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Editor

Igor Eeckhaut
Marine Biology and bioimitation
6, Av. Champ de Mars
University of Mons
7000 Mons Belgium
Email: Igor.Eeckhaut@umons.ac.be

Production

Fisheries Information Section
SPC, BP D5, 98848 Noumea Cedex
New Caledonia
Fax: +687 263818
Email: cfpinfo@spc.int
www.spc.int/coastfish

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Editorial

The 34th issue of the Beche-de-mer Information Bulletin includes, as always, a considerable amount of information on the biology, ecology and bio-management of sea cucumbers.

In the first article, Chantal Conand and co-authors describe the process used and the results obtained in an assessment of sea cucumber species for the International Union for Conservation of Nature (IUCN) Red List; 16 threatened species, out of 377 known aspidochirotidids examined, are presented.

The second article comes from Fiji. Watisoni Lalavanua and colleagues undertook a sea cucumber assessment survey in Batiki District in October 2012. The results indicate that the sea cucumber fishery there is under stress from overexploitation and requires effective management.

Pablo Navarro and co-authors provide some information on beche-de-mer activities at Pulau Misa, a small island in Indonesia's Flores Sea. The people from Pulau Misa carry out a semi-traditional sea cucumber fishery.

Katrin Lampe-Ramdoe and colleagues assessed holothurian diversity, abundance and distribution in the shallow lagoons of Mauritius. The authors surveyed many transects at various sites and recorded more than 7,000 holothurians, three-quarters of which are of commercial importance.

Maevel Romero and Jérôme Cabansag present some data about the diversity and sexual maturity of sea cucumbers in the mangroves of Babatngon in Leyte Province, Philippines. They identified five species, some of them characterised through gonad measurements.

Plotieau and co-authors characterised the mineral and organic features of the sediment in sea pens where *Holothuria scabra* individuals were farmed. They analysed the total organic carbon fraction, the abundance of five minerals and several organic parameters of the sediment in four villages in Madagascar.

Belbachir and colleagues assessed the selective feeding behaviour of four aspidochirotid holothurians: *Holothuria sanctori*, *H. forskali*, *H. poli* and *H. tubulosa*. The results show that some species are more selective than others.

Mercedes González-Wangüemert and colleagues assessed the occurrence of *Carapus acus* in six sea cucumber species from the Mediterranean Sea and northeastern Atlantic Ocean. They provide some new insights into the relationship between the fish and their holothurian hosts.

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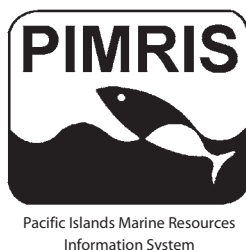
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Chantal Conand and co-authors present 2012 beche-de-mer trade statistics from Hong Kong, Peru, Fiji, USA and Yemen appear to be huge producers. Steve Purcell and co-authors also expose a range of “new” product forms for tropical sea cucumbers from a variety of locations.

A list of the Western Indian Ocean Marine Science Association presentations on holothurians, new books and future conferences are presented at the end of this issue. Ajith Kumara informs us about a recent training workshop on artificial breeding and larval rearing of *Holothuria scabra* in Sri Lanka, Jean Ruffez reports that sea cucumber harvesting still kills scuba divers, and Alexandre Ziegler provides a history of the Beche-de-mer Information Bulletin, and various authors report on natural breeding and juvenile observations.

Igor Eeckhaut

PIMRIS is a joint project of five international organisations concerned with fisheries and marine resource development in the Pacific Islands region. The project is executed by the Secretariat of the Pacific Community (SPC), the Pacific Islands Forum Fisheries Agency (FFA), the University of the South Pacific (USP) and the Pacific Regional Environment Programme (SPREP). This bulletin is produced by SPC as part of its commitment to PIMRIS. The aim of PIMRIS is to improve the availability of information



on marine resources to users in the region, so as to support their rational development and management. PIMRIS activities include: the active collection, cataloguing and archiving of technical documents, especially ephemera ('grey literature'); evaluation, repackaging and dissemination of information; provision of literature searches, question-and-answer services and bibliographic support; and assistance with the development of in-country reference collections and databases on marine resources.

The IUCN Red List assessment of aspidochirotid sea cucumbers and its implications

Chantal Conand^{1,}, Beth Polidoro², Annie Mercier³,
Ruth Gamboa⁴, Jean-François Hamel⁵ and Steve Purcell⁶*

Abstract

This article presents the results from the assessment of sea cucumbers in the order Aspidochirotida for the International Union for Conservation of Nature (IUCN) Red List of threatened species. The results were published by IUCN in June 2013. Of 377 species examined, 16 were classified as threatened with extinction (7 as endangered, 9 as vulnerable) based on standard IUCN methodology. We also summarise findings from a recent publication about the drivers of extinction risk in these sea cucumbers. The IUCN listing sends a stern message to resource managers for the conservation of threatened species. The IUCN Red List may also serve to guide future evaluation by CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora) for listing some of the species on Appendix II or III in order to set conditions on the trade of those species. We discuss some issues of CITES listing for the Philippines, as a “hotspot” country, and recommend that sea cucumbers should be re-evaluated for listing on CITES Appendix II and III.

Introduction

Sea cucumbers were once considered a marginal invertebrate marine resource and only recently shown to be significant to global trade, livelihoods and marine ecosystems. Correspondingly, they have been the subject of increased worldwide interest for scientific knowledge, sustainable use and conservation purposes (Lovatelli et al. 2004; Bruckner 2006; Toral-Granda et al. 2008; Purcell et al. 2013).

Unlike the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the International Union for Conservation of Nature (IUCN) Red List is not a multilateral political agreement and does not impose trade or other conservation conditions on countries and states. However, the scientific process of conducting standardised and systematic species extinction risk assessments for the IUCN Red List is often subsequently used as an information tool for conservation planning within countries, and can serve as a guide for CITES listing. The IUCN Red List Categories and Criteria are the most widely

accepted system for classifying extinction risk at the species level. This article explains the IUCN Red List categories and the process of conducting species assessments, as well as presents the species now listed as threatened and the implications of this conservation tool.

An IUCN Red List workshop on sea cucumbers in the order Aspidochirotida (Echinodermata: Holothuroidea) was held in Cartagena, Colombia from 17–21 May 2010 (see details in Polidoro et al. 2011). The workshop brought together regional and international scientific experts to assess, for the first time, the conservation status and probability of extinction for all aspidochirotid species by applying the assessment methodology of the IUCN Red List Categories and Criteria (IUCN 2001; 2013).

IUCN Red List methodology

The IUCN Red List Criteria are standardised quantitative tools to determine each species' probability of extinction, expressed as a Red List category. IUCN Red List methodology is the most widely accepted standard for determining

¹ Ecomar Laboratory, La Reunion University and MNHN, Paris, France

² International Union for the Conservation of Nature (IUCN) Marine Biodiversity Unit, Old Dominion University, Norfolk VA, 23529-0266, USA

³ Department of Ocean Sciences, Memorial University, St. John's NL, A1C 5S7, Canada

⁴ College of Science and Mathematics, University of the Philippines Mindanao, Mintal, Davao City 8022, Philippines

⁵ Society for the Exploration and Valuing of the Environment (SEVE), Portugal Cove-St. Philips NL, A1M 2B7, Canada

⁶ National Marine Science Centre, Southern Cross University, Coffs Harbour NSW 2450, Australia

* Corresponding author: conand@univ-reunion.fr

the impact of threats on species populations and conservation status. The IUCN Red List assessment process strives to provide the most up-to-date, peer-reviewed assessment of each species. For this reason, IUCN Red List assessments for complete taxonomic clades rely on extensive collaboration with scientific experts around the world. The process involves intensive species-specific data collection, review and updating of data (at least one workshop), subsequent external reviews and validation by experts, and several internal Red List consistency checks before publication on the IUCN Red List of Threatened Species (www.iucnredlist.org).

There are eight IUCN Red List categories: Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC) and Data Deficient (DD).

A species qualifies for one of the three threatened categories (CR, EN, or VU) by meeting the threshold for that category for any one of five criteria (A–E). These are summarised as follows:

Criterion A — population decline (thresholds: 30% for VU, 50% for EN, and 80% for CR) over a timeframe of more than 10 years or three generations.

Criterion B — small geographic range size (extent of occurrence < 20,000 km² or area of occupancy < 2,000 km² to meet the lowest threshold for VU) combined with continued decline and habitat fragmentation.

Criterion C — species with small population sizes, estimated to be less than 10,000 mature individuals, with continued decline.

Criterion D — species with less than 1,000 mature individuals, or those with an area of occupancy < 20 km², or those that are found in less than 5 locations as defined by a threat.

Criterion E — species with extensive population information that allows for population declines to be appropriately modelled over time.

The category NT is assigned to species that come close to but do not fully meet all the thresholds or conditions required for a threatened category under any criterion, and the category LC is assigned if a species does not meet or come close to meeting any of the thresholds required of a threatened category. A species is listed as DD if there are insufficient data (e.g. on population declines or geographic range) to apply the Red List Criteria. This can apply to species that need taxonomic clarification, or that are only known from a few specimens or the holotype, as was the case for the majority of Aspidochirotida in this category. In some cases, relatively well-known species are listed

as DD when significant threats are known but cannot be adequately quantified (IUCN 2013).

The order Aspidochirotida contains most of the sea cucumber species that are under threat from commercial exploitation. To conduct IUCN Red List assessments for all 377 known species in this order, data were compiled on each species' taxonomy, distribution, population trends, ecology, life history, past and existing threats, and conservation actions. The final comprehensive list of Aspidochirotida species was based primarily on species listed as valid on the World Register of Marine Species (www.marinespecies.org) as of December 2012, with subsequent refinement by taxonomic experts (Yves Samyn, pers. comm. 2012; Francisco Solis-Marin, pers. comm. 2012). Some species were omitted from the assessment, including a few that are commercially exploited in multiple countries (Purcell et al. 2012), because they were known only by common names and not yet described taxonomically (e.g. *Holothuria* spp. type "pentard"). We also note that there are other commercially important sea cucumber species (such as those in the family Cucumariidae, order Dendrochirotida) that were excluded in this taxonomically based assessment. The majority of Aspidochirotida species that met the threshold for a threatened category were assessed under Criterion A (Purcell et al. 2014). All maps of geographic ranges and related analyses (ecoregion, depth) were conducted in ArcGIS (v. 10.0), as detailed in Purcell et al. 2014.

Red List assessment results

In June 2013, the IUCN Red List for aspidochirotid holothuroids was published. The complete list of species along with each species' individual assessment account, or report, with all supporting data and references used for the assessment can be found by typing "Aspidochirotida" in the search term at the following site: <http://www.iucnredlist.org/search>

The search can be refined by Assessment, and selecting those Vulnerable and Endangered. The full assessment information can be found by clicking on the species names, and each species' digital distribution map can be found by clicking on the map icon. Additionally, the complete list of the 377 species assessed and other supporting information can be found in the supplemental online materials in Purcell et al. 2014.

Seven species were classified as "Endangered, or at a high risk of extinction", and nine species were classified as "Vulnerable, or at risk of extinction" (Table 1).

Table 1. Species listed as “Endangered, or at a high risk of extinction”, or “Vulnerable, or at risk of extinction”.

	Scientific name	English common name	IUCN status	Population trend
Endangered, or at a high risk of extinction				
1	<i>Apostichopus japonicus</i>	Japanese spiky sea cucumber	Endangered A2bd ver 3.1	Decreasing
2	<i>Holothuria lessoni</i>	Golden sandfish	Endangered A2bd ver 3.1	Decreasing
3	<i>Holothuria nobilis</i>	Black teatfish [Indian Ocean]	Endangered A2bd ver 3.1	Decreasing
4	<i>Holothuria scabra</i>	Sandfish	Endangered A2bd ver 3.1	Decreasing
5	<i>Holothuria whitmaei</i>	Black teatfish [Pacific, SE Asia]	Endangered A2bd ver 3.1	Decreasing
6	<i>Isostichopus fuscus</i>	Brown sea cucumber	Endangered A2bd ver 3.1	Decreasing
7	<i>Thelenota ananas</i>	Prickly redfish	Endangered A2bd ver 3.1	Decreasing
Vulnerable, or at risk of extinction				
1	<i>Actinopyga echinites</i>	Deepwater redfish	Vulnerable A2bd ver 3.1	Decreasing
2	<i>Actinopyga mauritiana</i>	Surf redfish	Vulnerable A2bd ver 3.1	Decreasing
3	<i>Actinopyga miliaris</i>	Hairy blackfish	Vulnerable A2bd ver 3.1	Decreasing
4	<i>Apostichopus parvimensis</i>	Warty sea cucumber	Vulnerable A2bd ver 3.1	Stable
5	<i>Bohadschia maculisparsa</i>		Vulnerable D2 ver 3.1	Unknown
6	<i>Holothuria arenacava</i>		Vulnerable D2 ver 3.1	Unknown
7	<i>Holothuria fuscogilva</i>	White teatfish	Vulnerable A2bd ver 3.1	Decreasing
8	<i>Holothuria platei</i>		Vulnerable D2 ver 3.1	Unknown
9	<i>Stichopus hermanni</i>	Curryfish	Vulnerable A2bd ver 3.1	Decreasing

Discussion

A recently published paper “The cost of being valuable: Predictors of extinction risk in marine invertebrates exploited as luxury seafood” (Purcell et al. 2014) used the Red List assessment results in conjunction with other data to assess various factors that could explain why some species are currently under threat. That study found that the main driver of extinction risk was high market value; in other words, high-value species face the greatest risk of extinction. Other important drivers were a shallow depth of occurrence, large geographic range, high human populations and poor economies in species’ distribution range. That paper contains important electronic supplementary materials, such as the list of the 377 species examined, and details on data for factors used in the analyses.

It emerges that high-value species, particularly those living in shallow waters, urgently need rigorous regulatory measures for their exploitation. Because species-specific bans do not prevent serial depletion of other species further down the value chain, it might be advisable to set a shortlist of allowable species, which excludes threatened species and those important for ecosystem functions, and to implement capacity and effort limitations (e.g. short fishing seasons). These measures will be challenging to enforce because developing countries, where

average per capita incomes are low, have many threatened species to manage (i.e. threats to biodiversity loss are most severe where capacity is weakest to manage them). International support (e.g. CITES listings) would be helpful but will require increasing research and capacity building in “conservation hotspots”, including countries in the western Indian Ocean and Coral Triangle, that exhibit a combination of dense human populations, coastal poverty and a high number of threatened sea cucumber species (Purcell et al. 2014).

The Philippines is a conservation hotspot and offers an example of some of the challenges for implementing trade agreements such as CITES. The Philippines has 11 of the 16 threatened aspidochirotid species, all of which are caught and traded by small-scale fishers, in open-access, unregulated fishing grounds. Listing of these 11 species in CITES Appendix II or III would need to consider the flow-on effects to fisher livelihoods and would likely be met with resistance by middlemen and traders. The Department of Agriculture — Bureau of Fisheries is presently working to implement minimum legal size limits for dried beche-de-mer. In addition, the Philippines has invested in developing technology to culture sandfish (*Holothuria scabra*) (Gamboa et al. 2012) and release them in the wild for sea ranching, and stock restoration is explored (Juinio-Menez et al. 2013). Those initiatives to improve management

and recover stocks may help towards conservation and could be preferable to international trade restrictions. However, without strong enforcement and other regulatory measures, the effectiveness of size limits and restocking in safeguarding species from extirpation (local extinction) is rather questionable (Purcell et al. 2013).

While some endangered species are now being successfully raised in captivity, aquaculture does not necessarily safeguard extinction in the wild, unless explicit restoration measures are implemented. This is exemplified by intensive aquaculture production and sea ranching of *Apostichopus japonicus* in China, which has apparently not resulted in the recovery of wild populations (Purcell et al. 2014). The recent IUCN Red List assessment may offer advocacy for restocking programmes that aim to recover depleted wild populations because this is now a global conservation issue for many of the threatened species. Certain countries may move to require regulated permits for the collection of broodstock of threatened species for aquaculture programmes, and certification that exports are from cultured stocks.

Regional consultations and/or agreements among countries are now needed, given the geographical distribution of commercial species. International trade regulations have to take these results into account; species listed as Endangered should probably be listed on CITES Appendix II and those as Vulnerable should at least be on Appendix III. In the past, listing sea cucumber species on CITES has been encumbered by a deficiency of information tools to identify species in trade and some uncertainties regarding taxonomy and biology; these limitations, however, have been largely addressed in recent years. As only one species is presently listed in Appendix III, it is hoped that scientists will be given the opportunity to collaborate on a new process of CITES listing to conserve populations and species at risk.

