pyongyang

Very little is known about the present holothurian exploitation in this country. In the FAO report (Toral-Granda et al. 2008), Poh Sze quoted an anonymous report that landings declined in the 1985–1990 period and that the Oruji Nature Reserve was established in 1996 mainly for the conservation of sea cucumbers. From a recent tour, Figure 1 from the market of Wonsan shows processed dry Apostichopus japonicus in large bags sold at 25 euros and small ones at 10 euros.

2. Democratic People's Republic of Korea

From FAO statistics, Poh Sze (Toral-Granda et al. 2008) quotes a decline of one third in the captures from 1995 to 2005 (around 1,100 t). From the same tour, in Pusan the same species is consumed raw. It is called "gingseng of the sea" or "Hai-som" (Fig. 2). *Urechis unicinctus* is also consumed raw (Fig. 3).

3. San Francisco

The Chinese community of San Francisco buys dry products of many species from many countries at prices up to USD 268 per pound (Fig. 4).

Translation of the Chinese names provided by marielle.dumestre@gmail.com.

Figure 1. Processed *Apostichopus japonicus* on Wonsan market (Image: M.J. Chalvin, 2014).

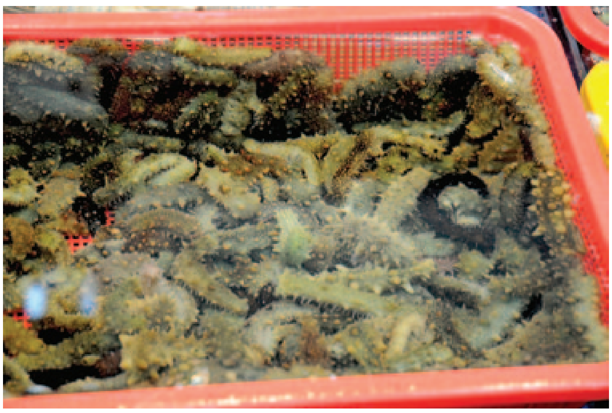

Figure 2. Live *Apostichopus* on Pusan market (Image: M.J. Chalvin, 2014).

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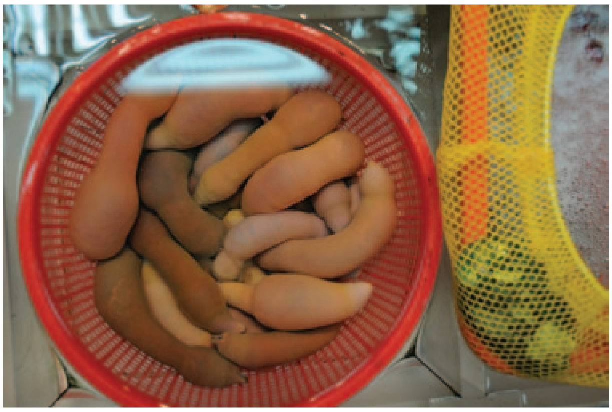

Figure 3. Live *Urechis unicinctus* belonging to the phylum Echiura on Pusan market (Image: M.J. Chalvin, 2014).

Figure 4. Sea cucumber in San Francisco (Image: J. Conand, 2014).

References

Conand C. 1979. Beche-de-mer in New Caledonia: Weight loss and shrinkage during processing in three species of holothurians. SPC Fisheries Newsletter 19:14–17.

Conand C. 1990. The fishery resources of Pacific island countries. Part 2: Holothurians. FAO Fisheries Technical Paper No. 272.2. Rome, Italy: Food and Agriculture Organization of the United Nations. 143 p.

Purcell S.W. 2010. Managing sea cucumber fisheries with an ecosystem approach. FAO Fisheries and Aquaculture Technical Paper No. 520. Rome, Italy: Food and Agriculture Organization of the United Nations. 157 p.

Purcell S.W. 2014a. Processing sea cucumbers into beche-de-mer: A manual for Pacific Island fishers. Southern Cross University, Lismore, and the Secretariat of the Pacific Community, Noumea. p. 44.

Purcell S.W. 2014b. Value, market preferences and trade of beche-de-mer from Pacific Island sea cucumbers. PLoS One 9:e95075.

Skewes T., Smith L., Dennis D., Rawlinson N., Donovan A. and Ellis N. 2004. Conversion ratios for commercial beche-de-mer species in Torres Strait. AFMA Project Number: R02/1195. Brisbane, Australia: Australian Fisheries Management Authority. 32 p.

Toral-Granda V., Lovatelli A. and Vasconcellos M. (eds). Sea cucumbers. A global review on fishery and trade. FAO Fisheries Technical Paper. No. 516. Rome, Italy: Food and Agriculture Organization of the United Nations. 319 p.

Sea cucumber products at the China Fisheries Seafood Expo 2014

Choo Poh Sze[1,] and Chantal Conand[2,3,*]*

Introduction

The China Fisheries Seafood Expo is Asia's largest seafood trade exposition. The 19th Expo was held in the Qingdao International Convention Center in November 2014, with a record number of 1,206 participating companies and approximately 27,490 visitors from over 114 countries. "A show such as this expo provides a chance for buyers, sellers and government officials to meet face-to-face, explore new opportunities and find solutions to existing challenges," said Peter Redmayne, president of Sea Fare Expositions.

About 67 finfish and 34 invertebrate species were exhibited, including sea cucumbers. China has traditionally sourced their sea cucumbers from countries in tropical waters such as the Philippines, Indonesia and Pacific island countries. With tropical sea cucumber resources declining from overfishing, temperate species from Canada, the United States of America, Europe and South America were being promoted at the Expo to attract Chinese buyers.

Report

This contribution describes, with photos taken at the Expo, some of the products displayed — their common name, scientific name whenever possible, origin and price. It was difficult to get information from the traders, as they do not know much about the products offered for sale. Recent information on the fisheries and trade of sea cucumbers can be found in Lovatelli et al. (2004), Toral-Granda et al. (2008) and Purcell et al. (2012, 2014).

1. South America

Scientific name: *Isostichopus fuscus*

Common name: Brown sea cucumber

Dried (if the order is more than 20 kg)**:** RMB 1,440 kg^{-1} (size not specified); CNY 1,440 or USD 234.72 kg^{-1}

2. South America

Scientific name: *Isostichopus badionotus*

Common name: Three-rowed sea cucumber

Dried (if the order is more than 20 kg)**:** CNY 1,100 kg^{-1} or USD 179.3 kg^{-1}

3. Canada and USA

Scientific name: *Parastichopus californicus*

Common name: Red sea cucumber

Dried (if the order is more than 20 kg)**:** CNY 1,600 kg^{-1} or USD 260.8 kg^{-1}

The red sea cucumber from British Columbia, Canada and the USA is a unique species consisting of two parts: a firm outer skin and a thick inner muscle, often referred to as the sea cucumber meat. They are sometimes called "big" or "giant red sea cucumbers" and are usually reddish or dark brown. They are found along the entire length of the British Columbia coast and the average commercially harvested length is 30–40 cm. The skin is highly sought after for its health benefits. The meat, or muscle, has great nutritional value and is used in a variety of very tasty dishes. British Columbia is known around the world for clean, pristine waters and it is in these conditions that experienced divers handpick the sea cucumbers. They are sent to the surface and immediately sliced, drained and stored for delivery to a dock and then sent on to a registered processing plant. At the dock the third party monitor weighs the product and deducts its total from the individual quota, thus insuring no over fishing in any given area. At the processing plant, the muscle is removed from the skin, vacuum packed and frozen, while the skin is cooked and packed for shipment. Each step of the process is carefully monitored and controlled to ensure that the highest regulatory standards are met. Red sea cucumbers are harvested between October and April. Products

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are sold dried, as half-dry skin, cooked, salted and frozen (Fig. 1). (Source: Pacific Sea Cucumbers Harvesters Association website, www.pscha.org)

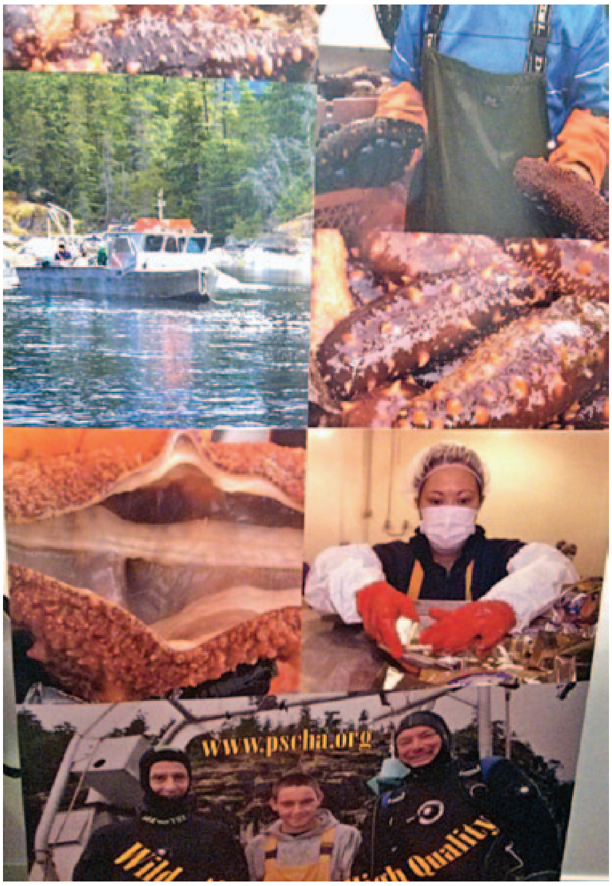

Figure 1. Poster showing the giant red sea cucumber (Photo taken at the booth of the Pacific Sea Cucumber Harvesters Association in the Seafood Expo, Qingdao 2014).

4. South Korea

Scientific name: *Apostichopus japonicus*

Common name: Japanese spiky sea cucumber

Ready to eat: CNY 1,680 kg^{-1} or USD 273.84 kg^{-1}

Dried: CNY 1,998 kg^{-1} or USD 325.67 kg^{-1}

Various value added products, such as instant sea cucumber (ready to eat from the package); solar salt with dried sea cucumber extract, and soap with sea cucumber extracts claimed to prevent ageing and help skin regeneration, were promoted in the Seafood Expo (Fig. 2). For the dried form, the Haeser company claimed that they are marketing wild sea cucumber caught from clean waters and it is the only Korean company to produce a saltless dried sea cucumber with a patented technology. Haeser Products Co., which was established in 2011, has its base in Busan.

Figure 2. Various sea cucumber products from *Apostichopus japonicus*, including solar salt (A), soap (B), ready-to-eat sea cucumber (C), and beche-de-mer (D).

5. Canada

Scientific name: *Cucumaria frondosa*

Common name: Orange footed sea cucumber

Frozen: USD 3 lb^{-1}

Ready to eat: CNY 1,400 kg^{-1} or USD 228.20 kg^{-1}

This sea cucumber is wild, captured in the North Atlantic Ocean off Canadian shores. They are found at approximately 10 m under water and where the maximum water surface temperature does not exceed 14°C. They are harvested from waters that are far from industrial plants and free from anthropogenic activities. After the anterior and posterior parts and internal organs are removed, they are baked without the use of preservatives, colouring agents or gelatine. This kind of processing results in irregularly shaped sea cucumbers with a "degree-ten" dryness that could be kept longer. Products are sold as dry skin without or with meat (Fig. 3). (Rosalyn United Trans Limited, website: www.unitedtrans.ca)

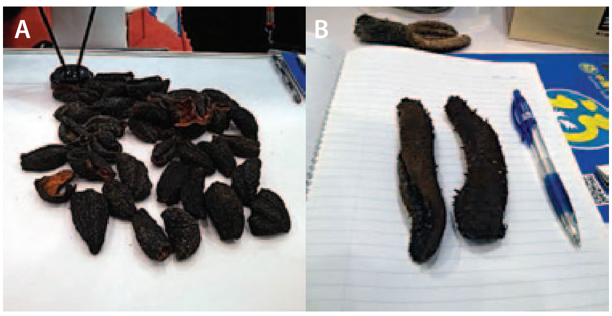

Figure 3. *Cucumaria frondosa.* A) Dried skin; B) Whole dried product.

6. Caribbean

Scientific name: *Holothuria mexicana* (Fig. 4)
Common name: Caribbean beche-de-mer
Dried with skin: USD 53 kg^{-1}
Dried without skin: USD 70 kg^{-1}

Figure 4. Caribbean beche-de-mer, *Holothuria Mexicana.*

7. Europe

Scientific name: *Holothuria tubulosa*
Common name: Tubular sea cucumber
Dried: CNY 1,360 kg^{-1}or USD 221.68 kg^{-1} — selling like hotcakes in the China Seafood Expo

The products from one stall came from Italy and those from another stall came from Greece.

8. Red Sea

Scientific name: *Holothuria scabra*
Common name: Sandfish

The National Aquaculture Group of Saudi Arabia is a fully integrated company with feed mills, hatcheries, and grow-out and processing facilities. The grow-out process takes place naturally in the pristine waters of the Red Sea. After harvesting, the sea cucumbers are quickly transported to the processing plants. The sandfish is grown in low-density concentration ponds with full traceability and high biosecurity standards.

9. Products from China

Scientific name: *Apostichopus japonicus* (Fig. 5)
Common name: Japanese spiky sea cucumber
Dried: Price range from CNY 700–8,000 per 500 g or USD 114.1–1,304 per 500 g

Figure 5. Dried beche-de-mer prepared from *Apostichopus japonicus* from Dalian and Qingdao in China showing products of different value according to whether they are wild caught (with higher value) or cultivated, and of different sizes. Prices shown are per 500 g.

Discussion

This brief overview reveals an increased awareness of certified hygienic and nutritional products, with an emphasis on food safety and sustainability in the sea cucumber fishery. Products from North America and Canada stressed the pristine conditions from where the sea cucumbers are fished, while those from China and South Korea implied that wild captured products are more nutritional than cultured ones, which may be subjected to the use of non-approved chemicals. Sustainability is also highlighted, e.g. by the Pacific Sea Cucumber Harvesters Association (PSCHA) of British Columbia.

The traditional sea cucumber trade from tropical countries will, therefore, have some catching up to do to ensure that they also emphasise clean, wholesome products that are harvested sustainably. The tropical sea cucumber producers could also add value to their products by looking into a wider array of processed products and not just depending on the traditional beche-de-mer.

A recent paper by Purcell (2014) was based on direct observations of exported products from Pacific Islands and Chinese markets in Hong Kong (five stores) and Guangzhou (11 stores); it shows that there is a good acceptance for these products, which have been produced and imported for a long time. Another contribution (Conand, this issue) also shows direct observations of the products from other markets (USA, North Korea, South Korea). It appears more difficult to confirm the species originating from the other countries, despite recent information and photos provided in the book published by FAO (Purcell et al. 2012). There is a need for further studies in order to get more precise data on the countries and ocean of origin of the products found in the Chinese markets.

The 20th China Fisheries and Seafood Expo will be held on 4–6 November 2015; it will be in the beautiful Qingdao International Exhibition Centre. The Seafood Fare China is already advertising for next year's fare: http://www.chinaseafoodexpo.com/

References

Lovatelli A., Conand C., Purcell S., Uthicke S., Hamel J.-F. and Mercier A. 2004. Advances in sea cucumber aquaculture and management. FAO Fisheries Technical Paper No. 463. Rome, Italy: Food and Agriculture Organization of the United Nations. 425 p.

Purcell S.W. 2014. Value, market preferences and trade of beche-de-mer from Pacific Island sea cucumbers. PLoS One 9: e95075.

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, Italy: Food and Agriculture Organization of the United Nations. 150 p.

Purcell S., Choo P.S., Akamine J. and Fabinyi M. 2014. Alternative product form, consumer packaging and extracted derivatives of tropical sea cucumbers. SPC Beche-de-mer Information Bulletin 4:47–52.

Toral-Granda V., Lovatelli A. and Vasconcellos M. 2008. Sea cucumbers. A global review of fisheries and trade. FAO Technical Paper No. 516. Rome, Italy: Food and Agriculture Organization of the United Nations. 319 p.

Juvenile holothurian observed at La Réunion (Indian Ocean)

Bourjon P.[1] *and Conand C.*[2]

Following the questionnaire published by Shiell (2004a), a number of reports on juvenile observations have been collated by Shiell (2004b) and James (2005). We report here on a recent observation, with photos (Fig. 1), of an unidentified stichopodid species from La Réunion fringing reef.

Species observed: Undetermined species of the family Stichopodidae

Number of individuals observed: 1

Approximate size: 2.5 cm

Location: Outer reef flat St Gilles / La Saline (La Réunion)

Habitat: In sand, near surf, under dead coral

Time of day: 11 am

Date: 21-09-2014

Were adults present within the same habitat or nearby? A few small *Stichopus chloronotus* and *Holothuria pervicax*

The photos taken *in situ* show the quadrangular shape and the transparent tegument, with tiny white spots. The bivium has numerous large white tipped papillae with a black circle at the base (Fig. 1A). The trivium has three rows of podia (Fig. 1B). No disaggregation of the tegument was observed during the manipulation, unlike that noted for *Stichopus chloronotus*, which reproduces sexually during the warm season (Conand et al. 2002). The other stichopodids present in La Réunion are *S. herrmanni*, *S. monotuberculatus* and *Thelenota ananas* (Conand et al. 2010), whose juveniles look different (Trentin 2011). Other observations remain necessary on this little known but important stage in the holothurian life history.