In conclusion, the Red List classifications of sea cucumbers serve as a tool for biodiversity conservation and resource management. Fishing pressure on sea cucumber populations has been extraordinarily intense in recent decades across much of the world (Toral-Granda et al. 2008; Purcell et al. 2013), placing species and coastal livelihoods at risk. Preserving both into the future will ultimately depend on concerted local level regulatory measures by resource managers and international support.

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The status of the sea cucumber fishery in Batiki District, Lomaiviti, Fiji

Watisoni Lalavanua^{1,*}, Ilisoni Tuinasavusavu¹ and Peni Seru¹

Abstract

The paper aims at assessing the status of sea cucumber stocks around Batiki District in eastern Fiji in order to provide communities with information about stock status and advice on whether to impose a ban on sea cucumber harvesting. In total, 99 specimens from 12 species were recorded during the assessment. The results of the survey indicate that the sea cucumber fishery in Batiki District is under stress or threat from overexploitation and requires effective management.

Introduction

Coastal communities in many Pacific Island countries and territories derive significant cash income from the harvesting of sea cucumbers and their transformation to the tradeable product beche-de-mer. Fiji is the third largest beche-de-mer producer in the Pacific Islands region although the real economic value of the region's sea cucumber fishery is likely to be underestimated (currently thought to be around USD 45 million), due to a lack of information.

The sea cucumber industry is an old trade in the Pacific, replacing the sandalwood trade in the early 1900s and later becoming Fiji's major export (FTIB 2009). It is also the Pacific's most valuable coastal fishery, second only to oceanic tuna fisheries. The number of sea cucumber species decreases from west to east across the Pacific, following the general trend of biodiversity in this region. Most Pacific Island countries and territories that live along the coast rely on this fishery as one of their major sources of incomes (Ram et al. 2008). Unfortunately, sea cucumber stocks have been overfished in many countries as a result of ever-increasing market demand, uncontrolled exploitation, inadequate fisheries management arrangements, and/or a lack of enforcement of regulations.

According to Conand (1989), of the 1,400 sea cucumber species known worldwide, 24–35 species are commercially exploited and 28 species are found in Fiji. The beche-de-mer industry in Fiji has undergone some major changes since 1813. From a small industry producing 20–30 tonnes of dried product a year, annual production rose dramatically

in 1984, and in 1988 total production was about 665 tonnes. Unfortunately, this increase in production was accompanied by a sharp decrease of the final product value. For example Preston (1993) reports that 33 tonnes of dried sea cucumber sold in 1983 for FJD 394,800 (or FJD 11,963 per tonne), while the 1988 production of 665 tonnes sold for FJD 1,850,800 (or FJD 2,783 per tonne) (Preston 1990).

Sea cucumbers are generally collected by hand while free diving or reef gleaning at low tide. The use of underwater breathing apparatus (UBA) such as scuba and hookah gear has made the task of collecting deeper dwelling sea cucumbers much easier. The use of this type of equipment significantly increases the likelihood of localised overharvesting, while the uncontrolled introduction of hookah and scuba to village fishers puts villagers at considerable personal risk of the "bends" or death. According to Ward (1972), as early as 1834, sea cucumber populations were considered depleted on reefs of western, central and northern Vanua Levu and south-eastern Viti Levu.

Management measures have also undergone some major changes over the past three decades. In 1984, the Fiji Cabinet approved the recommendation that the Fiji Fisheries Department regulate the beche-de-mer fishery. Soon after, a "Beche-de-mer Exploitation Guideline" was produced, which outlined that the harvesting and processing of sea cucumber products should be restricted to Fijian nationals; the use of scuba gear for the collection of beche-de-mer be forbidden; and no size limits were necessary because prices varied with size and smaller individuals were neither collected nor commonly seen (Lewis 1985).

¹ Partners in Community Development Fiji

* Corresponding author: wlalavanua@pcdf.org.fj

According to Adams (1993), the banning of scuba in the guideline did not apply to hookah and this contributed to a new exploitation boom in 1991. The guideline was then revised in 1988 when the Cabinet legislated to prevent the export of any beche-de-mer less than 7.6 cm (3 in) in length in any form and also banned the export of all *dairo* (*Holothuria scabra*) in any form unless permission was granted from the Minister for Agriculture, Fisheries and Forestry. *Dairo*'s export was prohibited because it was a source of traditional food (Adams 1993). In Fiji, *dairo* and, to a lesser extent, *vula* (*Bohadschia vitiensis*) and *mudra* (*B. similis*) are the main sea cucumber species consumed by Fijians in large quantities, and can be important emergency food sources in time of hardship (Adams 1992). *Dairo* is eaten fresh, marinated in lemon juice and salt, or cooked in coconut milk.

Partners in Community Development Fiji (PCDF) submitted an official request to the Secretariat of the Pacific Community (SPC) in May 2012 to improve PCDF's capacity in coastal invertebrate resource assessments and to assist with the development of Fiji's national sea cucumber management arrangements and governance structure for the effective management of the fishery. Following capacity building actions organised by SPC for PCDF and the Fiji Fisheries Department in the districts of Kubulau and Bua (August/September 2012) in Bua Province, PCDF conducted sea cucumber resource assessments in Batiki District using the assessment methods recommended by SPC. The present report is based on the assessment survey undertaken in Batiki District in October 2012. PCDF staff and the communities of Batiki District worked together to assess the status of sea cucumber stocks around Batiki in order to provide communities with information about stock status and advice about whether to impose a ban on sea cucumber harvests.

Batiki — The setting

Batiki Island is a district in the Lomaiviti archipelago in eastern Fiji, and is an administrative unit of Lomaiviti Province. Batiki has a total land area of

12 km² and consists of four villages, which include Mua as the chiefly residence of the "Toranibau", Yavu, Manuku and Naigani. Villagers' main source of income is from pandanus (*voivoi*), copra, fishing and small-scale farming. There is a primary school on the island that caters to approximately 50 students and 4 teachers, and also a nursing station administered by a registered nurse. Transportation out of the island is mainly by fibreglass boat or franchise cargo vessel.

Batiki has a large interior lagoon of brackish water flanked by mud flats. A broad barrier reef surrounds Batiki with a channel in Nakasava on the north side of the island. A small portion of the coastal area is covered by mangroves, mainly in Wainiketei Bay. The island's beche-de-mer fishery mainly involves male youths. Most of them transport their sea cucumbers to Suva on a weekly basis.

Materials and methods

The diversity and abundance of invertebrate species in Batiki District, including sea cucumbers, were determined with a broad-scale assessment (using a manta tow) and a fine-scale assessment of shallow water environments (using the reef benthos transect method, or RBt). The sea cucumber assessment team dived for approximately two weeks in Batiki and collated a wide-ranging series of data to determine sea cucumber distribution and density. The assessment was also designed to determine the effectiveness of the village marine protected area (MPA). In total, 2.04 ha were surveyed within the MPA and 3.12 ha were surveyed in non-MPA sites (Table 1). Because the total area surveyed in non-MPA sites was higher, the number of stations for manta tows was likewise higher in non-MPA sites ($n = 8$) than in MPA sites ($n = 5$). However, the same number of stations ($n = 10$) was used for the fine-scale assessment (RBt) of MPA and non-MPA sites.

Manta tow surveys were done to assess large sedentary invertebrates and habitats. A surveyor held onto a manta board that was towed behind a boat travelling at slow speeds of less than 2.5 km per hour. Manta tow stations were positioned

Table 1. Total area surveyed in the Batiki marine protected area (MPA) and non-marine protected area sites (non-MPA).

Sites	Survey type	No. of stations	No. of replicates	Area (m ²)	Area (ha)	Total area covered (ha)
MPA	Manta tow	5	30	18,000	1.80	2.04
	Reef benthos transect	10	60	2,400	0.24	
Non-MPA	Manta tow	8	48	28,800	2.88	3.12
	Reef benthos transect	10	60	2,400	0.24	
Total area covered (ha)						5.16

along the inner fringing reefs within the lagoon reefs and along back-reefs. Manta tow surveys were conducted in depths of 1 m to less than 10 m of water but mostly around 1.5–6.0 m, covering coral and sand substrates, and the edges of reefs. Each transect was 300 m long and 2 m wide along reef contours and habitats of interest on lagoon reefs. Transect length was calibrated using the odometer function within the “trip computer” option of a global positioning system (GPS) unit or equivalent. Waypoints were recorded at the start and end of each transect to an accuracy of within 10 m. The surveyor recorded the number of large sedentary invertebrates observed along the transect within a 2-m swath. Any invertebrates observed were recorded during the tow, and habitat records were made at the end of each tow. Hand counters were used to assist with enumerating commonly observed species.

Fine-scale RBt surveys were conducted on hard bottom habitats on back-reefs, reef flats and reef crest areas to capture invertebrates associated with those habitats. RBt assessments gave greater accuracy by assessing the range, abundance, size and condition of invertebrate species and their habitat at smaller spatial scales within fishing areas and areas of aggregated stocks. RBt assessments could also be conducted along the reef crest at low tide by walking and using the GPS odometer function to measure transect length. In this instance, transects were laid along the reef to assess species such as surf redfish, trochus and turbo shells. Surveys were conducted within six transects that were 40 m long and 1 m wide. Observations were made by snorkelling or by

walking at low tide. Species and habitat data were recorded, and a single waypoint was logged for each station (to an accuracy of ≤ 10 m).

Data were entered into the Reef Fisheries Integrated Database (RFID) developed by the Secretariat of the Pacific Community. RFID has pre-set queries to extract summaries of information on species composition, density and population size structure. Densities were compared with regional reference densities determined by SPC. These densities are used for comparison because Fiji does not have sea cucumber reference densities. This comparison allows greater insight into the stock status for some sea cucumbers species at Batiki.

RFID can provide information to determine population size structure, which can be extrapolated to biomass if size and weight information are collected during in-water assessments. Population size structure provides an indication of the condition of stocks, which enables an understanding of the proportion of stocks at different life stages and what proportion may be fished.

Results

Species survey

In total, 93 specimens from 11 species were recorded during the assessment. *Bohadschia argus*, *Pearsonothuria graeffei*, *Holothuria atra* and *Stichopus chloronotus* were recorded in both MPA and non-MPA sites (Table 2). In comparison, during the marine resource inventory made by the Fiji Fisheries Department in 2010, 34 specimens from 5 species of sea cucumber had been recorded.

Stichopus chloronotus was the most recorded species followed by *Holothuria atra* (Table 3). Both were mainly found on back-reefs and reef flats. Most of the specimens recorded were found near the main channel in Nakasava.

One specimen of *Holothuria scabra* (sandfish, or *dairo*) was recorded during a search in Wainiketei Bay. This is the bay where the local community usually collects sandfish for subsistence use. The size of the sandfish found was 250 mm, and according to locals it was smaller than those they usually collect.

Table 2. Species recorded from Batiki marine protected area (MPA) sites and from non-MPA sites using different survey methods.

Site	Species	Manta tow	Reef benthos transect
MPA	<i>Actinopyga miliaris</i>		+
	<i>Bohadschia argus</i>		+
	<i>Pearsonothuria graeffei</i>	+	
	<i>Bohadschia vitiensis</i>		+
	<i>Holothuria atra</i>	+	+
	<i>Holothuria whitmaei</i>		+
	<i>Stichopus chloronotus</i>	+	+
Non-MPA	<i>Bohadschia argus</i>	+	
	<i>Pearsonothuria graeffei</i>		+
	<i>Holothuria atra</i>	+	+
	<i>Holothuria edulis</i>	+	+
	<i>Holothuria fuscogilva</i>	+	
	<i>Holothuria fuscopunctata</i>	+	
	<i>Stichopus chloronotus</i>	+	+
<i>Thelenota ananas</i>	+		

Table 3. Number of specimens recorded.

Scientific name	Common name	Specimens recorded
<i>Stichopus chloronotus</i>	Greenfish	58
<i>Holothuria atra</i>	Lollyfish	18
<i>Bohadschia argus</i>	Tigerfish	6
<i>Bohadschia vitiensis</i>	Brown sandfish	4
<i>Holothuria edulis</i>	Pinkfish	4
<i>Pearsonothuria graeffei</i>	Flowerfish	2
<i>Holothuria whitmaei</i>	Black teatfish	2
<i>Holothuria fuscogilva</i>	White teatfish	1
<i>Holothuria fuscopunctata</i>	Elephant trunkfish	1
<i>Actinopyga miliaris</i>	Blackfish	1
<i>Thelenota ananas</i>	Prickly redfish	1
<i>Holothuria scabra</i> *	Sandfish	1

* *Holothuria scabra* was not recorded from any transect but was found during searches at Wainiketei Bay.

Sea cucumber densities

The density of greenfish (*S. chloronotus*) from RBt assessments was the highest (45.83 ind. ha⁻¹ ± 14.78 [SE]) of all sea cucumber species, and was found in 40% of all stations (Table 4). The density of *S. chloronotus* in Batiki, however, is far below the regional reference density of 3,500 ind. ha⁻¹. Lollyfish (*Holothuria atra*) and tigerfish (*Bohadschia argus*) were the second and third most commonly found species, with lollyfish found in densities of 12.50 ind. ha⁻¹ ± 5.32, and in 25% of all stations, and tigerfish found in densities of 10.42 ind. ha⁻¹ ± 7.33, and in 10% of all stations. The densities of both *H. atra* and *B. argus* were well below the regional reference densities of 5,600 ind. ha⁻¹ and 120 ind. ha⁻¹, respectively.

Table 4. Overall density (ind. ha⁻¹) of species for manta tow and reef benthos transects (RBt) completed at Baitiki. Numbers in parentheses indicate standard error.

Species	Overall density		Regional reference density	
	Manta tow	RBt	Manta tow	RBt
<i>Stichopus chloronotus</i>	8.12 (4.56)	45.83 (14.78)	1,000	3,500
<i>Holothuria atra</i>	5.88 (2.77)	12.50 (5.32)	2,400	5,600
<i>Pearsonothuria graeffei</i>	0.64 (0.64)	2.08 (2.08)	50	100
<i>Holothuria edulis</i>	0.64 (0.46)	4.17 (4.17)	250	260
<i>Bohadschia argus</i>	0.53 (0.37)	10.42 (7.33)	50	120
<i>Thelenota ananas</i>	0.32 (0.32)	-	10	30
<i>Holothuria fuscogilva</i>	0.21 (0.21)	-	-	20
<i>Holothuria fuscopunctata</i>	0.21 (0.21)	-	10	10
<i>Holothuria whitmaei</i>	-	4.17 (2.87)	10	50
<i>Actinopyga miliaris</i>	-	2.08 (2.08)	-	150
<i>Bohadschia vitiensis</i>	-	2.08 (2.08)	160	100

Only two species were found in both MPA and non-MPA sites: *S. chloronotus* and *H. atra*, and their densities in each area did not differ significantly (Fig. 1). *B. argus*, *H. whitmaei*, *Actinopyga miliaris* and *B. vitiensis* were only found in MPA sites while *H. edulis* and *Pearsonothuria graeffei* were only found in non-MPA sites.

S. chloronotus was the species found in the highest densities from RBt assessments in both MPA (33.33 ind. ha⁻¹ ± 16.24) and non-MPA (58.33 ind. ha⁻¹ ± 20.03) sites. Some localised aggregations of *S. chloronotus* were found in densities of 400 ind. ha⁻¹ ± 100 as seen in MPA sites and 350 ind. ha⁻¹ ± 66.7 in non-MPA sites.

The next most dominant species in MPA and non-MPA sites from RBt assessments were *B. argus* (20.83 ind. ha⁻¹ ± 10.78) and *H. atra* (12.50 ind. ha⁻¹ ± 7.09). In terms of aggregation, *B. argus* density reached densities of 312.50 ind. ha⁻¹ ± 62.50 and *H. atra* density can be 250 ind. ha⁻¹.

In total, 18 specimens of *H. atra* were measured in Batiki (recoded in both MPA and non-MPA sites) with a minimum size of 55 mm and a maximum size of 325 mm. Most specimens recorded were found in the MPA at Mua village. The mean size recorded was 159 mm. The recorded sizes indicate that the specimens recorded are below the regional common length of 230 mm and most of them are juveniles.

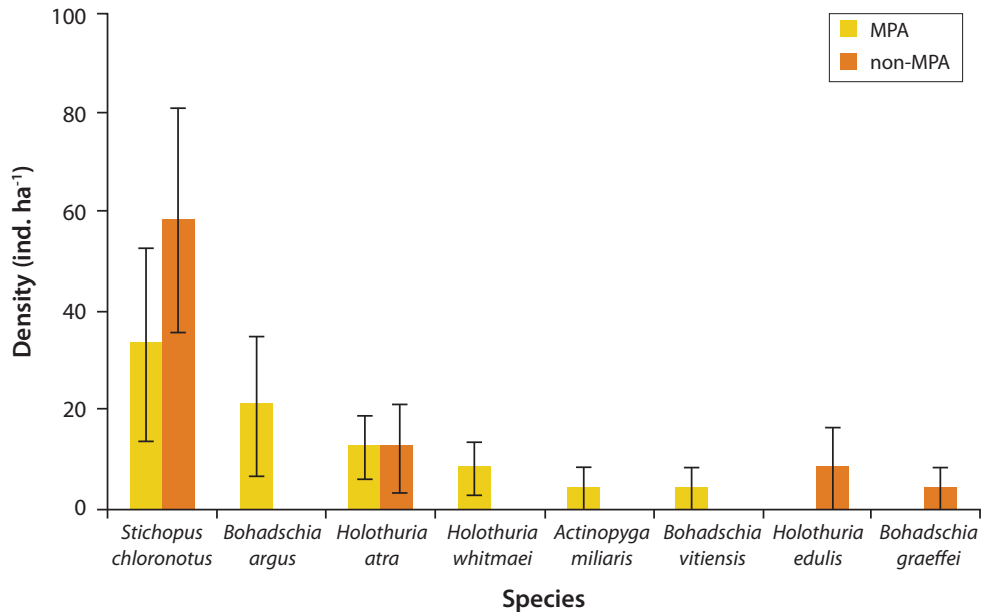


Figure 1. Sea cucumber densities in marine protected area (MPA) and non-MPA sites.

Discussion and conclusion

The results of the survey indicate that the sea cucumber fishery in Batiki is under stress or threat from overexploitation and requires effective management. The density of species present is low in comparison to regional reference densities. The two dominant species, *S. chloronotus* and *H. atra*, are medium- and low-value species, indicating that the fishing pressure applied to high-value species has probably resulted in their very low density. The presence of high-value sea cucumber species (in the reef system and seagrass beds) such as *H. whitmaei* and *H. scabra* indicates that they are still present but their numbers are so low that it will require a long closure of the fishery to allow these species' stocks to recover. If there is no closure, fishers might come across the last large high-value species specimens and harvest them while also harvesting medium- and low-value species.

The population structure also indicates that most specimens are in juvenile stages, which is another reason to recommend a permanent closure of the fishery in Batiki.

According to the survey, there was little difference in sea cucumber stock density between MPA and non-MPA sites. We therefore suspect that fishing activity is occurring in the MPA. During the presentation of preliminary assessment results to communities of Batiki, community members confirmed that poaching was occurring in their respective village

MPA. One of the factors limiting the work of the fish wardens in Batiki in policing their whole *qoliqoli*², and especially their MPA, is that they do not have the equipment — boat, engine and fuel — needed to monitor and control fishing inside the MPA. In addition, past experience of fish wardens shows that their work is difficult and risky because poachers are better equipped than they are, and are sometimes very aggressive. Since fish wardens are volunteers with no compensation at all, this affects their interest in carrying out their duty.

Based on the results of the assessment, the following measures are recommended.

- The sea cucumber fishery in Batiki be closed for a period of five years. After five years of permanent closure, another assessment should be conducted to determine the status of the fishery. If it is healthy, then it should be re-opened using a quota or total allowable catch system.
- The use of underwater breathing apparatus (UBA) to collect sea cucumbers should be prohibited in Batiki. UBA has had serious negative impacts on the health of divers and the fishery itself. Because sea cucumbers are sedentary and 80% of species are found between 0 m and 20 m depths, there is no need to use UBA.
- Night fishing should not be practiced at any time. This is to safeguard against overexploitation of nocturnal species.

² A *qoliqoli* is a customary fishing rights area.

- Wainiketei Bay should be closed to fishing and established as a dedicated sea cucumber marine protected area because this is the only site in Batiki where high-value species of *H. scabra* can be found. In future assessments, a dedicated survey of *H. scabra* should be made in Wainiketei Bay to better understand its status.

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An Indonesian sea cucumber fishing village: The case of Pulau Misa

Pablo G. Navarro^{1,*}, Sara García-Sanz² and Chantal Conand³

Abstract

Small traditional sea cucumber fishing villages are abundant throughout Indonesia but information about their activity is not always available. Pulau Misa is a small island in eastern Nusa Tenggara whose inhabitants perform one-day trips to capture sea cucumbers by free diving. Processing the animals is done on the island by the women from the community. At least eight species were identified during our visit although most of the animals were already dried, which made identification very difficult. Data about the community's total sea cucumber catches are not available. In Indonesia, the lack of specific management plans along with the difficulty of studying small remote fishing areas may lead to an underestimation of total sea cucumber annual catches. The study of small fisheries like the one at Pulau Misa is crucial for the conservation of natural sea cucumber populations.

Introduction

Sea cucumbers have been fished for more than 500 years in Indonesia, which is currently considered to be the world's main beche-de-mer (or *trepan*) producer and exporter (Conand 1990; Tuwo and Conand 1992; Conand and Byrne 1993; Purcell et al. 2013). Despite this fact, there is no clear sea cucumber management strategy (Choo 2008; Purcell et al. 2013) and many of the traditional fisheries carried out by small communities are not yet well documented. One of the main reasons for this lack of information is the difficulty of studying the fisheries throughout such a vast country of 8.3 million km², 17,508 islands and 81,000 km of coastline (Tuwo 2004). Some of the commercial sea cucumber species exploited in Indonesia are *Actinopyga echinites*, *A. mauritiana*, *A. miliaris*, *Bohadschia argus*, *B. vitiensis*, *Holothuria atra*, *H. edulis*, *H. fuscogilva*, *H. fuscopunctata*, *H. whitmaei*, *H. scabra*, *H. lessoni*, *H. coluber*, *Stichopus chloronotus*, *S. herrmanni*, *Thelenota ananas* and *T. anax* (Tuwo 2004). Indonesia's traditional sea cucumber fisheries are essentially carried out by two techniques: 1) with large boats, where approximately 10 fishers stay away for months, capture the animals with the help of diving equipment, process the sea cucumbers aboard and finally sell them in the nearest village; and 2) with small boats, where fishers, usually 2–4, perform one day trips and process the sea cucumbers when they return home (Tuwo and Conand 1992). Although some studies have been carried out in the

field, there is still a lack of information about the current number of active sea cucumber fisheries in the country, where are they based, and what species they focus on. So far, much of the field studies have been focused on the fisheries of Sulawesi Island (Conand and Tuwo 1996; Moore 1998; Massin 1999; Tuwo 1999) and Lombok Island (Purwati 2006) but little is known about fisheries in other areas of Indonesia. The present paper provides information on beche-de-mer activities at Pulau Misa, a small island with a fishing village located between Komodo, Rinca and Flores islands, in the Flores Sea, in eastern Nusa Tenggara, Indonesia (Fig. 1).

The case of Pulau Misa

We visited Pulau Misa in November 2011. The island has approximately 600–800 inhabitants whose main income comes from beche-de-mer (or *trepan* as it is called in Malaysia), although they also fish for abalone (Pet 1997) and lobsters (pers. obs.). The people from Pulau Misa carry out a semi-traditional sea cucumber fishery on small boats, collect the sea cucumbers by free diving and hookah, and process them the same day as they return to the island. The women eviscerate the sea cucumbers, boil them several times, and finally sun-dry them for a couple of days (depending on the moisture content and size of animals, see Fig. 2). In sun-drying, the sea cucumbers are usually covered and filled with salt (Fig. 3). Some large individuals are dried with a wooden stick across the slit to facilitate the drying of

¹ Viceconsejería de Medioambiente. Gobierno de Canarias. C/ Agustín Millares Carló, 18-5º, 35071, Las Palmas de Gran Canaria, Spain

² BIOGES, Universidad de Las Palmas de Gran Canaria, 35017, Las Palmas de G.C., Spain

³ Laboratoire d'Écologie Marine, Université de La Réunion, P.O. Box 7151, 97715, Saint-Denis, Île de La Réunion

* Corresponding author: pgonnav@gmail.com

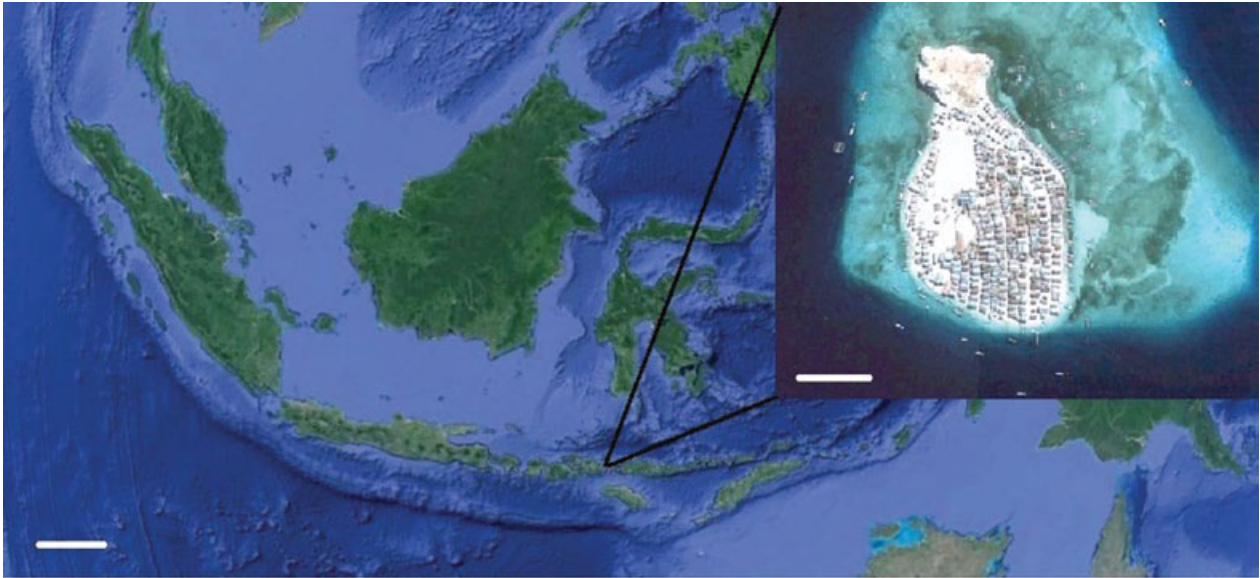


Figure 1. Indonesia and the location of Pulau Misa. Scale bars are 300 km (left) and 100 m (insert map).



Figure 2. Women processing sea cucumbers at Pulau Misa.



Figure 3. Sun-dried individuals of various sea cucumber species.



Figure 4. Size comparison between unprocessed and processed *Stichopus herrmanni*.



Figure 5. Unprocessed individuals of *Stichopus herrmanni* and *Stichopus vastus*.

the interior part of the body. Some species, such as *H. scabra*, *H. sp. aff. arenicola* and *H. sp. aff. notabilis* are peeled with a knife to remove the outer part of the body wall and are later boiled and dried like other sea cucumbers. Although the identification of species becomes particularly difficult once they are processed, with drastic changes to their overall morphology (e.g. size, Fig. 4) we were able to identify

the following species using the method of Purcell et al. (2012): *Stichopus herrmanni* (which was very abundant) (Figs. 4 and 5), *S. vastus*, *Pearsonothuria graeffei*, *Actinopyga lecanora*, *Holothuria pardalis*, *H. whitmaei*, *Bohadschia argus* and *B. marmorata*. In Pulau Misa, all members of the community are involved in the fishery and processing of sea cucumbers. For most of them it constitutes their only source of

income. Future studies should focus on quantifying and identifying the annual catches of Pulau Misa's fishers in order to assess the impact of this fishery on the area, especially taking into account the proximity of Komodo National Park and its unique biodiversity, with more than 1,000 species of fish, 385 species of reef-building corals, 70 species of sponges and 7 species of seagrass (Harvey and Yusamandra 2010).

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An assessment of holothurian diversity, abundance and distribution in the shallow lagoons of Mauritius

Katrin Lampe-Ramdoo¹, Ruby Moothien Pillay² and Chantal Conand³

Abstract

The sea cucumber industry, which is known to be particularly vulnerable to overexploitation and collapse, has been under tremendous pressure in Mauritius since the mid-2000s. Consequently, in 2010, the Ministry of Fisheries imposed a two-year ban on the collection of sea cucumbers, which was later extended for another four years (2012–2016) to avoid the collapse of the fishery. This study collected data on the diversity and abundance of sea cucumbers in the shallow lagoons of Mauritius in order to assist with the sustainable management of the fishery. Previous surveys conducted in 2011 in the lagoons of the south and west coasts of the island revealed the presence of 17 holothurian species. The present study visited some of the earlier study sites as well as some new ones in the north and east coasts to assess sea cucumber abundance and diversity. From March to June 2013, 115 daytime transects at 23 sites (totally 92,000 m² in area) revealed a total of 7,488 holothurians, of which 76% were of commercial importance. The holothurians were distributed within a range of habitats with no significant correlation detected between abundance and habitat types. Holothurian distribution in the shallow lagoons of Mauritius seems to be influenced by physical, biological and anthropogenic factors. The present survey revealed that some species could be recovering from exploitation.

Introduction

The lagoons of Mauritius are impacted by climatic changes and various anthropogenic factors, all of which cause a reduction in habitats for marine organisms and a potential loss of biodiversity (Moothien Pillay et al. 2012). Moreover, the overexploitation of commercially important species is threatening the persistence of the most demanded and high-priced species. The sea cucumber industry, which is vulnerable to overexploitation and collapse, has been under tremendous pressure in Mauritius since the mid-2000s. Surveys carried out in 2010 by the Ministry of Fisheries revealed a decrease in abundance, species diversity and size of sea cucumbers at the surveyed sites when compared with data collected in 2007–2008 (AFRC 2012). As a consequence, a two-year moratorium was imposed on the fishery, and later extended to 2016, to reverse the rapid decline of sea cucumber populations. Because little is known about the ecology of sea cucumbers and the extent of their exploitation in Mauritius, this study was undertaken at a larger scale to assist the Ministry of Fisheries with the sustainable management of this fishery. This study builds on the baseline study that was carried out in

2011 on the abundance, diversity and distribution of holothurian species inhabiting the western and southern shallow lagoons of Mauritius (Lampe 2013). For a more comprehensive understanding of the population dynamics of sea cucumbers around the island, besides the western and southern coasts, the northern and eastern regions were also studied. This was undertaken in light of the history and recent development of the sea cucumber fishery in Mauritius, including non-commercial species.

Materials and methods

Site description

Mauritius is a small island state of volcanic origin located in the western Indian Ocean, approximately 900 km east of Madagascar (Saddul 1995). The island forms part of the Mascarene Archipelago with La Reunion, Rodrigues, St. Brandon and a few other smaller islands. The coastline is surrounded by a fringing reef and includes a lagoon that extends from the near shore to the reef flat and is composed of different zones that are further subdivided, depending on the size of the lagoon, into shore reef, mid-lagoon, back-reef, reef flat and fore reef (Baird et al. 2003).

¹ University of Applied Sciences, Bremen, Neustadtswall 30, 28199 Bremen, Germany (lampe-katrin@gmx.de)

² Mauritius Oceanography Institute, France Centre, Victoria Avenue, Quatre-Bornes, Mauritius (rubykm@moi.intnet.mu)

³ Laboratoire d'Écologie Marine, Université de La Réunion, P.O. Box 7151, 97715, Saint-Denis, Île de La Réunion and MNHN Paris (conand@univ-reunion.fr)

Methodology

From March to June 2013, 115 daytime transects were set within 23 survey sites in the north, west, south and eastern shallow lagoons of Mauritius (Fig. 1a) in a staggered fashion (Fig. 1b). Five belt transects were surveyed by a pair of divers swimming along a 100-m long main transect line with five 20-m long side transect lines (Fig. 1c), thus covering a total area of 4,000 m² per site. Species were identified and measured lengthwise in the relaxed state to the nearest 10 mm. The visibility, depth and temperature of the water were recorded along with currents and occurrences of other invertebrates within the same shallow water habitats. Survey sites were categorised as remote beaches with difficult access, public beaches, and beaches directly in front of hotels that are utilised mostly for tourism activities.

Generally, the collection of holothurians is possible at any of these shallow sites because all beaches in Mauritius are public and accessible⁴.

The percentage cover of the various substrate types (e.g. sand, coral rubble, live coral, dead coral, seagrass, algae and rocks) in each belt transect was recorded. For calculating the dominance and species diversity within the four regions and each of the 23 sites under study, the Shannon-Wiener index (H') (Nentwig et al. 2004) was used.

$$H' = - \sum_{i=1}^R p_i \ln p_i$$

Body wall tissue samples were taken from each species to examine their microscopic skeletal ossicles for identification.