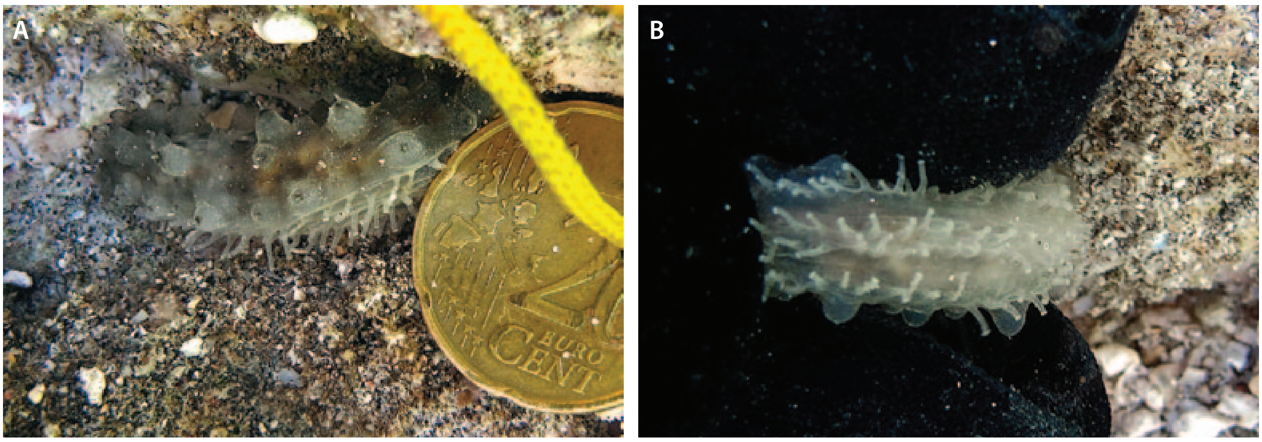

Figure 1. Juvenile stichopodid observed in La Réunion. A) Bivium; B) Trivium (Images: P. Bourjon).

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References

Conand C., Uthicke S. and Hoareau T. 2002. Sexual and asexual reproduction of the holothurian *Stichopus chloronotus* (Echinodermata): A comparison between La Réunion (Indian Ocean) and east Australia (Pacific Ocean). Invertebrate Reproduction and Development 41:235–242.

Conand C., Michonneau F., Paulay G. and Bruggemann H. 2010. Diversity of the holothuroid fauna (Echinodermata) in La Réunion (Western Indian Ocean). Western Indian Ocean Journal of Marine Science 9(2):145–151.

James D.B. 2005. Information on juvenile holothurians. SPC Beche-de-mer Information Bulletin 21:26.

Shiell G. 2004a. Questionnaire on the field observations of juvenile sea cucumbers. SPC Beche-de-mer Information Bulletin 19:41.

Shiell G. 2004b. Field observations of juvenile sea cucumbers. SPC Beche-de-mer Information Bulletin 20:6.

Trentin F. 2011. Observation of a juvenile of the commercial species *Thelenota ananas*, in La Réunion, Indian Ocean. SPC Beche-de-mer Information Bulletin 31:56.

Communications...

From: *Frédéric Ducarme*[1,*]

Participative sciences and naturalist biology

New technologies allow new data and new opportunities for science. On his Echinoblog website (http://echinoblog.blogspot.fr/), Dr C. Mah (Mah 2008) has proved how useful some public websites, such as *FlickR* (https://www.flickr.com/), could be, providing thousands of underwater pictures from all around the world, allowing scientists to discover unknown behaviours, strange physical patterns and unsuspected geographical ranges of echinoderms, but also potential new species.

Another website is becoming increasingly important as a link between research and popularisation of knowledge: the free open-source, web-based, encyclopaedia *Wikipedia* (www.wikipedia.org). The scientific accuracy of its content is still heterogeneous, but improving at a fast rate. *Wikipedia* content is more and more often used as a basis in more professional websites and databases, such as *Encyclopaedia of Life* (http://eol.org/) or iNaturalist (http://www.inaturalist.org/). Wikipedia is also a promising platform for popularising some lesser known groups of animals, especially invertebrates. Hence, some professional scientists have already started writing scientific articles about echinoderms on *Wikipedia*, including labelled articles (see *Acanthaster planci* for example, see reference). A few taxonomists and divers generously uploaded hundreds of copyright-free professional pictures to illustrate them, or helped to identify pictures uploaded by others. But there is still a lot of work to be done, and most species lack a proper picture or article.

Knowledge about sea cucumbers is still heterogeneous, and not always of easy access for scientists on fieldwork or non-professionals. Hence, making *Wikipedia* a reliable source of knowledge could be useful, providing a lot of accessible pictures, descriptions and information. As *Wikipedia* exists in many languages and articles are translated from most complete versions to others, this could also be a powerful tool for popularisation, along with awareness rising about protected species and ecological issues. Articles about sea cucumbers are available from the following address: https://en.wikipedia.org/wiki/Sea_cucumber.

Many scientists possess pictures, data and knowledge that could be shared. Creating an account, uploading files (especially research-grade pictures of rare animals) is easy, and other *Wikipedia* contributors are ready to explain the rules, help in identification, review, or correct mistakes. We strongly believe that giving a little of one's time to a project such as Wikipedia is part of a scientist's work.

Acknowledgements

Thanks are expressed to all *Wikipedia* contributors for one of the most exciting scientific projects ever. I am personally grateful for the help of Chantal Conand, Philippe Bourjon, Christopher Mah, François Michonneau and Gustav Paulay.

References

Mah C.L. 2008. The Flickr Field Guide Challenge. The Echinoblog.http://echinoblog.blogspot.fr/2008/11/flickr-field-guide-challenge.html.

Wikipedia (French version). 2011. *Acanthaster planci*, labelled as "Featured article". https://fr.wikipedia.org/wiki/Acanthaster_planci

Wikipedia (English version). 2011. *Acanthaster planci*. https://en.wikipedia.org/wiki/Acanthaster_planci

Wikipedia (English version). Sea cucumber. https://en.wikipedia.org/wiki/Sea_cucumber

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From: *Choo Poh Sze*[1,*]

China Central Television (CCTV) exposed the overuse of drugs in farmed sea cucumber in Northeast China's coastal Liaoning province, which has tainted the nearby seawater and killed many sea creatures, the Beijing Morning Post reported

Sea cucumber farms abound in Dalian city's Pikou town, located on the coast of the Bohai Sea. It is no secret that drugs are used to keep farmed sea cucumbers healthy, the investigative report said. Small bottles labelled ceftriaxone sodium, a type of antibiotic, are frequently dumped outside a farm in the town. Reporters learned that mariculture famers use several types of antibiotics and Chinese herbal concoctions to protect sea cucumbers from illness. One farmer told reporters that they also spike the water with pesticide to kill organisms that might otherwise steal nutrients from sea cucumbers. And sodium hypochlorite and clinical dextrane, all disinfectants, are used to clean up excrement from the sea creatures, he added. Farmers dump this contaminated water into the sea every three or four days, undermining water quality near the fishing farms. In general, the farmland is cleaned up every four years. After removing all sea cucumbers and draining the water, local farmers cover the land with lime, 150 to 160 kg per mu (666 m^2), and then wait for waves to take the lime and waste into the sea. Dozens of dead fish have been seen floating on the sea when these large-scale clean-ups are carried out.

In nearby areas, other sea creatures like squid and shrimp have been wiped out, a farmer said.

See more at http://www.thefishsite.com/fishnews/24073/antibiotic-overuse-causing-species-extinction-in-china#sthash.R5dkFPU6.yIfzXVgk.dpuf

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Abstracts and new publications...

Meetings 2014 and communications on sea cucumbers

1) 47th North American Echinoderm Conference, University of West Florida, Pensacola, Florida, 1–6 June 2014

- Paulay Gustav, Scott Smiley, David L. Pawson, Mandy Bemis — Echino-WoRMS and beyond: Tracking sea cucumber nomenclature from 1765 to the future.
- Mike Reich — On the relationships of early holothurians and ophiocistioids: A question of wheels?
- Tanja R. Stegemann, P. Mark O'Loughlin, Mike Reich — Hard part morphology of some living *Taeniogyrus* species (Holothuroidea: Apodida: Chiridotidae).
- John Starmer, Gustav Paulay — Evolutionary relationships within *Stichopus* (Holothuroidea: Stichopodidae): A combined approach using genetics and morphology.
- Julio Adrián Arriaga-Ochoa, Francisco A. Solís-Marín, Mariano Martínez — *Psolus squamatus* (Müller, 1776): A species complex (Echinodermata: Holothuroidea).
- François Michonneau, Gustav Paulay — Cryptic and not-so-cryptic species in sea cucumbers.
- Liliane Veras Leite, José de Sousa Junior, Renata Vieira do Nascimento, Maria Eduarda Magalhães de Souza, Júlia Trugilio Lopes, Carminda Sandra Brito Salmito-Vanderley, Annie Mercier, Jean-François Hamel — Reproductive seasonality of *Holothuria grisea* in northeastern Brazil.
- Vladimir S. Mashanov, Olga R. Zueva, José E. García-Arrarás — Differential gene expression during neural regeneration in a sea cucumber.
- Vladimir S. Mashanov, Olga R. Zueva, José E. García-Arrarás — Myc regulates programmed cell death and radial glia dedifferentiation after neural injury in sea cucumbers.
- Allison K. Miller, Alexander M. Kerr, Greg W. Rouse — Higher level systematics of the walking, swimming, and burrowing Holothuroidea (Echinodermata): A six-gene molecular phylogenetic approach.
- Sun W. Kim, Allison K. Miller, Alexander M. Kerr — Holothuroid fauna of Chuuk (Federated States of Micronesia).
- Luciana Martins, Camilla Souto, Marcos Tavares — Revision of the western Atlantic *"Ocnus"* species (Dendrochirotida: Cucumariidae).
- Camilla Souto, Luciana Martins — Morphology of the *Dendrochirotida* calcareous ring: *Phyllophorus occidentalis* Ludwig (Phyllophoridae) as a Sclerodactylid.
- Jing Wen, Chaoqun Hua, Sigang Fana — Chemical composition and nutritional quality of sea cucumbers (wileyonlinelibrary.com) doi:10.1002/jsfa.4108.