Results

The total surveyed area of 92,000 m² contained 7,488 holothurians, comprising 19 species and one additional genus (*Synapta*) that was not identified to the species level (Table 1). Fourteen species (76% of all individuals) were of commercial value and five species (24% of all individuals) were of

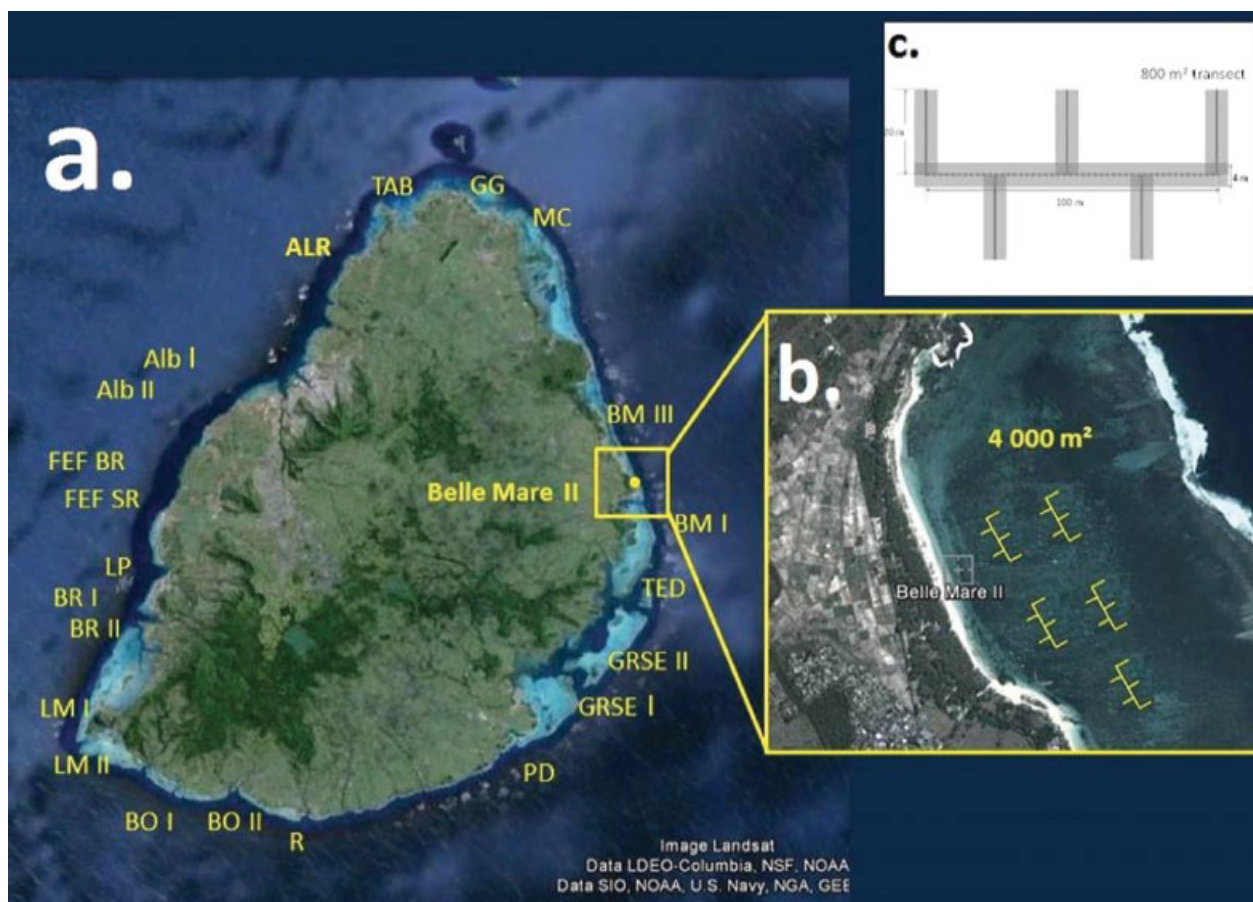


Figure 1. a) The island of Mauritius and the location of the 23 survey sites in the four regions (Google Earth 2013);
 b) five belt transects per site covering a total area of 4,000 m²;
 c) one belt transect comprising five subtransects, covering an area of 800 m².

⁴ <http://beachauthority.intnet.mu/beach-authority-use-of-public-beach-regulations-2004.html>, last access:11.01.2014

Table 1. Total and relative abundance (%) of each holothurian species recorded, ordered from highest to lowest abundance and its occurrence (%) in the 23 survey sites around the island over an area of 92,000 m².

Species	No. of individuals	Relative abundance (%)	Occurrence (%)
<i>Holothuria atra</i>	3,889	51.94	95.65
<i>Synapta</i> spp.	1,836	24.52	78.26
<i>Stichopus chloronotus</i>	881	11.77	56.52
<i>Bohadschia vitiensis</i>	354	4.73	82.61
<i>Holothuria leucospilota</i>	240	3.21	78.26
<i>Holothuria pervicax</i>	115	1.54	43.48
<i>Actinopyga echinites</i>	56	0.75	56.52
<i>Holothuria cinerascens</i>	47	0.63	4.35
<i>Holothuria hilla</i>	18	0.24	17.39
<i>Actinopyga mauritiana</i>	14	0.19	17.39
<i>Bohadschia subrubra</i>	11	0.15	30.43
<i>Holothuria arenicola</i>	10	0.13	8.70
<i>Stichopus monotuberculatus</i>	5	0.07	17.39
<i>Actinopyga capillata</i>	3	0.04	8.70
<i>Stichopus herrmanni</i>	3	0.04	8.70
<i>Bohadschia marmorata</i>	2	0.03	8.70
<i>Holothuria fuscocinerea</i>	2	0.03	8.70
<i>Holothuria nobilis</i>	1	0.01	4.35
<i>Holothuria scabra</i>	1	0.01	4.35
Total	7,488		

no commercial value, including *Synapta* (Table 1). The three most abundant species were *Holothuria atra* (3,889 individuals), individuals from the genus *Synapta* (1,836 individuals) and *Stichopus chloronotus* (881 individuals). The least abundant species were *Holothuria nobilis* and *H. scabra*, both represented by only one individual (Table 1).

H. atra was not only the most abundant species (52%), it was also present at 96% of the sites (Table 1). With 1,836 individuals (representing 25% of all holothurians recorded), holothurians from the genus *Synapta* were the second most abundant species, and were observed in 18 out of the 23 sites surveyed (78% occurrence) (Table 1). *B. vitiensis* was the most frequently encountered species, found in 19 of the 23 sites (83%).

Substrate types

The most common substrate recorded at each site along each transect (4,000 m²) was sand (39%), followed by seagrass (15%) and coral rubble (15%). Areas of algal aggregations accounted for 12% and live coral patches 9%, while rocks and dead coral combined made up 5% of the substrate.

Although the substrate types were highly diverse and patchy within the 23 surveyed sites, sandy

areas were present everywhere, representing at least 15% of the substrate cover composition.

In general, the depth of the surveyed sites ranged from 0.5 m to 2 m, with a temperature ranging from 25°C to 27°C and visibility ranging from 1 m to 10 m. The sites were also characterised by the current strength, as well as the turbulence of the water surface.

Commercial species

Following the commercial value key provided by Conand (2008), the identified holothurians in the current study were classified into four groups, indicating their commercial value: high, medium and low, as well as non-commercial. Among the commercially valuable species, two high-value species, *Holothuria nobilis* and *H. scabra*, were represented by one individual each, four species of medium value were represented by two individuals each, and eight species of low commercial value were represented by three individuals each. The remaining five species were without commercial value. Overall, species of commercial value were more abundant, with a total number of 5,511 individuals (70%), and those of no commercial value, consisted of only 1,977 individuals (30%) (Table 2).

Table 2. Total abundances and densities (ind. 100 m⁻²) of holothurians of high (red), medium (orange), low (yellow) commercial value, and no commercial (light grey) value observed between March and June 2013 in the shallow lagoons of Mauritius.

Species	Total abundance	Density (ind. 100 m ⁻²)
<i>Holothuria nobilis</i>	1	0.00
<i>Holothuria scabra</i>	1	0.00
<i>Actinopyga echinites</i>	56	0.06
<i>Actinopyga mauritiana</i>	14	0.02
<i>Stichopus chloronotus</i>	881	0.96
<i>Stichopus herrmanni</i>	3	0.00
<i>Bohadschia marmorata</i>	2	0.00
<i>Bohadschia subrubra</i>	11	0.01
<i>Bohadschia vitiensis</i>	345	0.38
<i>Holothuria atra</i>	3,898	4.24
<i>Holothuria cinerascens</i>	47	0.05
<i>Holothuria fuscocinerea</i>	2	0.00
<i>Holothuria arenicola</i>	10	0.01
<i>Holothuria leucospilota</i>	240	0.26
Subtotal	5,511	5.99
<i>Actinopyga capillata</i>	3	0.00
<i>Holothuria hilla</i>	18	0.02
<i>Holothuria pervicax</i>	115	0.13
<i>Stichopus monotuberculatus</i>	5	0.01
<i>Synapta</i> spp.	1,836	2.00
Subtotal	1,977	2.15
Total	7,488	8.14

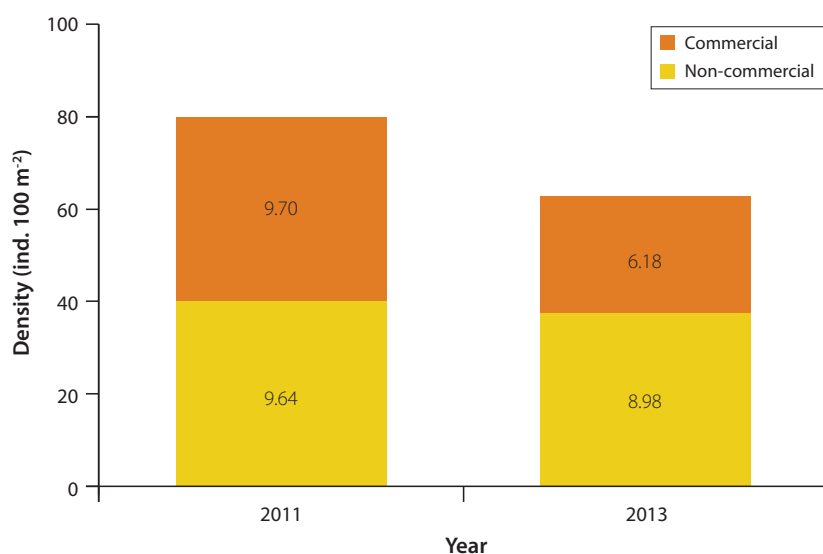


Figure 2. Commercial and non-commercial species' densities (ind. 100 m⁻²) in 2011 compared with 2013.

Species of low commercial value formed the largest group of holothurians assessed in the present study, and consisted mainly of *H. atra* (3,898 ind.) and *B. vitiensis* (345 ind.) (Table 2). Among the species of intermediate value, *Stichopus chloronotus* was the most abundant (881 ind.), followed by *Actinopyga echinites* (56 ind.) (Table 2). Among the species of no commercial value, the genus *Synapta* was most abundant (1,836 with 2 ind. 100 m⁻²), representing more than 80% of the non-commercial value species (Table 2). *H. pervicax* (115 ind.) and *H. hilla* (18 ind.) were among the non-commercial species.

A comparison of these results to those of Lampe (2013) in the western and southern shallow lagoons of Mauritius, shows a decreasing trend in density. Holothurian density (measured as individuals per 100 m²) was 19.33 ind. 100 m⁻² in 2011 and 15.16 ind. 100 m⁻² in 2013 (Fig. 2). The density of species of no commercial value decreased from 9.7 ind. 100 m⁻² in 2011 to 6.18 ind. 100 m⁻² in 2013, and the density of commercially important species from 9.64 ind. 100 m⁻² in 2011 to 8.98 ind. 100 m⁻² in the current study (Fig. 2).

The density of holothurians of medium value increased from 1.44 ind. 100 m⁻² in 2011 to 1.98 ind. 100 m⁻² in 2013, whereas the low value species decreased from 8.19 ind. 100 m⁻² (2011) to 7 ind. 100 m⁻² (2013) (Fig. 3). The density of species of high value did not change considerably (0.008 ind. 100 m⁻² in 2011 and 0.002 ind. 100 m⁻² in 2013) (Fig. 3).

Species diversity

Overall, 19 different species of holothurians, including the genus *Synapta*, were inventoried in the present

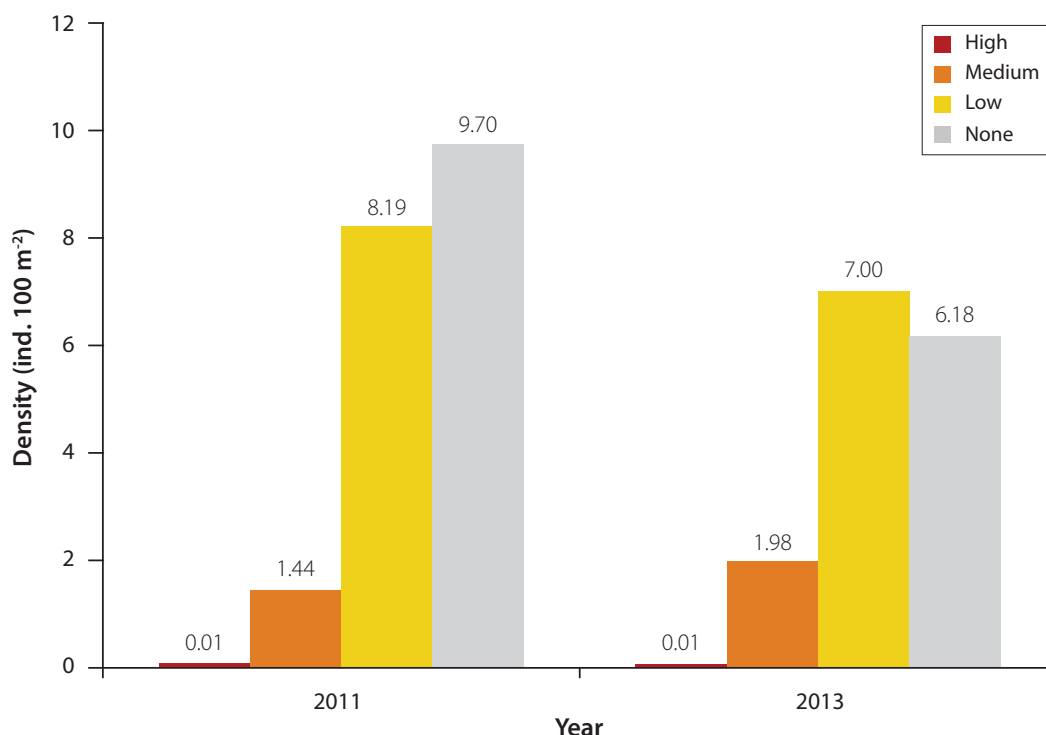


Figure 3. Comparison of holothurian densities in Mauritius' shallow lagoons between 2011 and 2013. Species are grouped according to their respective commercial value: red = high; orange = medium; yellow = low; and grey = no commercial value (following the key of Conand 2008).

study. Following the previous study of Lampe (2013), four additional species were identified by spicules examination in the shallow lagoons of Mauritius for the first time: *Holothuria arenicola*, *H. scabra*, *H. fuscocinerea* and *Actinopyga capillata* (Fig. 4).

The highest species diversity was found among the eastern survey sites, whereas species abundance was lowest on this side of the island (Fig. 5). Similarly, the western side had a relatively high diversity of species ($H' = 1.49$) whereas abundance was low (1,490 individuals). The highest holothurian abundance was found in the south (3,251 individuals) with a diversity of $H' = 1.14$ (Fig. 5). On the other hand, the sites on the northern side showed the lowest diversity ($H' = 0.21$) whereas abundance was the second highest (1,843 individuals).

Discussion

In this study, 18 species from the families Holothuriidae and Stichopodidae (Aspidochirotrida) and 1 genus (*Synapta*) from Apodida were recorded. In general, similar patterns of species composition, especially of the six most abundant species recorded in this study, are typical of tropical shallow waters in the Mascarene Islands although they are distributed in a heterogeneous manner (Müller 1998; Conand and Mangion 2002; Conand 2004; Rowe and Richmond 2004; Conand et al. 2010).

Habitat associations

Holothurian distribution in the current study did not show a clear correlation with habitats. Similar observations were made in the study conducted in 2011 in the western and southern shallow lagoons of Mauritius (Lampe 2013). It appears that the majority of species have a wide and diverse distribution, most probably due to a combination of physical, chemical and biological factors. However, there are two types of habitats that could favour species occurrences: the first type would consist of a high diversity of substrates, characterised by good visibility (6–8 m) as well as a depth range of 1–2 m. The second type would be more homogeneous and shallow (0.5–1.0 m), consisting mostly of two dominating substrates with high levels of turbidity (1 m visibility). This type of site is predominantly favoured by the species *H. atra*. In the former one, a variety of species may be encountered due to habitat heterogeneity. The loss of certain habitats could also influence species abundance and composition. In a study conducted by James (1982) in India, several species, such as *S. chloronotus*, which were abundant in 1927, had disappeared as a result of habitat destruction. Seagrass beds, for example, are essential during the early life history stages of sea cucumbers (Friedman et al. 2011). A loss of these settlement areas would have a severe impact on holothurian populations in shallow water areas (Eriksson et al. 2012).



Figure 4. Species that have been encountered for the first time in this study: a) *Holothuria arenicola*; b) *Actinopyga capillata*; c) *Holothuria scabra*; d) *Holothuria fuscocinerea*. (Photos: K. Lampe-Ramdoe)

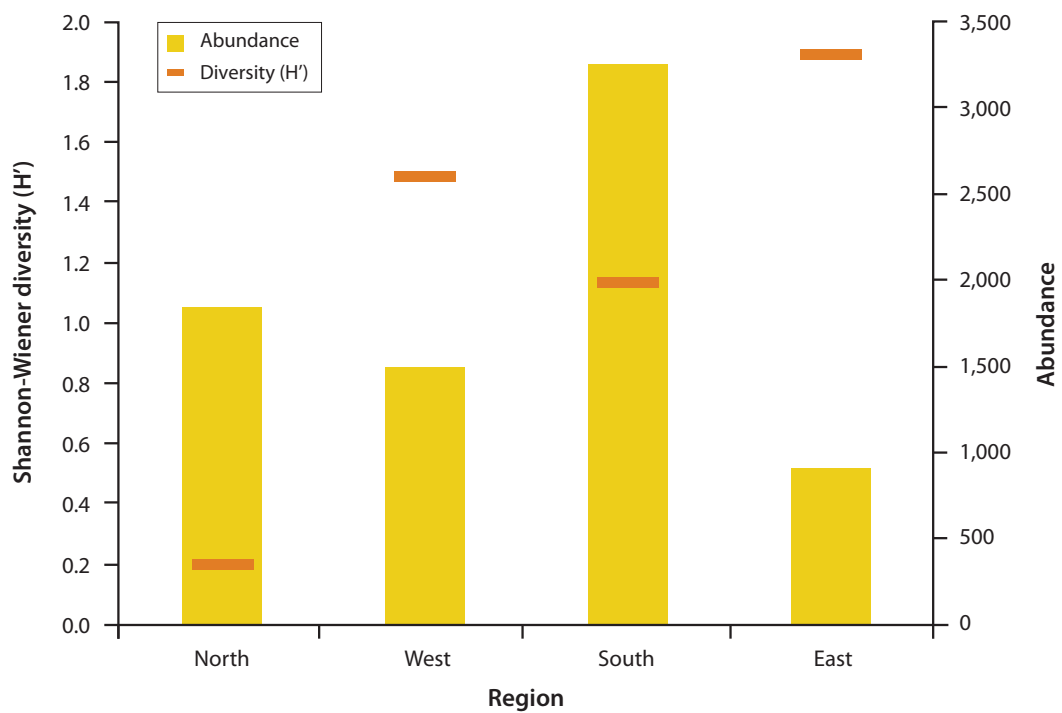


Figure 5. The abundance of holothurians and the Shannon-Wiener diversity index (H') for the four regions of Mauritius: north (4 sites), west (7 sites), south (6 sites) and east (6 sites).

Commercial value

Because species of commercial importance are the main targets of fishers, their densities were expected to be lower than species without commercial value. However, at all four regions (north, west, south, east) around Mauritius, holothurians of commercial importance were, by far, more abundant (5,271 individuals) than those without (2,217 individuals). It has been suggested that overexploitation of high-value commercial species leads to exploitation of low-value species, such as *H. atra* and *H. leucospilota* (Conand 2004; Moore 1998). This shift from high- to low-value species, and from easy access to deeper or more remote sites, are signs of an unsustainable fishery that needs urgent management attention (Purcell et al. 2013). Other signs of overexploitation are declining catches and decreases in sizes of individuals (Conand 2004).

Besides climatic impacts that degrade habitats of sea cucumbers, anthropogenic impacts could also account for holothurian occurrence and distribution in lagoons. For example, in sunbathing zones in front of resorts there is minimal collection of sea cucumbers by fishers, but the hotels themselves sometimes remove the holothurians, thus reducing their population densities.

Species diversity

The eastern side of the island had the greatest species diversity due, most probably, to the large extent of the lagoon that would harbour a large variety of habitats. The lagoon in the east extends to 5 km in width and sites are, therefore, characterised by varying depths, current patterns, substrate types, visibility and other physical parameters. Various holothurian species could be using this diversity of habitats and environments in contrast to other lagoons. Furthermore, sea cucumbers within the eastern sites are naturally protected from exploitation because of the relative inaccessibility of these sites due to their depth (4–6 m) and remoteness. This study shows that lagoons that were characterised by shallow water and a homogenous substrate had low holothurian diversity. However, a few species such as *H. atra* were highly abundant, due most probably to their high adaptability to a variety of habitat types. It was observed that very few other species would occur in areas where *H. atra* was abundant. This dominance could be preventing other species to recruit successfully within the same habitat.

Generally, the relatively high abundances of *H. atra* and *S. chloronotus* might be due to their reproduction rate. In fact, they reproduce faster than other species that inhabit the same lagoon. Another point

to consider is the establishment of new ecological niches for other species once the population stock of a certain species under exploitation is depleted or drastically reduced. As a consequence, species with a wider range of possible habitats, such as *H. atra*, *H. leucospilota* and *Synapta* spp., may settle in new potential habitats or attain higher densities due to less interspecific competition.

Conclusion

Little research was done on holothurian abundance and diversity prior to 2007 in Mauritius when this fishery was opened as a commercial fishery on a pilot basis (AFRC 2011). This study has provided baseline data for further investigations. It is of utmost importance to gather sound scientific data for the management and protection of sea cucumbers in Mauritius in order to address the decline in holothurian stocks. It is better to adopt the precautionary principle, and the moratorium in Mauritius should be maintained to prevent the collapse of the sea cucumber fishery.

Acknowledgment

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Some data on the diversity and sexual maturity of sea cucumbers in the mangroves of Babatngon, Leyte Province, Philippines

Maevel M. Romero^{1,*} and Jerome Benedict P. Cabansag¹

Abstract

This study was conducted from August 2012 to January 2013 and assessed sea cucumbers in mangroves of Babatngon, Leyte Province in the Philippines. Species diversity, length-weight relationship, gonadal development and gut content data were recorded. In total, 104 individuals were collected within a total area of 1,800 m² and five species were identified: *Holothuria leucospilota*, *H. atra*, *H. impatiens*, *H. verrucosa* and *H. erinaceus*. The population density of sea cucumbers in Babatngon reached 0.058 m⁻². Only 54.7% of the 24 dissected specimens had gonads with a gonad index ranging from 0.55–33.38, and 5 of these specimens were males in the maturing stage. Gut contents, which were very similar to the substrate, comprised silt and sand with shell and seaweed fragments.

Introduction

For almost a century, the harvesting and processing of sea cucumbers has become a source of income for many Filipinos (Schoppe 2000). The Philippines has now become the second major producer and exporter of dried sea cucumber in the world (Purcell et al. 2013). Residents from the study area claimed there has been a drastic decrease in the abundance of sea cucumbers compared with three decades ago. There was also a time when a purposive and selective collection was carried out using compressors (*hookah*) that eventually led to the total ban of sea cucumber fishing in Babatngon. The present study developed an inventory of sea cucumber species, along with their ecology and biology, found in selected mangrove areas of Babatngon.

Materials and methods

The study covered the shallow waters of the mangroves of Babatngon in Leyte Province, Philippines. Specimen collections were done at three sampling stations from three different areas — Sangputan, District 1 and Uban (Fig. 1). These sites were chosen to represent the different waters geographically surrounding Babatngon. The areas were alternately visited twice so that each station was sampled during the dry and wet seasons. Three 100 m² (50 m x 2 m) belt transects per sampling station were laid in parallel because the mangrove forest width is < 20 m. A 20-m gap was also established between transects to avoid

pseudo-replication. Coordinates of the sampling stations were acquired using the Garmin 76 Global Positioning System Receiver Unit and plotted with the GIS software Manifold 8.0. Photographs of the sampling sites were taken using Panasonic Lumix DMC-TS3 for further site description.

Sea cucumbers were collected seasonally from the three areas, from August 2012 to January 2013. Each area was sampled on a different month and was resampled after three months. Specimen collection was conducted during night time. For each 100 m² belt, all sea cucumber specimens encountered were collected and placed in plastic bags. They were then transported and immersed for 10 minutes in 5% MgCl₂ solution for relaxation and anaesthesia (Ahmed 2009). Temperature, substrate type and salinity were also recorded.

The length, width and weight were measured along with the number of tentacles. Morphology of the sea cucumbers was observed, noted and photographed. A maximum of three individuals per species were preserved in 70% ethanol and brought to the laboratory for further analysis. The remaining specimens were returned to the area where they were collected from.

Some specimens were dissected to obtain gonad weight. The gonad staging was based from the macro- and microscopic features such as gonad colour, thickness, shape, length, and diameter of tubules. The stages were classified as immature,

¹ Division of Natural Sciences and Mathematics, University of the Philippines Visayas Tacloban College, Magsaysay Avenue, Tacloban City, Philippines 6500

* Corresponding author: maevelromero@gmail.com

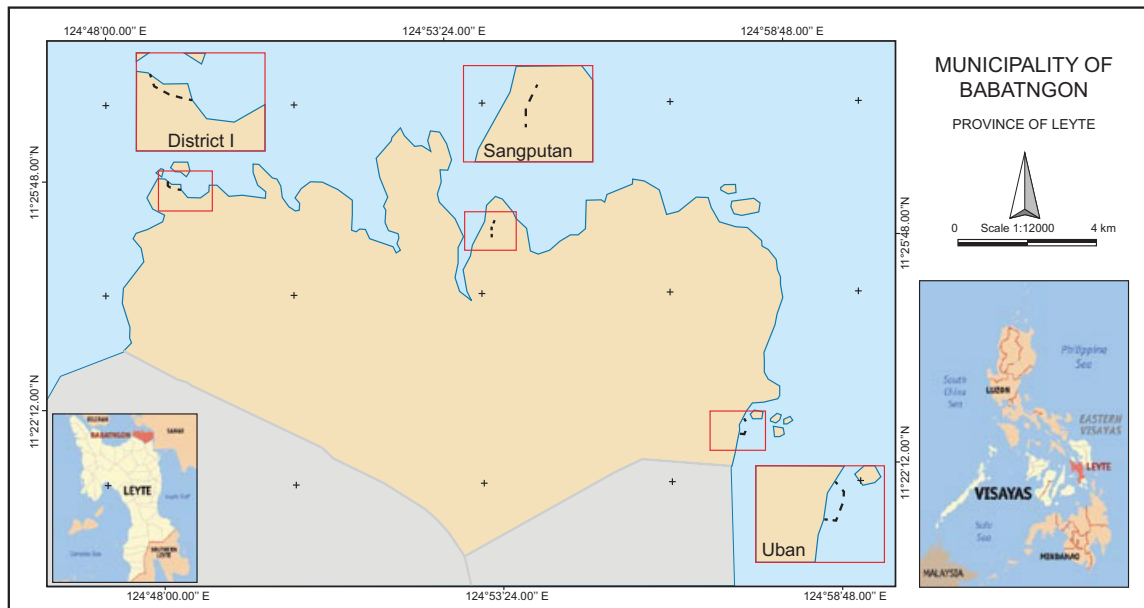


Figure 1. Location of the sampling stations along with their 50-m transect lines in the mangrove ecosystem of Babatngon, Leyte Province, Philippines.

maturing, ripe, and spent (Hoareau and Conand 2001). The identification of the species was done by examining their morphological features (tentacles, warts, papillae) and calcareous spicules.

Results and discussion

In total, five sea cucumber species (*Holothuria leucospilota*, *H. impatiens*, *H. atra*, *H. verrucosa* and *H. erinaceus*) were collected, observed, and evaluated from Sangputan, Uban and District I of Babatngon. Table 1 lists the five species collected from the three areas with their corresponding counts per sampling. The most frequently found species was *H. erinaceus* with 81 individuals collected from Uban (32 and 54 individuals for the first and second sampling, respectively). The least frequently observed species was *H. atra*, found only in Uban, with only 2 counts of the total population.

Sangputan and District I were the only sites that had a common sea cucumber species, *Holothuria leucospilota*. This can be attributed to the prevalence of rocks and crevices, which are used by this species as hiding places. Both Sangputan and District I sites are near coral reefs. Uban is adjacent to seagrass beds, and has the greatest concentration of silt and fewer coarse components.

Specimens found in Uban had fine substrate (e.g. silt and fine sand) in their gut. *H. atra*, a ubiquitous species, is typically found on bare sediment, reef flats and seagrass beds (Kerr et al. 2006). *H. verrucosa* is a cryptic species collected insites from Uban, which offer blocks and crevices that are preferred by this species (Conand 1989).

Table 2 shows the average weight and length of the three species that were present in the two sampling collections of each area. *Holothuria leucospilota* had the highest average weight and length of 301 g and 37 cm, while *H. erinaceus* had the least at 50 g and 17 cm.

The gonad index (GI) is used to measure the sexual maturity (Table 3). Twenty-four individuals were dissected and 46% had no gonads. Furthermore, the only female *H. leucospilota* was collected from Sangputan and District I during the months of August and September, respectively. The maturity stage with the greatest frequency was the maturing (male), totalling five or 38% of the dissected specimens with gonads. *H. leucospilota* from Sangputan and District I showed a decrease of GI from 10.167 (August) to 0.554 (November) and from 29.647 (September) to 18.847 (December). *H. impatiens*, however, showed an increase of GI from 12.205 (September) to 22.877 (December).

From Table 3, it can be observed that of the 24 dissected specimens, 11 had no gonads, 10 were male and only 3 were female. This is far from the expected sex ratio of 1:1 of many holothurian species (Hassan 2005). From the data it can be assumed that *H. leucospilota* was already ripe during August–October 2012 and started spawning by November, while *H. impatiens* was still maturing from August–October 2012 and started to ripen by December. No conclusion can be drawn for the species *H. verrucosa* and *H. erinaceus* because they were only encountered once and no trend can be assumed. *H. verrucosa* had maturing gonads in August 2012, and *H. erinaceus* was maturing to ripe in January 2013.

Table 1. Sea cucumber species observed in mangrove areas at different sampling stations at Babatngon in Leyte Province, Philippines from August 2012–January 2013 (n = 104).

Species	Sangputan		District I		Uban		n	%
	August	November	September	December	October	January		
<i>Holothuria leucospilota</i>	1	3	3	2	-	-	9	8
<i>Holothuria impatiens</i>	-	-	1	8	-	-	9	9
<i>Holothuria atra</i>	-	-	-	-	2	-	2	2
<i>Holothuria erinaceus</i>	-	-	-	-	27	54	81	78
<i>Holothuria verrucosa</i>	-	-	-	-	3	-	3	3
Total	1	3	4	10	32	54	104	100

Table 2. Minimum, maximum and mean measurements for both the weight and length of all the species found at Babatngon, Leyte Province, Philippines.

Species	Weight (g)			Length (cm)		
	Min	Max	Mean	Min	Max	Mean
<i>Holothuria leucospilota</i>	155	598	301	23	65	37
<i>Holothuria impatiens</i>	67	189	139	18	39	32
<i>Holothuria atra</i>	95	113	104	24	28	26
<i>Holothuria verrucosa</i>	68	102	90	13	31	20
<i>Holothuria erinaceus</i>	17	169	50	11	29	17

Table 3. Sex, stage, gonad index (GI), gonad colour, length and diameter of tubules of dissected specimens.

Station	Species	Month	Colour	Sex	GI	Length (mm)	Diameter (mm)	Maturity stage*
Sangputan	<i>Holothuria leucospilota</i>	August	Y	F	10.17	110	1.15	3
		November	Y	M	0.55	150	1.06	4
		September	W	F	25.92	160	1.02	3
			W	M	33.38	180	0.86	3
		December	W	M	18.85	144	0.54	3
District I	<i>Holothuria impatiens</i>	September	W	M	12.21	56	0.83	2
		December	W	M	19.2	63	0.52	3
			W	M	31.73	68	0.85	2
			W	M	17.7	66	1.08	3
Uban	<i>Holothuria verrucosa</i>	October	W	M	14.56	40	0.51	2
			W	M	28.42	45	0.67	2
	<i>Holothuria erinaceus</i>	January	W	M	19.1	90	0.75	3
			W	M	16.41	90	0.66	2

* Maturity stages are: 1 = immature, 2 = maturing, 3 = ripe, 4 = spent.