2) 2nd World Small-Scale Fisheries Congress, Mérida, México, 21–26 September 2014

Congress run by Too Big to Ignore Network: http://toobigtoignore.net; https://2wsfc.files.wordpress.com/2013/10/congress-schedule-final.pdf

Communicated by Marc Léopold, IRD, U227 COREUS2, BP A5, 98848 Nouméa cedex, New Caledonia; Fisheries Department of Vanuatu, Private Bag 9045, Port-Vila, Vanuatu, marc.leopold@irf.fr; and Jim Prescott, Australian Fisheries Management Authority, PO Box 131 Darwin, NT 0801 Australia Jim.Prescott@afma.gov.au.

Oral presentations in which sea cucumbers featured

- Léopold Marc, Ham Jayven, Kaku Rocky, Moenteapo Zacharie — Putting spatial management into practice: A case study of sea cucumber fisheries in New Caledonia and Vanuatu (Southwest Pacific).
- Bennett Abigail, Basurto Xavier — Cooperatives, fish buyers, and pepineros: Geographically differentiated effects of neoliberal policy reform on local responses to contemporary market pressures in Mexican small-scale fisheries.
- Rodríguez Luis Alfonso, Reyes Sosa Carlos Francisco, Dzib Sara Nahuat — Diagnose, distribution and a SWOT analysis of the economic benefits generated by sea cucumber fisheries in a fishing cooperative in the Yucatán, Mexico.

- Guarneros Pável Galeana, Gurri Francisco — Depletion of sea cucumbers in Isla Arena may have enhanced local governance to promote resilience in the social-ecological system.
- James Riwu, James Prescott, Natasha Stacey, Andhika Prasetyo, Dian Oktaviani, Anthony Panggbean — An unlikely partnership: Data collection in a small scale fishery in the Timor Sea.

Sea cucumber discussions

As part of the congress a field trip was taken to the nearby fishing port of Progresso, on the Yucatán Peninsula, Mexico, where one group of 27 participants (including local fishermen) held a "sea cucumber discussion circle". Discussion was moderated by Dr Alvaro Hernandez (Mexico) and M.Sc. Juan Carlos Murillo (Ecuador). The moderators explained the organisation of the circle and presented the common problems of sea cucumber fisheries, followed by a discussion period. This was reported:

Galapagos

Juan Carlos Murillo spoke on the status of the sea cucumbers, *Isostichopus fuscus*, in the Galapagos, Ecuador. He noted that exploratory fishing operations started in 1995 and legal fishing began in 1999. High catches were observed (about 5 M sea cucumbers per year). However, in 2003 catches began to decline. Since 1998 there has been a scheme of co-management, but it was not fully effective. The first management plan was established in 2008 and included the first fishery reference point (established on historical data), which required a minimum density of 11 sea cucumbers per 100 m^2 for the fishery to be opened. Since 2009 the fishery has been opened only one year because the reference point was not met during the other years. The low densities can be explained by the density-dependent reproductive success for these species. Recent densities were seven and eight sea cucumbers per 100 m^2 in 2012 and 2013, respectively. It is believed that illegal fishing is not significant and the management goal is to recover the population to a level of 15 cucumbers per 100 m^2 by 2017. The fishery has not experienced an economic collapse due to the high prices received now (prices increased from USD 0.80 to USD 4.00 per kg (wet weight) between 1999 and 2011). Recommended fisheries policies include alternative livelihoods for the fishers during periods of closures, which could include remunerated monitoring, research and conservation activities. Also recommended are: a public auction to improve the prices of sea cucumber; stock restoration; and longer closures.

Yucatán

Alvaro Hernandez spoke on sea cucumber fishing in the Yucatán Peninsula where there is a small-scale fishery. As with other such fisheries, the high demand in Asia drives prices high and stocks are very vulnerable to overfishing. In 1990 Zetina et al. performed the first study of sea cucumber in Yucatán, and in 2005 a high demand for Yucatán sea cucumber was documented by Cervera-Cervera (2007).

In May 2006 five fishing licenses were issued. In 2008 low abundance was reported due to a red tide event. In 2010, a prospective analysis began in Yucatán and nearby Campeche followed by catch quotas; however, it is estimated that the catch is five times greater than the quota. Estimated earnings from one fishing trip for traditional species (fish, octopus, etc.) is 1,500 pesos, but a sea cucumber fishing trip produces 11,500 pesos, which makes this fishery very attractive. There is a serious social problem because many fishermen are requesting fishing licenses for sea cucumber; there have even been protest marches.

The species caught in Yucatán is *Isostichopus badionotus* while the species in Campeche is *Holothuria floridana*. The status of *Isostichopus badionotus* stocks on the coast of Yucatán in 2013 is shown in Table 1.

Table 1. Yucatán fishing zones and biomass (t) estimates for *Isostichopus badionotus* and associated density estimates in 2013.

Zone	Biomass (t)	Density (ind. m^{-2})
I	3,261	0.027
II	714	0.026
III	5,667	0.152
IV	3,697	0.110
V	437	

In recent years in the Campeche port of Isla Arena fishing has been closed due to a conflict between large licensed vessels and other local fishermen who cannot compete during the open season. A total of 200 fishing licenses were issued to catch sea cucumber (for 200 boats and 600 fishermen). However, it is estimated that there are about 1,000 boats and 3,000 fishermen actively involved in catching sea cucumbers. The fishery's problems were even reported in the New York Times, revealing the violence, decompression accidents and the social problems.

3) CUMFISH WORKSHOP, Faro, Portugal, 14–15 May 2014

CUMFISH — Sea cucumbers: The new resource for a hungry fishery

Communicated by Mercedes Wangüemert, CCMAR, University of Algarve, Faro, Portugal

The over-exploitation of sea cucumber fisheries has resulted in fishing for new target species from Mediterranean Sea and the North Atlantic Ocean, where fisheries are in the process of development. The main problem of these new fisheries is the existence of several sea cucumber species living in the same region with similar external morphology, very difficult identification and about which there is scarce information on life stages, population dynamics and evolution history.

Therefore, the main goals of the CUMFISH project are to study the incipient sea cucumber fisheries of the Mediterranean Sea and Atlantic Ocean and to assess the genetic structure of these species, including the selection effects of fisheries. To reach these aims we have carried out studies on ecology, reproduction, genetics, behaviour, growth and fisheries of six target species from the Mediterranean Sea and North Atlantic Ocean.

Presentations

- Mercedes González-Wangüemert — CUMFISH Project. Sea cucumbers: the new resource for a hungry fishery.
- Chantal Conand — International, regional and local efforts during the last decade to promote the conservation of commercial sea cucumbers.
- Sara Valente — West versus East Mediterranean Sea: origin and genetic differentiation of the sea cucumber *Holothuria polii*.
- Filipe Henriques — Genetic connectivity patterns in *Holothuria mammata* considering different spatial scales.
- Camilla Maggi — Population and genetic structure of *Parastichopus regalis* (Cuvier, 1817) from the Mediterranean Sea and its commensal *Carapus acus* (Brünnich, 1768).
- Mercedes González-Wangüemert — Sea cucumber in the Aegean Sea (Turkey): Assessment of fishery protection on growth and genetic structure.
- Luisa Custodio — Nutritional profile and antioxidant activity of sea cucumbers from the Mediterranean Sea and north-eastern Atlantic.
- Silke Bossers — The sea cucumber microbiome project.
- Nuno Vasco — CUMFISH in Peniche, West of Portugal.
- Tiago Braga — CUMFISH, get involved as a volunteer!
- Nathalie Marquet — The reproductive cycle of the sea cucumber *Holothuria arguinensis* in the Algarve (Southern Portugal): Preliminary results.
- Julian Olaya — Ecology of *Holothuria arguinensis*: Estimation of population parameters and relation with subtrate types.
- Chiara Magliozzi — The analysis of the ecological niche of *Holothuria arguinensis* for conservation purposes.
- Jorge Domínguez — Sea cucumbers: New perspectives for Integrated multi-trophic aquaculture (SECUIMTA).
- Matthew Slater — Integrated aquaculture research with sea cucumbers in Europe, Africa and Oceania.
- Colin Hannon — Developing sea cucumber aquaculture: Spawning and larval rearing of *Holothuria forskali*.

Visit to the field laboratory at Ramahete

Workshop participants.

Visit to the Ramahete laboratory: Participants looking at *Holothuria arguinensis*.

4) Meeting summary, co-hosted by the governments of Fiji, Tonga and Republic of the Marshall Islands: Pacific beche-de-mer and the future of coastal fisheries, Nadi, Fiji, 6–8 August 2014

Communicated by A. Lovatelli, Alessandro.Lovatelli@fao.org; S.W. Purcell, steven.purcell@scu.edu.au; C. Conand, conand@univ-reunion.fr; and H. Govan, hgovan@gmail.com.