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Mineral and organic features of the sediment in the farming sea pens of *Holothuria scabra* (Holothuroidea, Echinodermata)

Thomas Plotieau¹, Gilles Lepoint², Jean-Marc Baele³, Gaëtan Tsiresy⁴,
Richard Rasolofonirina⁴, Thierry Lavitra⁴ and Igor Eeckhaut^{1,4,*}

Abstract

The mineral and organic features of the sediment in sea pens where *Holothuria scabra* is farmed in Madagascar are characterised here for the first time. The study was undertaken in four villages in southwest Madagascar where the growth rate of sea cucumbers was 0.5–2.1 g day⁻¹. The results show that the sediment from Tampolove, where the growth rate of *H. scabra* was the fastest among the four villages surveyed, had the highest proportion of fine sand, protein concentration, and bacterial count of the four villages. In contrast, the total organic carbon proportion and the value of $\delta^{15}\text{N}$ in the sediment from Tampolove were the lowest among the four villages.

Introduction

Holothuria scabra is a deposit feeder whose growth rate has been estimated to reach values of 0.2–0.9 g d⁻¹ (Hamel et al. 2001). As with other sea cucumbers, *H. scabra* extracts nutrients required for its growth from sediments on the sea floor. Little is known, however, about the mineral and organic components of the sediment ingested by *H. scabra*. Knowing the features of the sediment is important for farming because the quality of the sediment could explain some variations in the growth rate of reared sea cucumbers. Recently, Schneider et al. (2011) showed that holothuroids influenced seawater alkalinity in the vicinity by digesting carbonates from the sediment, a point already recorded by Hammond (1981). Since 2008, holothuroid sea farming has been practiced in four villages that are spread across 200 km of coastline in southwestern Madagascar. Monitoring was done there in order to compare the growth rates of *H. scabra* in sea pens in four villages (Tsiresy et al. 2011). The aim of the present work was to determine the mineral and organic features of the sediment in the sea pens where *H. scabra* was farmed in southwestern Madagascar. Because this is the first time that the characteristics of the sediment ingested by *H. scabra* are detailed, this work is a reference for anyone who wishes to grow this species in sea pens.

Materials and methods

Growth monitoring was conducted in four villages in southwestern Madagascar near Toliara from May 2009 to October 2010. One of the villages, Sarodrano, is situated south of Toliara and the three others (Andrevo, Fiherenamasay and Tampolove) are in the north (Fig. 1).



Figure 1. Southwestern Madagascar and the location of the four villages where intensive sea cucumber farming has been monitored since 2009.

¹ Laboratory of Marine Organisms and Biomimetics, University of Mons, B-7000 Mons, Belgium

² Oceanology, University of Liège, B6 Sart Tilman, B-4000 Liège, Belgium

³ Fundamental and Applied Geology, University of Mons, B-7000 Mons, Belgium

⁴ Polyaquaculture Research Unit, IHSM, Université de Toliara, 601 Toliara, Madagascar

* Corresponding author: igor.eeckhaut@umons.ac.be

Juvenile sea cucumbers were spread out in sea pens such that their density was 2 ind. m⁻² maximum at the beginning of the trial (see Eeckhaut et al. 2009 and 2012 for the development of juveniles before farming), a density recommended by Lavitra et al. (2010). Results of the growth monitoring were detailed in Tsiresy et al. (2011) except for that in Tampolove. The daily growth rate was 2.1 g in Tampolove, 1.7 g in Andrevo, 1.5 g in Sarodrano and 0.5 g in Fiherenamasay.

Sampling

The upper layer of the surface sediment where *H. scabra* feeds (the top 2 cm) was sampled from inside sea pens of each village farm in October 2010. Sediment samples were either directly stored at 4°C or placed in 4% paraformaldehyde (in 0.2 µm filtered sea water) before being stored at 4°C. Once in Toliara, a fraction of the non-fixed samples was used to quantify the chlorophyll *a* concentration arising from photosynthetic microorganisms. Another fraction was put in a drying kiln at 60°C for 48 hours, for later analyses at the Biology of Marine Organisms and Biomimetics Laboratory. These dried samples were used to determine the grain size, organic matter content, carbonate abundance, and nature of the minerals. Samples fixed with 4% paraformaldehyde were used to quantify bacteria.

Organic matter and mineral composition analyses

The methods used here are explained in Plotieau et al. (2013a). For each trial, the average values (given in the Results section) were calculated from five replicates.

The percentage of organic matter content was determined by carbonisation. The quantity of bacteria was estimated by using diamidino-2-phenylindole (DAPI) colouration. The quantity of photosynthetic microorganisms in sediments was estimated by chlorophyll *a* concentration. Stable

isotope analyses ($\delta^{13}\text{C}$ and $\delta^{15}\text{N}$) were conducted on sediment samples and sea cucumbers.

Sediment samples of 100 g from each village were sieved and weighed to determine their grain size composition. Carbonates were recorded after HCl dissolution and x-ray diffractometry was carried out to determine the abundance of four minerals: quartz, which consisted of almost pure SiO₂; calcite, the most stable polymorph of calcium carbonate (CaCO₃); aragonite, a thermodynamically metastable form of CaCO₃ at standard temperature and pressure; and magnesian calcite (Ca,Mg)CO₃, a variety of calcite consisting of randomly substituted magnesian carbonate in a disordered calcite lattice. Magnesian calcite is the typical biomineral found in echinoderm skeletons.

For direct DAPI counts, total organic content, carbonate proportions and chlorophyll *a* content, the non-parametric Kruskal Wallis test was performed ($\alpha < 0.05$) in order to compare the sea pens with the arcsin transformation used for percentages.

Results

Table 1 summarises the results obtained. Sand fractions < 500 µm represent 85% of the dry weight of the sediment from Tampolove, 73–50% from Sarodrano and Andrevo, and less than 50% from Fiherenamasay. Fiherenamasay is the only village where the sediment had more than 25% of sand grains greater than 1 mm in size. In comparison, the sediment from Tampolove had less than 2% of these particles.

The total organic carbon (TOC) in the sediments constituted 0.4–2.0% of the total dry weight of the sediment sampled in the four villages (Table 1). The TOC in the sediments from Fiherenamasay and Tampolove differ significantly, and also differ from the two other villages ($P < 0.05$). The highest TOC observed was in Sarodrano, followed by Andrevo

Table 1. Mineral and organic features of the sediments in the sea pens. Higher values are highlighted in bold, lower values are in italics.

	Sarodrano	Andrevo	Fiherenamasay	Tampolove	Average
Growth rate	1.5	1.7	0.5	2.1	1.45
Proportion of particles < 500 µm (%)	73	50	43	85	62.7
Total organic carbon (%)	2.0 ± 0.24	1.8 ± 0.26	1.1 ± 0.13	<i>0.4 ± 0.13</i>	1.325
Protein concentration (µg µl ⁻¹)	<i>0.015 ± 0.001</i>	0.024 ± 0.01	0.018 ± 0.003	0.049 ± 0.002	0.0265
$\delta^{15}\text{N}$ (‰)	3.1 ± 0.2	2.2 ± 0.5	4.2 ± 0.2	<i>0.9 ± 0.9</i>	2.6
Bacterial count (DAPI) (x 10 ⁹)	0.9 ± 0.4	<i>0.7 ± 0.07</i>	0.8 ± 0.1	2.0 ± 0.9	1.1
Chlorophyll <i>a</i> concentration (mg g ⁻¹)	6.9 ± 1.1	1.4 ± 0.3	3.3 ± 0.8	4.5 ± 3.7	4
Carbonate proportion (%)	35 ± 1	48 ± 5	94 ± 2.5	74 ± 0.5	62.75
Magnesium calcite (%)	9	7	35	16	16.7

and Fiherenamasay. Surprisingly, Tampolove, the village with the highest *H. scabra* growth rate, had the lowest TOC. The protein content of sediments varied from $0.015 \mu\text{g } \mu\text{l}^{-1}$ to $0.049 \mu\text{g } \mu\text{l}^{-1}$ (Table 1). Only the protein content of the sediment from Tampolove differed significantly from the other three villages ($P < 0.05$): it included three times as many proteins as the other villages. The three other villages have protein contents less than $0.025 \mu\text{g } \mu\text{l}^{-1}$. The mean number of bacteria found with the DAPI colouration varied between 7×10^8 and 2×10^9 , and was highest in the sediment from Tampolove (Table 1). The number of bacteria in the sediment from Tampolove is quite different from the number in the sediments from Andrevo and Fiherenamasay ($P < 0.05$). The number of bacteria from Tampolove does not, however, differ significantly from that of Sarodrano because the standard deviations in both locations are important, although the mean is two times higher in Tampolove. Chlorophyll *a* mean concentrations varied between 1.4 mg g^{-1} and 6.9 mg g^{-1} of sediment (wet weight) (Table 1), and was highest in the sediment from Sarodrano and lowest in the sediment from Andrevo.

Figure 2 illustrates the means of $\delta^{15}\text{N}$ and the $\delta^{13}\text{C}$ obtained for the sediments and the holothuroids reared in the four villages. The mean values of $\delta^{15}\text{N}$ obtained for holothuroids are significantly different in the four villages meaning that their diets are different. Yet, the sediments of the four villages have similar mean values of $\delta^{13}\text{C}$ but have significantly

different mean values of $\delta^{15}\text{N}$, suggesting that the organic matter content coming from primary producers is different in the sediments.

The mean proportion of carbonates determined by acid attack is $35 \pm 1\%$ of the wet weight of sediment from Sarodrano, $48 \pm 5\%$ of the wet weight of sediment from Andrevo, $94 \pm 2.5\%$ of the wet weight of sediment from Fiherenamasay and $74 \pm 0.5\%$ of the wet weight of sediment from Tampolove. Carbonate fraction is surprisingly most important at the location where holothuroid growth is the lowest.

The relative abundance of the main identified minerals (quartz, magnesian calcite, aragonite and calcite) of the two grain-size fractions ($>$ and $< 500 \mu\text{m}$) in the four villages is illustrated in Figure 3, which shows the mineralogical profile of each farm. The most important mineral at Sarodrano, Andrevo and Tampolove is quartz, no matter the analysed fractions. However, the most important mineral at Fiherenamasay, the site with the lowest holothuroid growth, is magnesian calcite. For all sites, there is more magnesian calcite than calcite (except in the fraction $< 500 \mu\text{m}$ at Fiherenamasay where the proportion is the same). At Fiherenamasay, the pattern is very different from the one observed in the other villages, with the most important mineral in the two fractions being magnesian calcite followed by aragonite, quartz and finally calcite.

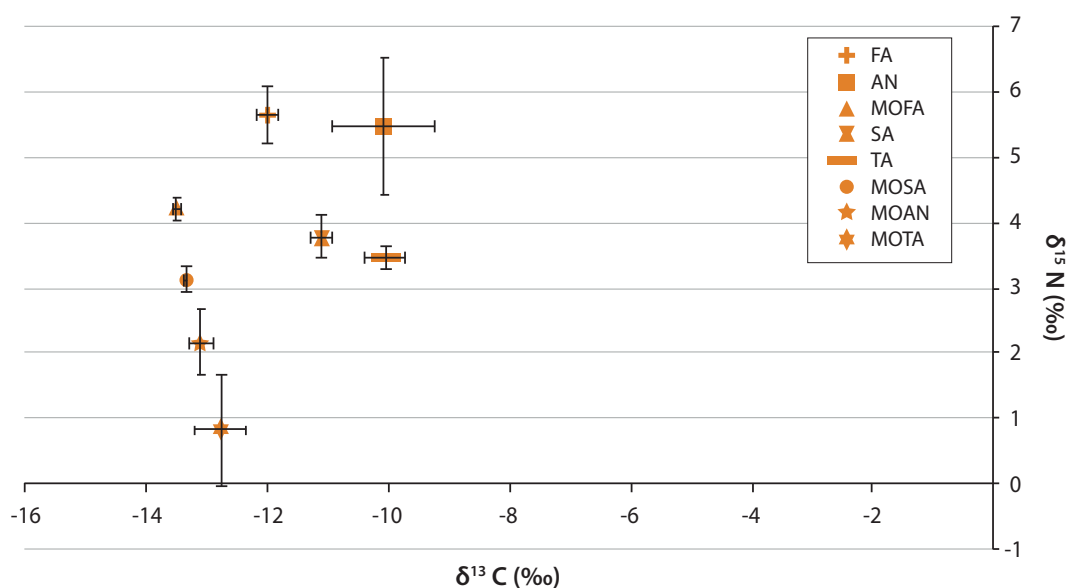


Figure 2. Mean $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of sea cucumber and organic matter of each studied villages. TA = sea cucumbers of Tampolove; AN = sea cucumbers of Andrevo; SA = sea cucumbers of Sarodrano; FA = sea cucumbers of Fiherenamasay; MOTA = organic matter of Tampolove; MOAN = organic matter of Andrevo; MOSA = organic matter of Sarodrano; MOFA = organic matter of Fiherenamasay.

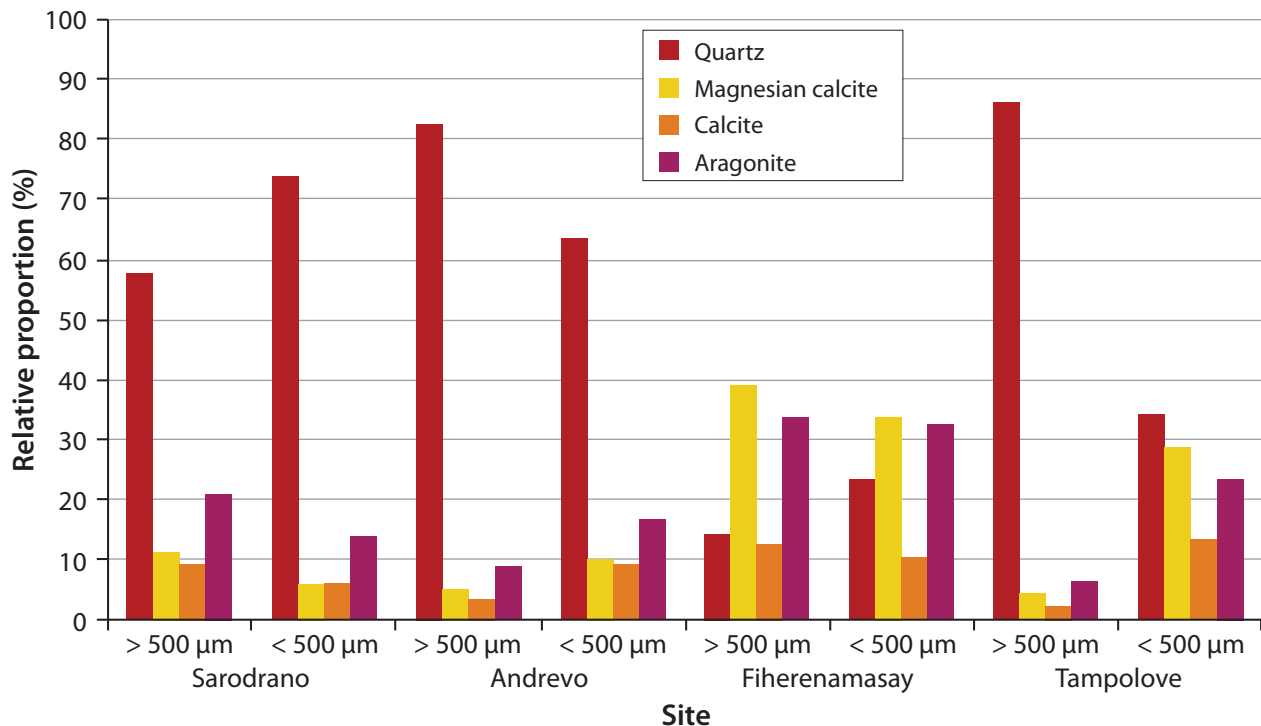


Figure 3. The abundance of principal minerals identified by x-ray diffractometry in the two grain-size classes of sediments from the four villages.

Discussion

In a recent paper (Plotieau et al. 2013a), we compared the sediment features inside (where holothuroids fed) and outside the sea pens of two villages after the completion of six cycles of farming. The samplings for this study were done one year after the present analyses (Plotieau et al. 2013a). We observed that the component of the sediment was sometimes greatly influenced by holothuroid feeding: the proportion of the finest grain-size fraction (< 250 µm) decreased from 5% to 14%, the global carbonate proportion decreased by 5% and the number of bacteria decreased by up to 50% (Plotieau et al. 2013a).

In the present paper, we provide information on the values of some important parameters of the sediment inside the range of which holothurians were observed to grow from 0.5 g d⁻¹ to 2.1 g d⁻¹. Table 1 summarises the results obtained in this study. Although no direct correlation can be made between the growth rate of *H. scabra* and the features of the sediment, a general trend can be suggested when comparing the farms. In Tampolove, where the growth rate is fast, fine sand, protein concentration, and bacterial count had the highest values among the four villages. Also in Tampolove, the TOC proportion and the value of $\delta^{15}\text{N}$ are lowest. A low TOC value recorded in Tampolove indicates that the growth of *H. scabra* is not better if sediments are charged in organic matter. The TOC concentration

seems particularly low, with an average of 1.325% when pooling all farms, the rest being minerals.

A low $\delta^{15}\text{N}$ suggests that organic matter includes mainly primary producers (dead and alive). Isotopic analyses reveal that there are differences in the global nature of organic matter eaten by holothuroids: $\delta^{13}\text{C}$ is similar in the four villages but $\delta^{15}\text{N}$ differs. Variations in $\delta^{15}\text{N}$ suggest that dead organisms in organic matter were not on the same level of the trophic chain when they were alive. The results further suggest that the organic matter in the sediment from Tampolove includes a high proportion of primary producers in contrast to Fiherenamasay where organic matter included fragments of organisms coming from a higher level in the trophic chain. This could be explained by the occurrence of a very dense population of ophiuroids (*Ophiocoma scolopendrina*) with a density of > 3 ind. m⁻² in Fiherenamasay (pers. obs.) but not in the three other villages. When dying, these organisms would contribute greatly to the formation of organic matter, a result that is supported by the high proportion of magnesium calcite found in the sediment, magnesium calcite composing the skeleton of echinoderms.

We sometimes observed poor coherence in some of the obtained results. Chlorophyll *a* concentration does not match perfectly with what was found with the isotopic analyses. This could be due to the fact that chlorophyll *a* concentration is correlated with

live primary producers while a low $\delta^{15}\text{N}$ value would suggest that the organic matter includes primary producers that are dead or alive. Protein concentrations also differ from both the bacterial counts and chlorophyll *a* concentrations when the four farms are compared. We suppose that this is because a protein concentration sums all micro- and macro-organisms (such as nematodes) of a sample and can thus differ from the concentration of one particular category of organisms, here bacteria or primary producer. We observed, however, that protein concentration was the highest in Tampolove where the highest growth rate and the highest bacterial concentration were recorded (see Plotieau et al. 2013b for the bacterial composition of the gut of *H. scabra*).

Results obtained with the mineral fraction show that the mineral profile varies greatly from one farm to another but that the changes do not seem to significantly affect the growth of holothuroids. The quartz proportion varies greatly from 6% to 65%, indicating that mineral composition is dependent on water runoff from rivers. Andrevo and Sarodrano are influenced by runoff from the Manombo and Onilahy rivers, respectively, while Fiherenamasay and Tampolove do not receive direct runoff from rivers. Fiherenamasay in particular has a totally different mineral composition from the other villages, having a very weak proportion of quartz and much more calcite and aragonite. It is also the only farm that lies on a fringing reef; the farms at Sarodrano and Andrevo are located in lagoons behind a barrier reef, while the farm at Tampolove is in a bay. Recently, Schneider et al. (2011) investigated the potential role of holothurians on the CaCO_3 balance of a coral reef. These deposit feeders process carbonate sand and rubble through their digestive tract and dissolve CaCO_3 as part of their digestive process. The holothuroid population was estimated to be responsible for nearly 50% of night-time CaCO_3 dissolution. We have shown that the growth of *H. scabra* was good even in low concentrations of CaCO_3 and did not improve when holothuroids were farmed on sediments that had a higher concentration of carbonate compounds. It is known that the presence of quartz is often accompanied by feldspar in which K, Na and Ca ions are more bioavailable but, at present, it is impossible to say that the growth of *H. scabra* is facilitated by the presence of either quartz or calcite. Laboratory experiments should be designed with laboratory-made sediments to explore the real impact of minerals and organic compounds on the holothuroid growth.

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Selective feeding behaviour in some aspidochirotid holothurians (Echinodermata: Holothuroidea) at Stidia, Mostaganem Province, Algeria

Noreddine Belbachir^{1,2,*}, Karim Mezali² and Dina Lila Soualili²

Abstract

A study of the feeding behaviour of some aspidochirotid holothurian species inhabiting the *Posidonia oceanica* meadows near Stidia in Mostaganem Province, Algeria, was carried out in order to assess their ability to selectively feed. This study is an assessment of the level of organic matter in sediments of the gut contents of these species, their faeces, and the sediment of their biotope. A granulometric analysis of the ingested particles by *Holothuria (Roweothuria) poli* and sediment particles of its biotope was also conducted as part of this study in order to estimate this species' degree of feeding selectivity. The holothurians studied showed a selectivity for organic matter: *H. (Platyperona) sanctori* is the most selective species, followed by *H. (Panningothuria) forskali*, *H. (R.) poli* and *H. (Holothuria) tubulosa*. This difference in selectivity may be related to their micro-distribution in the different habitats of the *Posidonia* meadows ("herbier sur matre", "intermatre", "tombants de matre"). The fine and very fine fractions of the sediment are selected by *H. (R.) poli*, thereby confirming the "optimal foraging theory".

Introduction

The aspidochirotid holothurians are the major representatives of the benthic component of the *Posidonia oceanica* ecosystem of the Mediterranean Sea; they actively contribute to the recycling of organic matter and play an important role in the "detritus food web" of this ecosystem (Zupo and Fresi 1984). Selective feeding behaviour in sea cucumbers has been studied in many works; set apart from the obvious benefit of getting food with high nutritional value, the selection of nutrients by sea cucumbers could be a way to explain the niche partitioning between different species that live in the same habitat (Roberts 1979). Recently, Mezali and Soualili (2013) analysed the digestive contents of Algerian shallow water holothurians species and showed that some holothurians ingest both coarse and fine sediments — *Holothuria (Holothuria) tubulosa*, *H. (Roweothuria) poli* and *H. (H.) stellati* — while others select fine and very fine sediments — *H. (Panningothuria) forskali* and *H. (Platyperona) sanctori*. The aim of the present work was to study the selective feeding behaviour of the aspidochirotid holothurians of the coastal fringe of Mostaganem Province in Algeria.

Materials and methods

Sampling was conducted at Stidia (Fig. 1) at an average depth of less than 3 m. For the organic matter (OM) rate analysis, batches of samples of 10 individuals were collected for each species: *H. (H.) tubulosa*, *H. (R.) poli*; *H. (P.) sanctori* and *H. (P.) forskali*.



Figure 1. Location of the study area.

¹ Département de biologie, Université Abdelhamid Ibn Badis de Mostaganem, BP 300, Algérie

² Département des Sciences de la Mer et de l'Aquaculture, Université Abdelhamid Ibn Badis de Mostaganem, BP 300, Algérie

* Corresponding author: belbachirnoreddine@hotmail.fr

The first few millimetres of the biota sediment (BS) and faeces (F) ejected by holothurians were collected. The digestive contents (DC) of each individual were carefully collected. The rate of organic matter in DC, BS and F was determined according to the protocol recommended by Massin (1980); the sediments were oven dried and weighed (dry weight: DW), then incinerated in a muffle furnace and then re-weighed (ashes weight: AW). The following formula was used: $OM (\%) = (1 - AW/DW) \times 100$. A one-way ANOVA was performed. For the granulometric analysis, 20 individuals of *Holothuria (R.) poli* were collected, together with the first millimetres of their BS. The digestive tracts of each individual and their contents were collected. In order to have a sufficient quantity of dry sediment (≥ 150 g), the sediment of the gut contents of the 20 individuals were pooled (following Roberts' [1979] protocol). The sediment was then oven dried, then weighed to obtain the initial weight. The fine fraction is obtained after wet sieving (40- μ m mesh sieve). The remaining part was again oven dried, weighed (final weight) then mechanically sieved on an AFNOR sieve series. Each sieve residue was weighed and expressed as a percentage of the initial weight. The percentage of the different fractions: very coarse ($> 2,000$ μ m); coarse (600–2,000 μ m); medium (200–600 μ m); fine (60–200 μ m) and very fine (40–60 μ m) are thus determined (Berthois 1975). This protocol is also used for BS. The selectivity of *H. (R.) poli* in the choice of the grain sediment has been studied through the calculation of the electivity index: $E' = (ri - pi) / (ri + pi)$ (ri : % of retained sediment; pi : % of ambient sediment; $E' = 0$ indicates no selectivity; $-1 < E' < 0$ indicates avoidance; $0 < E' < 1$, indicates preference) (Ivlev 1961 in Stamhuis et al. 1998).

Results

The rate of OM found in the DC sediment of the four holothurians species was high compared with that found in the sediment of their biotope (Fig. 2). The rate of OM in the DC varies from one species to another ($P < 0.01$) (Fig. 2), these results allow us to classify species according to their selectivity to the OM: *H. (P.) sanctori* is the most selective species followed by *H. (P.) forskali*, *H. (R.) poli* and *H. (H.) tubulosa*. The rate of OM in the DC sediment of *H. (R.) poli* is very high (7.45%) compared with that obtained for *H. (H.) tubulosa* (2.99%) (Fig. 2), a high rate of OM was found in the faeces of *H. (P.) sanctori* and *H. (R.) poli* compared with the sediment of their biotope ($P < 0.01$) (Fig. 2). However, the OM rate from the faeces of *H. (H.) tubulosa* and *H. (P.) forskali* is practically equal to that of the BS (Fig. 2).

Stidia sediments are dominated by medium sand fraction (200–600 μ m) (Fig. 3). All proportions of size fractions originating from the DC sediment of *H. (R.) poli* are greater than those of BS, except for the medium fraction (Fig. 3).

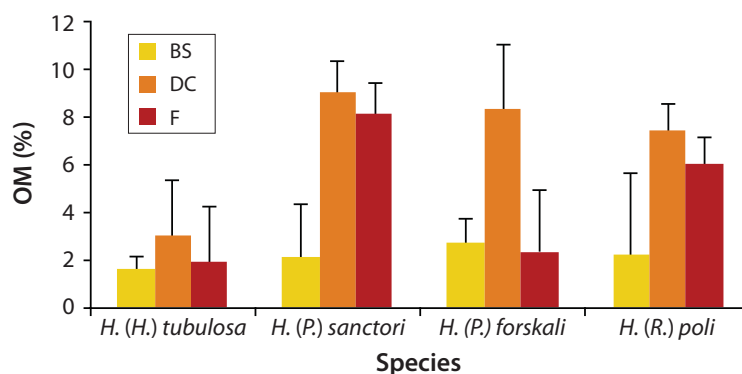


Figure 2. Percentage of organic matter in the biota sediment (BS), the digestive content (DC) and faeces (F) of the aspidochirotid holothurians at Stidia, Mostaganem Province, Algeria.

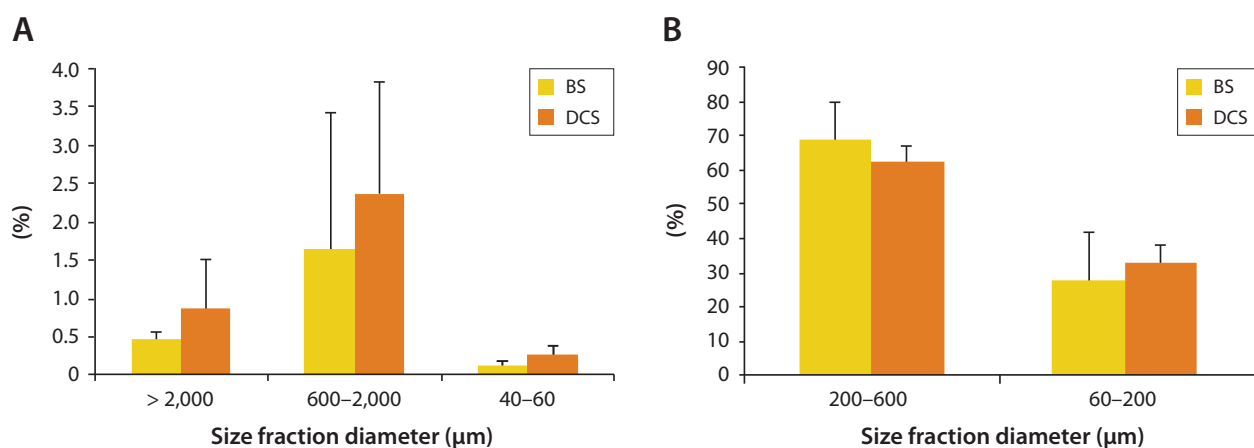


Figure 3. Percentage of size fractions of the biota sediment (BS), and the digestive content sediment (DCS) of *H. (R.) poli* at Stidia. (A): very coarse fraction ($> 2,000$ μ m), coarse fraction (600–2,000 μ m) and very fine fraction (40–60 μ m); (B): medium fraction (200–600 μ m) and fine fraction (60–200 μ m) (According to Berthois [1975] classification).

Holothuria (R.) poli tends to select a large amount and preferably the fine fraction (Fig. 3). However, it is the very fine fraction that is preferred as long as it has the highest E' (Fig. 4). *Holothuria (R.) poli* presents an almost equal selectivity degree for fine and coarse sand (Fig. 4).

Discussion

Organic matter rate analysis

The high rate of OM found in the DC compared with the BS, may be the result of the action of selectivity by these holothurians species to OM (Moriarty 1982; Mezali and Soualili 2013). The difference between the OM concentrations in the DC of these species could be explained by the fact that each species frequents a specific biota within the *Posidonia* meadow: *H. (H.) tubulosa* occurs in the inter-matte (Mezali 2004), which is heavily influenced by the hydrodynamic environment and, therefore, tends to disperse the food; *Holothuria (P.) sanctori* and *H. (P.) forskali* often occur between the rhizomes of *Posidonia* at the tombant de matte (Mezali 2008) biota where a large amount of biodegradable material accumulates (Boudouresque and Jeudy De Grissac 1983). The high rate of OM obtained in the DC of *H. (R.) poli* compared with that obtained in *H. (H.) tubulosa* does not corroborate the results obtained by Mezali and Soualili (2013) in Tamentefoust, where 8.70% of OM was found in the DC of *H. (H.) tubulosa* and 6.67% of OM was found in the DC of *H. (R.) poli*; therefore, it is considered to be a surprising result because these two species frequent the same biota (inter-matte). In addition, the rate of OM obtained for the DC of *H. (R.) poli* at Stidia (exposed area) is almost similar to that obtained by Mezali and Soualili (2013) at the protected site of Tamentefoust (6.67%), and is higher than the rate of OM obtained by the same authors in the exposed site of Sidi-Fredj (2.49%); normally, hydrodynamism, which is common in the exposed site, disperses biodegradable materials rich in OM. We noticed in our samples that the majority of individual *H. (R.) poli* were confined within a *Caulerpa prolifera* meadow, which preceded the *Posidonia* seagrass bed. This biota preference was also reported by Tortonese (1965). According to Holmer et al. (2009), *Caulerpa prolifera* promotes the enrichment of sediment in OM through its ability to retain and trap organic particles, and it is for this reason that *H. (R.) poli* was able to accumulate high rates of OM in its DC. Thus, *H. (R.) poli* might have the ability to select habitats rich in OM, and leave its favourite biotope, the inter-matte. According to

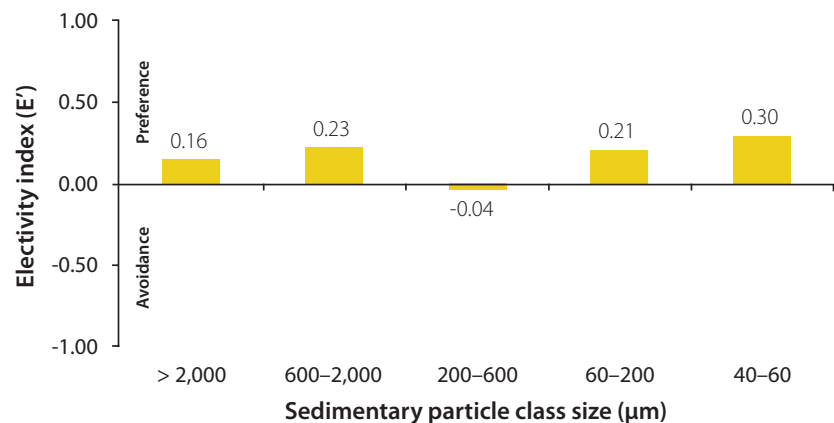


Figure 4. Electivity index (E') with sizes class of sediment particles, indicating preference (positive values) or avoidance (negative values) of a size class of sediment during the selection of the sediment particles by *Holothuria (R.) poli*.

Pyke et al. (1977), it is sometimes better for a species to move from one biota to another that is richer in nutrients. The high OM rate found in *H. (P.) sanctori* and *H. (R.) poli* faeces, shows that faecal matter contains a high rate of nutritive compounds. These results confirm those of Mezali (2008), at least for *H. (P.) sanctori*, *H. (H.) tubulosa* and *H. (P.) forskali*.