The Pacific Islands region is reaching a critical point in the management of its coastal fisheries, especially sea cucumbers. Coastal fisheries are the lifeblood of coastal communities, underpinning subsistence and livelihoods across the region. Sea cucumbers have been fished in the Pacific Islands as a subsistence food and export commodity for more than 150 years (Conand 1990; Kinch et al. 2008). For many Pacific Island nations and countless communities, sea cucumbers are the most valuable invertebrate fishery. To coin the words of an ex-director of the SPC Fisheries Division, if sea cucumber fisheries cannot be managed properly, there is little hope for other coastal fisheries. Sadly, management of most sea cucumber fisheries of Pacific Islands has been failing miserably.

The past decade has seen overfishing force the hand of fishery managers to close the largest sea cucumber fisheries in the Pacific Islands: Papua New Guinea and Solomon Islands. Sea cucumber fisheries in Vanuatu and Tonga have also been closed for many years due to depletion of stocks (Pakoa and Bertram 2013). Of the few countries that have not yet had moratoria on fishing, Fiji and Kiribati, have seen stocks dwindle to worrying levels. Smaller sea cucumber fisheries in the Pacific are experiencing intense pressure to exploit resources and face increasing incidence of illegal fishing (Pakoa and Bertram 2013).

In addition, ten sea cucumber species from Pacific waters were recently listed on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species as vulnerable or endangered (Conand et al. 2014). This recent listing shows that biodiversity loss is an additional threat to declining catches and weakened fishery productivity. The reality is that the management measures and approaches used in Pacific Island sea cucumber fisheries have been insufficient, and often inappropriate.

In response to the urgent need for improved approaches to managing sea cucumber fisheries, a meeting of ministers was held in Fiji in 2014, organised by IUCN. The meeting aims were as follows:

- to obtain a common understanding of status and socio-economic benefits of sea cucumber fisheries and other coastal fisheries to Pacific Island countries, and the urgent need to take action;
- to discuss constraints and opportunities to collectively and effectively address threats and challenges to sea cucumber fisheries and coastal fisheries management; and
- to obtain political will and ministerial-level commitments to an effective national and regional approach to sea cucumber fisheries and coastal fisheries management that can better support actions at the national and local levels.

The following key statements were given:

- Economically, sea cucumber fisheries are the second-most important of fisheries in the region in economic terms, after tuna, and provide around USD 50 million per year to coastal communities trading the dried products (beche-de-mer) to Asian markets.
- Harvesting of sea cucumbers is still widely unregulated and unsafe, with people diving at depth without appropriate diving equipment or certification. This jeopardises the health of individuals, in extreme cases causing death.
- Shifting to sustainable management of these resources has been the main topic of discussion at the *Pacific Beche-de-mer and the Future of Coastal Fisheries* meeting in Nadi, Fiji. It aimed at building collective will in the region in managing these resources appropriately, so that they remain available for future generations.
- Regional fisheries meetings in the Pacific have predominantly focussed on tuna but local coastal communities depend on inshore fisheries, which are increasingly under threat.
- Shortcomings needing to be addressed are the inadequate allocation of resources for management at all levels, lack of political will to approve new management measures and weak community-based management.

A few potential solutions and ideas were generated during the discussions, drawing on presentations and also inputs from researchers and recent projects (Carleton et al. 2013; Purcell et al. 2014):

- Implementation of a regional certification or branding scheme for products that have been grown or fished sustainably. Pressure would then be placed on the consumption end of the market to encourage the purchase of certified beche-de-mer.
- Creation of a region-wide database of beche-de-mer export companies, and blacklisting companies that encourage unsustainable practices. Conversely, companies could also be white-listed if they support sustainable management of the resources.
- Sharing of regional information on pricing, to ensure that countries and communities are receiving their rightful economic return for their resources.
- Regional training courses on specific marketing aspects to ensure that countries have the expertise to manage the value chain, including the acquisition of proper processing techniques.
- Coordination of fishing seasons and moratoria across the region, so that any trade outside of the fishing season would be illegal, without the need to identify its origin.

During the meeting, the Australian Government announced it would be providing important funding to the Secretariat of the Pacific Community (SPC) to provide Pacific Island countries with science-based technical support and information for the sustainable management and conservation of their coastal fisheries.

At the conclusion of the meeting, the ministers representing Cook Islands, Fiji, Marshall Islands, Papua New Guinea, Samoa, Tonga and Vanuatu signed an agreement calling for action on threats to beche-de-mer and other coastal fisheries in the region. The key elements of the agreement included:

i. taking political leadership and urgent action to implement more robust coastal fisheries management regimes at a national and sub-national level by ensuring that effective, practical and enforceable policies are in place and are implemented, targeting essential capacity at national and sub-national levels, reviewing budgetary commitments and strengthening coordination of implementing partners;
ii. harmonising the regional framework for coastal fisheries, including the role of current regional and international institutions, agencies and NGOs to promote collaboration and integration in order to ensure that countries receive strong, coordinated and effective support on coastal fisheries management;
iii. improving structures and processes for sharing data and information on buyers, markets and best practices at a regional level, with SPC and interested partners; targeting research on opportunities and market mechanisms that will improve the value of beche-de-mer to Pacific Island nations and other areas to improve knowledge and management of sea cucumbers; and
iv. having a follow-up coastal fisheries ministerial meeting in 2015.

We recall that the Food and Agriculture Organization of the United Nations (FAO) in coordination with SPC, ACIAR and Southern Cross University organised a training workshop on sea cucumber fisheries management for many Pacific Island nations in 2011 (FAO 2012; Purcell et al. 2014). We hope that those efforts will help the countries implement their agreement, also taking into account the guidance provided in the publication synthesising the workshop results (Purcell et al. 2014).

References

Carleton C., Hambrey J., Govan H. and Medley P. 2013. Effective management of sea cucumber fisheries and the beche-de-mer trade in Melanesia: Bringing the industry under rational control. A report prepared by Nautilus Consultants on Behalf of the Secretariat of the Pacific Community (SPC).

Conand C. 1990. The fishery resources of Pacific island countries. Part 2. Holothurians. FAO Fisheries Technical Paper No. 272.2. Rome, Italy: Food and Agriculture Organization of the United Nations. 143 p.

Conand C., Polidoro B.A., Mercier A., Gamboa R.U., Hamel J.-F. and Purcell S.W. 2014. The IUCN Red List assessment of aspidochirotid sea cucumbers and its implications. SPC Beche-de-mer Information Bulletin 34:3–7.

FAO. 2012. Report on the FAO Workshop on Sea Cucumber Fisheries: An Ecosystem Approach to Management in the Pacific (SCEAM Pacific). Nadi, Fiji, 15–18 November 2011. FAO Fisheries and Aquaculture Report. No. 1003. Rome, Italy: Food and Agriculture Organization of the United Nations. 43 p.

Kinch J., Purcell S., Uthicke S. and Friedman K. 2008. Population status, fisheries and trade of sea cucumbers in the Western Pacific. p. 7–55. In: Toral-Granda V., Lovatelli A. and Vasconcellos M. (eds). Sea cucumbers: A global review on fisheries and trade. FAO Fisheries Technical Paper No. 516. Rome, Italy: Food and Agriculture Organization of the United Nations. 317 p.

Pakoa K. and Bertram I. 2013. Management state of Pacific sea cucumber fisheries. SPC Beche-de-mer Information Bulletin 33:49–52.

Purcell S.W., Lovatelli A. and Pakoa K. 2014. Constraints and solutions to managing Pacific sea cucumber fisheries with an ecosystem approach. Marine Policy 45:240–250.

5) Latin American and Caribbean countries meet to discuss how to improve the management and sustainability of the exploitation of sea cucumber, Havana, Cuba, 30 April 2014

Communicated by A. Lovatelli.

Over 50 experts from 14 countries met in Havana, Cuba, to share experiences and move forward on the sustainable management of sea cucumber exploitation. The situation of sea cucumber fisheries in the region was presented, paying special attention to the fact that the sea cucumber trade is the driver of over-exploitation and is usually carried out illegally. The geographical development of the sea cucumber trade and its expansion from an area closer to the main consuming markets (namely China) to other producing regions was addressed. The Caribbean was noted as the last region remaining to develop trade. However, in the last two years, this region has also been reached by international traders, resulting in sea cucumber over-exploitation. Given the sedentary nature and life-history characteristics of the species make sea cucumber vulnerable to overexploitation. The importance of developing management plans that are appropriate to the capacity of the responsible agency and the role of enforcement were underscored as the key drivers of sustainability.

The recent developments of sea cucumber aquaculture were presented. In particular, the challenges faced by aquaculture facilities, the possibilities for multi-species aquaculture and the need to set realistic goals before venturing into sea cucumber aquaculture in the Caribbean were addressed.

Finally, the workshop adopted the "Resolution on sea cucumber fisheries management and aquaculture", which will be submitted to WECAFC for its consideration. This resolution recommends the following:

i. biological research on the life cycle characteristics and the reproductive biology of the commercially interesting species, including size at sexual maturity, longevity, recruitment and growth rate;
ii. development of aquaculture technologies of native species applying a precautionary approach;
iii. study of the socio-economic aspects of the fishing communities and the stakeholders in the value chain;
iv. monitoring the sea cucumber fisheries and combating illegal fishing and trade;
v. research on the development of new products, including pharmaceutical uses, and the utilisation of by-products;
vi. marketing research and monitoring of international sea cucumber trade dynamics;
vii. strengthening the monitoring and controls by international, regional, national and local authorities;
viii. preparation and implementation of management plans applying the ecosystem approach on fisheries; and
ix. data collection on captures, prices, processing and foreign trade;
x. capacity building on all the above mentioned topics;
xi. joint coordination of the efforts in the framework of WECAFC; and
xii. identification of funding from governments, regional and international organisations, for the implementation of effective actions on the points of this resolution.

Group photo of participants of the workshop.

6) Portugal CUMFISH: Mares Conference on Marine Ecosystems Health and Conservation, Olhão, Portugal, 17–21 November 2014

Posters on sea cucumbers

- Domínguez-Godino J.A., Slater M., Serrão E.A., González-Wangüemert M. — Seagrass as new potential food resource for sea cucumber aquaculture.
- González-Wangüemert M., Aydin M., Maggi C., Valente, S., Conand C. — Sea cucumbers in the Mediterranean Sea: Effects of their fishery on growth and genetic structure.

- Valente S., Borrero-Pérez G., Serrão E.A., González-Wangüemert M. — Genetic patterns and growth parameters of two new target sea cucumber species of the Mediterranean Sea fishery.
- González-Wangüemert M., Cánovas F., Valente S., Henriques F., Rodrigues F., Maggi C., Erzini K., Gonçalves J., Serrão E., Conand C. — CUMFISH project. Sea CUcumbers: the new resource for a hungry FISHery.

7) Lionfish and sea cucumber workshop, Havana, Cuba, 29–30 April 2014

http://www.infopesca.org/content/taller-sobre-pez-le%C3%B3n-y-pepino-de-mar-0#Publicaciones%20y%20materiales

8) Second International Training Courses on marine molecular taxonomy, Mostaganem, Algeria, 18–25 October 2014

Prepared by Abdelouahab Chouikhi, Inter-Islamic Science and Technology Network on Oceanography, Izmir, Turkey; and Karim Mezali, University of Abdelhamid Ibn Badis, Mostaganem, Algeria

The courses included many practical and theorical examples about sea cucumbers developed by invited speakers: Ahmed S. Tandar, Alexander Kerr and Igor Eeckhaut.

Meetings 2015

1) BEM Society — 44th Annual Benthic Ecology Meeting, Quebec City, Canada, 4–8 March 2015

Registration: 15 January 2015, http://www.bemsociety.org/

2) Aquaculture 2015 — Cutting Edge Science in Aquaculture, Montpellier, France, 23–26 August 2015

www.aquaculture-conference.com

3) ICCB and ECCB, Montpellier, France, 2–6 August 2015

Registration: 1 December 2014, http://iccb-eccb2015.org/content/about-meeting

4) Progress in Echinoderm Palaeobiology, 2015 (PEP´15) in honour of Dr Andrew B. Smith, Zaragoza, Spain, 14–21 June 2015

5) Ninth WIOMSA Scientific Symposium, Durban, South Africa, 26–29 October 2015

WIOMSA secretariat (secretary@wiomsa.org) for more details

6) IEC Mexico 2015, Playa del Carmen, Mexico, May 25–29 May 2015

Contact: Francisco A. Solís-Marín, iec15th@gmail.com

7) China Fisheries and Seafood Expo, Qingdao, China, 4–6 November 2015

http://www.chinaseafoodexpo.com/

Movies on sea cucumbers

1) L'or noir du Pacifique

Film makers: Dominique Roberjot / Christine Della-Maggiora (Communicated by C. Conand)

Beche-de-mer or holothurians are not generally well known. It is, nevertheless, the second largest fishery export product of South Pacific after tuna. They have been fished since the 19th century for Asian markets. Recently, with the economic growth of China, the demand has been so high that several countries in the Pacific have over-exploited their resources. In New Caledonia several initiatives are under way to protect the beche-de-mer, ensure sustainable exploitation for the fishermen and protect the health of the lagoons. This film The black gold of the Pacific will help to discover issues around this strange animal, from New Caledonia to Vanuatu, through Hong-Kong and Fiji.

52 min.; Format HD 1920 x 1080; Sound AIFF; Documentary; All public; Beche-de-mer; Original language French, English, Chinese, Bislama, Fijian; Subtitles French; Production year 2014, New Caledonia (France); Producing society: Latitude 21 Pacific, 1768 rue du pic Kou, la Coulée, 98809 Mont-Dore, Nouvelle-Calédonie, Phone: +687 446827 or +687 504938; Distributed by Latitude 21 Pacific; First TV diffusion on NC 1ère in March 2014; Non-commercial diffusion by IRD Calédonie, Service des pêches de la province Nord de Nouvelle-Calédonie; Selected at Festival Les ÉCRANS DE LA MER 2014. The film was presented on October 11th at Marseille, Palais Longchamp (France) for "La fête de la Science" and commented on by C. Conand, on behalf of IRD.

2) Massive antibiotics use found in sea cucumber farming

CRJ English.com (Communicated by S. Purcell)

A media article about antibiotics use in aquaculture of sea cucumbers in China.

http://english.cri.cn/12394/2014/09/10/3781s843618.htm

3) Hunt for sea cucumber leads to black market

CCTV America on Youtube

New video about the sea cucumber fishery on the Yucatán, Mexico. Nicely filmed and tells a good story from the perspective of the fishers. https://www.youtube.com/watch?v=XUWtMZpBov4

Books

1. The sea cucumber *Apostichopus japonicus*: History, biology and aquaculture

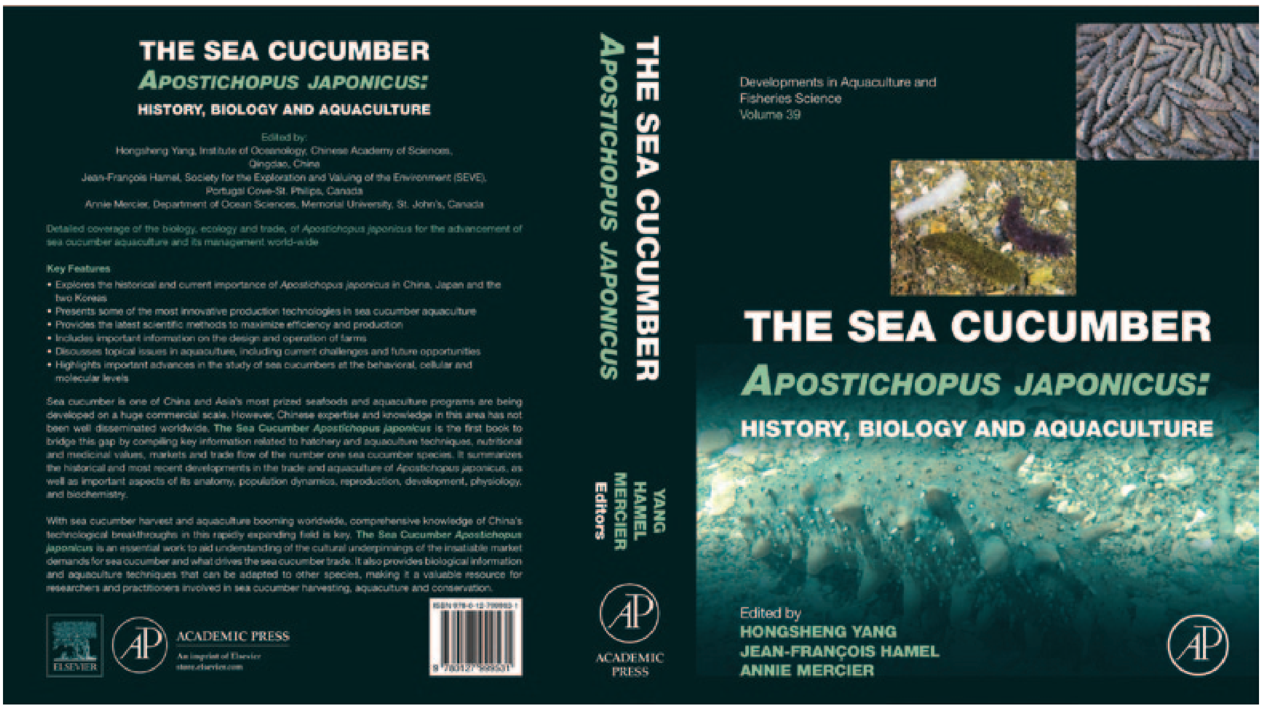
Yang H., Hamel J.-F. and Mercier A.

2015 – Academic Press. 454 p.

Included chapters:

1. Yang H. and Bai Y. 2015. Chapter 1. *Apostichopus japonicus* in the life of Chinese people. p. 1–23. In: Yang H., Hamel J.-F. and Mercier A. (eds.). The sea cucumber *Apostichopus japonicus*: History, biology and aquaculture. Academic Press. 454 p.
2. Liu G., Sun J. and Liu S. 2015. Chapter 2. From fisheries toward aquaculture. p. 25–36. In: Yang H., Hamel J.-F. and Mercier A. (eds.). The sea cucumber *Apostichopus japonicus*: History, biology and aquaculture. Academic Press. 454 p.
3. Zhao H. 2015. Chapter 3. Taxonomy and identification. p. 37–52. In: Yang H., Hamel J.-F. and Mercier A. (eds.). The sea cucumber *Apostichopus japonicus*: History, biology and aquaculture. Academic Press. 454 p.
4. Gao F. and Yang H. 2015. Chapter 4. Anatomy. p. 53–76. In: Yang H., Hamel J.-F. and Mercier A. (eds.). The sea cucumber *Apostichopus japonicus*: History, biology and aquaculture. Academic Press. 454 p.
5. Liu J. 2015. Chapter 5. Spatial distribution, population structures, management, and conservation. p. 77–86. In: Yang H., Hamel J.-F. and Mercier A. (eds.). The sea cucumber *Apostichopus japonicus*: History, biology and aquaculture. Academic Press. 454 p.
6. Wang Q., Zhang T., Hamel J.-F. and Mercier A. 2015. Chapter 6. Reproductive biology. p. 87–100. In: Yang H., Hamel J.-F. and Mercier A. (eds.). The sea cucumber *Apostichopus japonicus*: History, biology and aquaculture. Academic Press. 454 p.
7. Liu S., Sun J., Ru X., Hamel J.-F. and Mercier A. 2015. Chapter 7. Broodstock conditioning and spawning. p. 101–110. In: Yang H., Hamel J.-F. and Mercier A. (eds.). The sea cucumber *Apostichopus japonicus*: History, biology and aquaculture. Academic Press. 454 p.
8. Qiu T., Zhang T., Hamel J.-F. and Mercier A. 2015. Chapter 8. Development, settlement, and post-settlement growth. p. 111–132. In: Yang H., Hamel J.-F. and Mercier A. (eds.). The sea cucumber *Apostichopus japonicus*: History, biology and aquaculture. Academic Press. 454 p.
9. Zhang L., Pan Y. and Song H. 2015. Chapter 9. Environmental drivers of behaviour. p. 133–152. In: Yang H., Hamel J.-F. and Mercier A. (eds.). The sea cucumber *Apostichopus japonicus*: History, biology and aquaculture. Academic Press. 454 p.
10. Xu Q., Hamel J.-F. and Mercier A. 2015. Chapter 10. Feeding, digestion, nutritional physiology, and bioenergetic. p. 153–176. In: Yang H., Hamel J.-F. and Mercier A. (eds.). The sea cucumber *Apostichopus japonicus*: History, biology and aquaculture. Academic Press. 454 p.
11. Wang T., Sun L. and Chen M. 2015. Chapter 11. Aestivation and regeneration. p. 177–210. In: Yang H., Hamel J.-F. and Mercier A. (eds.). The sea cucumber *Apostichopus japonicus*: History, biology and aquaculture. Academic Press. 454 p.
12. Zhao H., Chen M. and Yang H. 2015. Chapter 12. Albinism. p. 211–228. In: Yang H., Hamel J.-F. and Mercier A. (eds.). The sea cucumber *Apostichopus japonicus*: History, biology and aquaculture. Academic Press. 454 p.
13. Gao F. and Yang H. 2015. Chapter 13. Tissue biochemistry. p. 229–241. In: Yang H., Hamel J.-F. and Mercier A. (eds.). The sea cucumber *Apostichopus japonicus*: History, biology and aquaculture. Academic Press. 454 p.

14. Yu Z., Yang H., Hamel J.-F. and Mercier A. 2015. Chapter 14. Larval, juvenile, and adult predators. p. 243–256. In: Yang H., Hamel J.-F. and Mercier A. (eds.). The sea cucumber *Apostichopus japonicus*: History, biology and aquaculture. Academic Press. 454 p.
15. Chen M., Wang F., Xing K., Zhu A. and Zhang S. 2015. Chapter 15. Immunology and diseases. p. 257–287. In: Yang H., Hamel J.-F. and Mercier A. (eds.). The sea cucumber *Apostichopus japonicus*: History, biology and aquaculture. Academic Press. 454 p.
16. Zhang L., Song X., Hamel J.-F. and Mercier A. 2015. Chapter 16. Aquaculture, stock enhancement, and restocking. p. 289–322. In: Yang H., Hamel J.-F. and Mercier A. (eds.). The sea cucumber *Apostichopus japonicus*: History, biology and aquaculture. Academic Press. 454 p.
17. Yuan X., Zhou Y. and Mao Y. 2015. Chapter 17. *Apostichopus japonicus*: A key species in integrated polyculture systems. p. 323–332. In: Yang H., Hamel J.-F. and Mercier A. (eds.). The sea cucumber *Apostichopus japonicus*: History, biology and aquaculture. Academic Press. 454 p.
18. Lin C. and Zhang L. 2015. Chapter 18. Habitat enhancement and rehabilitation. p. 333–352. In: Yang H., Hamel J.-F. and Mercier A. (eds.). The sea cucumber *Apostichopus japonicus*: History, biology and aquaculture. Academic Press. 454 p.
19. Xia S. and Wang X. 2015. Chapter 19. Nutritional and medicinal value. p. 353–366. In: Yang H., Hamel J.-F. and Mercier A. (eds.). The sea cucumber *Apostichopus japonicus*: History, biology and aquaculture. Academic Press. 454 p.
20. Mao Y., Huang Y. and Liu Q. 2015. Chapter 20. Processing and cuisine. p. 367–382. In: Yang H., Hamel J.-F. and Mercier A. (eds.). The sea cucumber *Apostichopus japonicus*: History, biology and aquaculture. Academic Press. 454 p.
21. Xu D., Su L. and Zhao P. 2015. Chapter 21. *Apostichopus japonicus* in the worldwide production and trade of sea cucumbers. p. 383–398. In: Yang H., Hamel J.-F. and Mercier A. (eds.). The sea cucumber *Apostichopus japonicus*: History, biology and aquaculture. Academic Press. 454 p.
22. Akamine J. 2015. Chapter 22. *Apostichipus japonicus*: Fisheries, trade and foodways in Japan. p. 399–422. In: Yang H., Hamel J.-F. and Mercier A. (eds.). The sea cucumber *Apostichopus japonicus*: History, biology and aquaculture. Academic Press. 454 p.
23. Park S., Hong S., Yoon I. and Lovatelli, A. 2015. Chapter 23. *Apostichopus japonicus*: "Dolgi Haesam" in the Republic of Korea (South Korea). p. 423–432. In: Yang H., Hamel J.-F. and Mercier A. (eds.). The sea cucumber *Apostichopus japonicus*: History, biology and aquaculture. Academic Press. 454 p.
24. Yong Ho J., Lovatelli A. and Hamel J.-F. 2015. Chapter 24. *Apostichopus japonicus* in the Democratic People's Republic of Korea. p. 433–438. In: Yang H., Hamel J.-F. and Mercier A. (eds.). The sea cucumber *Apostichopus japonicus*: History, biology and aquaculture. Academic Press. 454 p.



2. ACIAR project produces book, training video and village-based workshops on sea cucumber processing

Sea cucumbers are one of the most important fishery resources for Pacific Island fishers. Critical issues facing sea cucumber fisheries are the poor quality of postharvest processing by fishers, and inadequate or ineffective management frameworks, enforcement and governance. Recent initiatives are focussing on reforming fisheries management but need to progress in tandem with improved postharvest processing if fishers are expected to harvest less yet still earn sufficient income for their families.

A four-year project funded by the Australian Centre for International Agricultural Research (ACIAR) began in 2013 with the overall goal: *to improve the income of village fishers in Kiribati, Tonga and Fiji through support to improve the quality of postharvest processing of sea cucumbers*. The researchable questions concern evidence of economic and sociological impacts to small-scale fishers.

The primary outputs comprise the following:

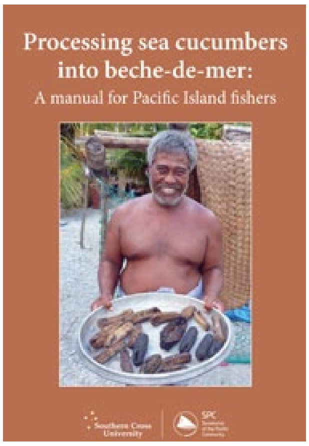
i. a village-level manual and training DVD on processing methods, translated into local languages;

ii. training workshops for fisheries officers and village fishers in postharvest processing; and

iii. a quantitative analysis of economic and livelihood impacts.

The manual on processing sea cucumbers was produced in English, Fijian, Tongan and Kiribati. These versions can be downloaded at: http://aciar.gov.au/publication/cop026. Hard copies are available on request.

Purcell S.W. 2014. Processing sea cucumbers into beche-de-mer: A manual for Pacific Island fishers. Southern Cross University, Lismore, and the Secretariat of the Pacific Community, Noumea. 44 p.



The training video has been produced in English, and the three island language versions are being finalised. A limited number of DVD copies will be distributed. The video versions will be available from the ACIAR website and can also be accessed from YouTube: https://www.youtube.com/watch?v=P4KdY68ktsk.

The village-based training workshops are currently being rolled out by the project collaborators in Fiji, Tonga and Kiribati. These comprise a one-day hands-on workshop with fishers to demonstrate all methods of processing various species of sea cucumber, and a short follow-up session a couple of days later.

The research will provide proof-of-concept of impacts for future investments in similar interventions in other countries. The impact testing will also show whether such support to fishers results in them spending more time on value-adding of wild captures and less time fishing — thus, indirect impacts on resource sustainability.

The project is led by Southern Cross University, and carried out in collaboration with Partners in Community Development Fiji, the Ministry of Agriculture and Food, Forests and Fisheries Tonga, the Ministry of Fisheries and Marine Resources Development Kiribati, James Cook University and the Secretariat of the Pacific Community.

Village-based training workshops on postharvest processing in Fiji (left), Tonga (centre), and Kiribati (right).

Scientific articles

Bahrami Y., Zhang W., Franco C. 2014. Discovery of novel saponins from the viscera of the sea cucumber *Holothuria lessoni*. Marine Drugs 12(5):2633–2667.

Bahrami Y., Zhang W., Chataway T. and Franco C. 2014. Structural elucidation of novel saponins in the sea cucumber *Holothuria lessoni*. Marine Drugs 12(8):4439–4473.

Díaz-Balzac C.A., Vázquez-Figueroa L.D. and García-Arrarás J.E. 2014. Novel markers identify nervous system components of the holothurian nervous system. Invertebrate Neuroscience 14(2):113–125.

Dolmatov I.Y. 2014. New data on asexual reproduction, autotomy, and regeneration in holothurians of the Order Dendrochirotida. Russian Journal of Marine Biology 40(3):228–232.

Eriksson H., de la Torre-Castro M., Purcell S.W. and Olsson P. 2014. Lessons for resource conservation from two contrasting small-scale fisheries. Ambio. doi:10.1007/s13280-014-0552-5.

González-Wangüemert M., Aydin M. and Conand C. 2014. Assessment of sea cucumber populations from the Aegean Sea (Turkey): First insights to sustainable management of new fisheries. Ocean and Coastal Management 92:87–94.

González-Wanguemert M., Valente S. and Aydin M. 2015. Effects of fishery protection on growth and genetic structure of two target sea cucumber species from the Mediterranean Sea. Hydrobiologia 743:65–74.

Jinadasa B.K.K.K., Samanthi R.I. and Wicramsinghe I. 2014. Trace metal accumulation in tissue of sea cucumber species; North-Western Sea of Sri Lanka. American Journal of Public Health Research 2(5A):1–5.

Jontila J.B.S., Balisco R.A.T. and Matillano J.A. 2014. The sea cucumbers (Holothuroidea) of Palawan, Philippines. AACL Bioflux 7(3)194–206.

Kazanidis G., Tyler P.A. and Billett D.S.M. 2014. On the reproduction of the simultaneous hermaphrodite *Paroriza prouhoi* (Holothuroidea: Synallactidae) in the Porcupine Abyssal Plain, north-east Atlantic. Journal of the Marine Biological Association of the United Kingdom 94(4):847–856.

Kim S.W., Miller A.K., Brunson C., Netchy K., Clouse R.M., Janies D., Tardy E. and Kerr A.M. 2014. Shallow-Water Holothuroids (Echinodermata) of Yap, Federated States of Micronesia. Pacific Science 68(3):397–420.

Lane D.J.W. and Limbong D. 2014. Catastrophic depletion of reef-associated sea cucumbers: Resource management / reef resilience issues for an Indonesian marine park and the wider Indo-Pacific. Aquatic Conservation: Marine and Freshwater Ecosystems. doi: 10.1002/aqc.2421.

Martinez M.I., Solís-Marín F.A. and Penchaszadeh P.E. 2014. *Benthodytes violeta*, a new species of a deep-sea holothuroid (Elasipodida: Psychropotidae) from Mar del Plata Canyon (south-western Atlantic Ocean). Zootaxa 3760(1):89–95.

Massin C., Robar-Matheson A., Hamel J.-F. and Mercier A. 2014. First records of *Thyone inermis* and *Labidoplax buskii* (Echinodermata, Holothuroidea) in Canadian waters. Marine Biodiversity Records 7:1–5.

Mercier A. and Hamel J.-F. 2015. Lunar periods in the annual reproductive cycles of marine invertebrates from cold subtidal and deep-sea environments. p. 99–120. In: Numata H. and Helm B. (eds). Annual, lunar and tidal clocks: Patterns and mechanisms of nature's enigmatic rhythms. Japan: Springer. 360 p.

Mezali K. and Thandar A. 2014. First record of *Holothuria* (*Roweothuria*) *arguinensis* (Echinodermata: Holothuroidea: Aspidochirotida: Holothuriidae) from the Algerian coastal waters. Marine Biodiversity Records. doi:10.1017/S175526721400043.

Michonneau F. and Paulay G. 2014. Revision of the genus *Phyrella* (Holothuroidea: Dendrochirotida) with the description of a new species from Guam. Zootaxa 3760:101–140.

Navarro P.G., García-Sanz S. and Tuya F. 2014. Contrasting displacement of the sea cucumber *Holothuria arguinensis* between adjacent nearshore habitats. Journal of Experimental Marine Biology and Ecology 453:123–130.

Prata J., Pereira Dias T.L. and Christoffersen M.L. 2014. Occurrence of *Holothuria* (*Holothuria*) *dakarensis* (Holothuroidea: Echinodermata) in the south-western Atlantic, with notes on distribution and ecology. Marine Biodiversity Records. doi:10.1017/S1755267214000049.

Purcell S.W., Lovatelli A. and Pakoa K. 2014. Constraints and solutions to managing Pacific sea cucumber fisheries with an ecosystem approach. Marine Policy 45:240–250.

Purcell S.W., Polidoro B.A., Hamel J.-F., Gamboa R. and Mercier A. 2014. The cost of being valuable: Predictors of extinction risk in marine invertebrates exploited as luxury seafood. Proceedings of the Royal Society B: Biological Sciences. doi: 10.1098/rspb.2013.3296.

Purcell S.W. 2014. Value, market preferences and trade of beche-de-mer from Pacific Island sea cucumbers. PLoS One 9: e95075.

Purcell S.W. and Eriksson H. 2014. Echinoderms piggybacking on sea cucumbers: Benign effects on sediment turnover and movement of hosts. Marine Biology Research. doi:10.1080/17451000.2014.962544.

Rowe M.l., Achhala S., Maurice R. and Elphick M.R. 2014. Neuropeptides and polypeptide hormones in echinoderms: New insights from analysis of the transcriptome of the sea cucumber *Apostichopus japonicus*. General and Comparative Endocrinology 197:43–55.

Skewes T., Plagányi É., Murphy N., Pascual R. and Fischer M. 2014. Evaluating rotational harvest strategies for sea cucumber fisheries. Brisbane, Australia: Commonwealth Scientific and Industrial Research Organisation. 176 p.

Smirnov A.V. 2014. Sea cucumbers symmetry (Echinodermata: Holothuroidea). Paleontological Journal 48(12): 1215–1236.

Solis-Marin F.A., Komatsu M., Soliman T., Uchida K., Shimotani T. and Nozaki M. 2014. *Scoliorhapis dianthus*, a new species of sea cucumber (Apodida: Chiridotidae) from the Sea of Japan. Proceedings of the Biological Society of Washington 127(2):323–327.

Valente S., Serrao E.A. and Gonzalez-Wanguemert M. 2014. West versus East Mediterranean Sea: Origin and genetic differentiation of the sea cucumber *Holothuria polii*. Marine Ecology. doi:10.1111/maec.12156.

Xia J., Zhang I., Yu Z., Chen T. and Hu C. 2014. First record of *Holothuria* (*Theelothuria*) *notabilis* (Holothuroidea: Aspidochirotida) from the Beibu Gulf: Northward range expansion in the South China Sea. Marine Biodiversity Records. doi:10.1017/S1755267214001067.

Wamukota A., Brewer T.D. and Crona B. 2014. Market integration and its relation to income distribution and inequality among fishers and traders: The case of two small-scale Kenyan reef fisheries. Marine Policy 48:93–101.

Ziegler A., Mirantsev G.V., Jangoux M. and Kroh A. 2014. Historical aspects of meetings, publication series, and digital resources dedicated to echinoderms. Zoosystematics and Evolution 90(1):45–56.

PhD Thesis

Michonneau F. 2014. Species limit and diversity in sea cucumber (Echinodermata Holothuroidea). PhD Thesis, University of Florida. 163 p.Plotieau T., Baele J.-M., Vaucher R., Hasler C.-A., Koudad D. and Eeckhaut I. 2013. Analysis of the impact of *Holothuria scabra* intensive farming on sediment. Cahiers de Biologie Marine 54:703–711.

Masters Thesis

Miller A.K. 2014. The Higher-Level Systematics of Holothuroidea: A Six-Gene Approach. Masters Thesis, University of Guam. 120 p.

Maggi C. 2013. Population and genetic structure of *Parastichopus regalis* (Cuvier, 1817) and its commensal *Carapus acus* (Brünnich, 1768). Masters Thesis, CCMAR, Universidade do Algarve (Portugal) and Universita' Politechnica delle Marche (Italy). 95 p.

Olaya Restrepo J. 2014. Ecology of *Holothuria arguinensis*: Estimation of population parameters and relation with substrates types. Masters Thesis, CCMAR, Universidade do Algarve (Portugal). 60 p.

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