Granulometric analysis

The high proportion of medium sand fraction at the study site demonstrates an active hydrodynamism in the area (Jeudy De Grissac and Le Fur 1983). As noted by Mezali and Soualili (2013), *H. (R.) poli* has a preference for fine sediments. The increase in OM rate in fine fractions was demonstrated by Berthois et al. (1968). Effectively, as the surface to volume ratio increases with fine fractions, the surface to which the organic matter can adhere to is increased as well. Holothurians, therefore, have the ability to identify and generally select particles rich in OM (Massin and Jangoux 1976). The tendency to select coarse sediments was also observed by Mezali et al. (2003); some authors estimate that the presence of coarse particles in the digestive tract of holothurians can help them perform essential functions such as digestion (Dar and Ahmad 2006). It is assumed that the results obtained in this study are consistent with the model of feeding behaviour of marine deposit feeders proposed by Taghon and colleagues (1978). This model assumes that these animals tend to select smaller particles with high OM rates in order to maximise their energy gains. According to the authors, the model provides a relationship between particle size selection, food assimilation efficiency, gut transit time and the cost of rejecting particles. Marine deposit feeders adjust their food intake by selecting food that is efficiently assimilated with a short gut transit time, and with little cost of rejecting particles. This provides animals with the maximum amount of energy with a minimum

loss of time (and minimum loss of energy), which is consistent with the “Optimal Foraging Theory”, which assumes that animals recognise and select the food that provides them with the maximum amount of energy in a minimum amount of time (Taghon 1982; Pyke 1984).

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Parastichopus regalis — The main host of *Carapus acus* in temperate waters of the Mediterranean Sea and northeastern Atlantic Ocean

Mercedes González-Wangüemert^{1,*}, Camilla Maggi², Sara Valente¹,
Jose Martínez-Garrido¹ and Nuno Vasco Rodrigues³

Abstract

Pearlfish, *Carapus acus*, live in association with several species of sea cucumbers. Its occurrence in hosts is largely dependent on host availability and its distribution from potential larval areas. The occurrence of *Carapus acus* in six sea cucumbers species from the Mediterranean Sea and northeastern Atlantic Ocean was assessed. The sea cucumber species *Parastichopus regalis* was the only host detected. Pearlfish from southeastern Spain (21 individuals) ranged in length from 7.0 cm to 21.5 cm. Two sea cucumbers from the area around Valencia harboured two adult fish each. These pairs of pearlfish, which were sampled during the summer, were able to breed inside of *P. regalis*, an event already noted by other authors. Pearlfish do not seem to choose their host according its size, as the correlation between fish length and host weight was not significant.

Introduction

Symbiosis, the close relationship between organisms of different species, can occur in the marine environment and, in relation to the species involved, can take place in various forms, such as mutualism, commensalism or parasitism (Eeckhaut 2003). More than 800 species have been found in association with different members of the echinoderm phylum (Lyskin and Britaev 2005), and the class Holothuroidea has the higher number of associations (Eeckhaut et al. 2004).

A variety of fish, most commonly pearlfish, are able to live in association with different invertebrates, including holothurians. Pearlfish belong to the family Carapidae, which comprises two subfamilies, Pyramodontinae and the Carapinae, and further divided into two tribes: Echiodontini and Carapini (two genera: *Carapus* and *Encheliophis*) (Parmentier et al. 2000). Members of the Carapini tribe are small, eel-like fish that have developed a symbiotic relationship with sea cucumbers in which the fish lives inside the sea cucumber respiratory trees, or coelomic cavity, using it for protection from predation, as a source of food, and to develop into its adult stage of life (Trott 1981). Slight injuries to the echinoderm are caused by the pearlfish, which pierce the holothurian digestive wall and the respiratory trees when they enter or leave their hosts.

Carapus acus (Brünnich, 1768) is a species recorded throughout the Mediterranean Sea and the west coast of North Africa in depths of 1–150 m (Nielsen et al. 1999). It is common in the western Mediterranean Sea, mainly around Italy, Spain and France, and also occurs in the Adriatic and Aegean seas. It is usually found in the sea cucumbers *Parastichopus regalis* and *Holothuria tubulosa* (Gmelin 1790). It is an elongated, slender, scaleless fish with long dorsal and anal fins meeting at the tip of the long pointed tail (Fig. 1). Members of this species are characterised by a rounded snout, strong dentition and a wide mouth opening. They possess a row of large external, incurved conical teeth and several smaller internal teeth (Parmentier et al. 1998, 2000). The eel-like body is translucent with about 15 silver-gold iridescent spots appearing laterally on the operculum and thoracic regions. As with other pearlfish, they are about 20 cm or less in length. *C. acus* reproduce during July–September (Trott and Olney 1986). Members of *C. acus* are able to produce sounds that are not used by the fish to identify the presence of another fish in the holothurian before penetration, but are produced in the presence of congeneric individuals already inside the host (Eeckhaut et al. 2004).

In this article we report on the presence of *C. acus* (Brünnich, 1768) in *Parastichopus regalis* (Cuvier, 1817) from the western Mediterranean Sea and show

¹ Centro de Ciências do Mar (CCMAR), Universidade do Algarve, Campus de Gambelas, 8005-139 Faro, Portugal

² Università Politecnica delle Marche, Piazza Roma 22, 60121, Ancona, Italy

³ GIRM-School of Tourism and Maritime Technology, Marine Resources Research Group, Polytechnic Institute of Leiria, 2520-641 Peniche, Portugal

* Corresponding author: mwanguemert@ualg.pt

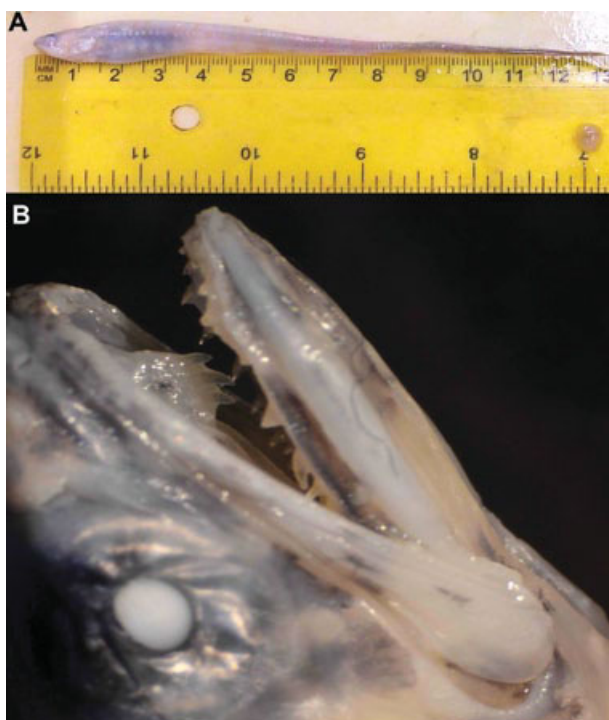


Figure 1. A) *Carapus acus* individual from southeastern Spain conserved in ethanol; B) Detail of *Carapus acus* dentition.

some anatomical, morphological and behavioural features of *C. acus* that could help gaining a better understanding of this species.

Materials and methods

Study sites

Sea cucumber sampling to test the occurrence frequency of *Carapus acus* individuals was carried out with the support of the CUMFISH project⁴. During the sampling, individuals belonging to different sea cucumber species were caught: *Holothuria poli* (Delle-Chaije, 1823), *H. mammata* (Grube, 1840), *H. tubulosa*, *H. sanctori* (Delle Chiaje, 1823), *H. arguinensis* (Koehler and Vaney, 1906) and *Parastichopus regalis*. The geographic range included the Mediterranean Sea and Atlantic Ocean according the species' geographic distribution (González-Wangüemert et al. 2013). Most of the samples were caught by scuba diving except for *P. regalis*, which lives in deep water. *P. regalis* individuals were collected in May–July 2013 by the Spanish Oceanographic Institute (IEO, <http://www.ieo.es>) during MEDITS (international trawl) surveys conducted along the continental shelf and slope off the southeastern Spanish coast. Individuals from Sicily were sampled in 2012–2013 using trawls, thanks to the collaboration with Istituto per l'Ambiente Marino

Costiero del Consiglio Nazionale delle Ricerche (IAMC-CNR, <http://www.iamc.cnr.it/IAMC/>).

Analysis

The occurrence of *Carapus acus* inside of sea cucumbers was recorded. Each pearlfish was photographed inside its host, and its total length and total weight were measured. Specimens were then stored in 100% ethanol. A small (3–5 mg) section of tissue was removed from the dorsal muscle of each fish and placed in absolute ethanol for further genetic analysis. The correlation between host weight and fish size was calculated.

Total length and count of vertebrae of *C. acus* specimens found in *P. regalis* were chosen as meristic parameters (i.e. measurements that indicate the count of body parts related to body segmentation). Information regarding the axial skeleton was obtained using the Kodak DXS (digital x-ray specimen) 400 System, which offers the highest resolution available for digital specimen radiography.

Results and discussion

During the CUMFISH project, 1,880 individual sea cucumbers of different species were caught: *Holothuria tubulosa* (n = 390), *H. mammata* (n = 427), *H. poli* (n = 397), *H. sanctori* (n = 100), *H. arguinensis* (n = 269) and *Parastichopus regalis* (n = 297). The occurrence of *Carapus acus* was very variable, depending on the host species and their geographic origin. Of the six sea cucumber species studied belonging to two different genera, only *Parastichopus regalis* had *C. acus* as a commensalist. In Sicily, 51 individuals of this sea cucumber species were sampled, and 41.17% (21 individuals) had *C. acus* inside of them. In total, 241 individuals of *P. regalis* were collected along the eastern Spanish coast: 39 from Catalonia, 74 from Valencia, 37 from Alicante, 9 from Cabo de Gata, 9 from Castell de Ferro and 73 from Alboran Sea. Twenty-one individuals of *C. acus* were found inside holothurian specimens (*P. regalis*) from three localities: Alicante, Valencia and Cabo de Gata (Table 1); six were found in Alicante, fourteen in Valencia and only one in Cabo de Gata (TL = 12.1 cm; TW = 1.94 g). The occurrence frequencies in each locality were 16.2% for Alicante, 18.9% for Valencia and 11.1%, for Cabo de Gata.

The pearlfish from southeastern Spain ranged in length from 7.0 cm to 21.5 cm and in weight from 0.28 g to 16.78 g (Table 1). As already noted by other authors (e.g. Trott and Olney 1986; Eeckhaut et al. 2004), two fish have been observed inside the same

⁴ The new resource for a hungry fishery, PTDC/MAR/119363/2010; <http://www.ccmr.ualg.pt/cumfish/>

Table 1. Morphological characteristics of *Carapus acus* found in *Parastichopus regalis* from southeastern Spain. Minimum and maximum values for each locality are in bold.

Locality	Sample code	Total length (cm)	Total weight (g)
Alicante (AC)	RAC7	13.10	2.23
	RAC20	14.80	3.33
	RAC21	17.00	8.08
	RAC22	15.00	3.62
	RAC34	14.10	3.12
	RAC37	8.10	0.41
Mean ± STD		13.70 ± 3.02	3.47 ± 2.54
Valencia (VL)	RVL9	14.00	2.79
	RVL15	7.50	0.28
	RVL25	12.00	5.20
	RVL27	13.00	2.24
	RVL33	7.00	0.68
	RVL42	21.50	11.35
	RVL48a	18.00	7.71
	RVL48b	18.50	11.46
	RVL50	17.00	16.78
	RVL52	17.50	9.68
	RVL54	14.50	3.40
	RVL55a	18.00	6.60
	RVL55b	20.00	8.45
	RVL58	16.00	4.59
Mean ± STD		15.32 ± 4.31	6.52 ± 4.71

STD = standard deviation

**Figure 2.** A) *Parastichopus regalis* hosting two *Carapus acus* individuals; B) *Carapus acus* attached to the sea cucumber's respiratory trees.

host (Fig. 2), in two sea cucumbers from around Valencia (sample codes RVL48 & RVL55). The size and weight of each member of the pair were compared: one pair measured 18 cm and 18.5 cm, and 7.71 g and 11.46 g, and the other pair measured 18 cm and 20 cm, and 6.6 g and 8.45 g. Therefore, both couples could be considered adults, although their sex determination was not possible due to the preservation status of their gonads. The reproductive behaviour among the Carapini tribe has never been described in detail but different elements suggest that coupling could occur inside sea cucumbers. In the wild, several individuals per host have been found, and these were sometimes adult carapids of the opposite sex. The presence of sexual pairs suggests that sea cucumbers could serve also as breeding sites (Eeckhaut et al. 2004); reproduction occurring in the respiratory trees would greatly favour the gametes meeting and the adults and their eggs could be temporarily sheltered from predators during fecundation (Parmentier and Vandewalle 2005). The *C. acus* reproduction has been recorded in July–September (Trott and Olney 1986). Maybe the couples sampled by us during the summer, were breeding inside the *P. regalis* individuals, considering that the fish were identified as adults according their length and weight, and were caught during their reproductive season.

Dimensional relationships were tested comparing host weight versus fish length (Fig. 3). Due to the natural contraction behaviour of sea cucumbers, weight was considered to be a better parameter for establishing size relationships among sea cucumbers and fish. The correlation between fish length and host weight was not high or significant and, therefore the fish probably does not choose its host in relation to its size.

Specimens of *C. acus* with similar dimensions were investigated by x-ray analysis in order to count vertebrae. Similar size fish were used in order to avoid mistakes

caused by different developmental stages. Usually, the calcification process is weaker in the distal part of the organisms, and therefore, vertebrae counts were less accurate in the tail region. The number of vertebrae ranged from 84 to 92 (Fig. 4). The body curvature displayed by fish differs remarkably among species, but some non-muscular features (e.g. number of vertebrae) are known to influence axial flexibility, especially in *Carapus* spp. fish (Schwarz et al. 2012).

In conclusion, *C. acus* was found only in individuals of *P. regalis* although more than 1,800 samples belonging to 6 different sea cucumber species were examined. Further studies using molecular markers will allow us to improve our knowledge of this species, particularly with regard to its genetic connectivity and diversity and possible links with its hosts.

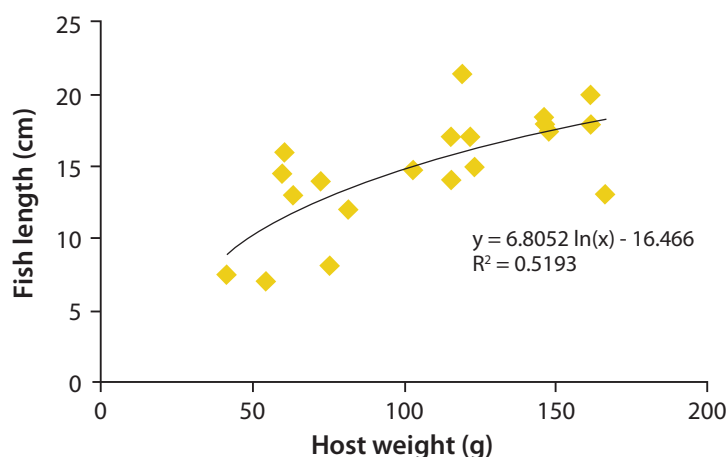


Figure 3. Regression among sea cucumber weight (g) and fish length (cm).



Figure 4. Skeleton of *Carapus acus* using Kodak DXS (digital x-ray).

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Beche-de-mer trade statistics for Hong Kong in 2012

Chantal Conand^{1,*}, Stanley Shea² and Allen To³

Sea cucumbers are presently overfished and proper management of this resource is urgently needed (Purcell et al. 2013). The availability and quality of major market statistics are important tools for understanding the evolution of sea cucumber exploitation and trade routes (Conand 1993; Jaquemet and Conand 1999). Hong Kong is considered to be the major trade hub for the trade in sea cucumbers and as such, plays an important role in the import and re-export of dried sea cucumber product (referred to as either beche-de-mer or *trepan*). Following the recent paper by To and Shea (2012) on the patterns and dynamics of the beche-de-mer trade in Hong Kong for over 16 years (from 1996 to 2011), this paper presents the latest available data for 2012. The statistics are extracted from the database of the Census and Statistics Department of the Government of Hong Kong (Special Administrative Region). Table 1 presents the code and description of the imports and re-exports (exports are not taken into account here, as only negligible quantities are presented).

It is important to note that these codes have recently changed, but unfortunately the data are not presented by species. Table 2 presents the quantities (in kg) imported into Hong Kong and the countries of origin (when more than 1,000 kg are reported).

The code 03081990 corresponds to traditional beche-de-mer, and deserves more attention because in the other categories the weights are subjected to variations. It corresponds to the former code 03079930, which was used in To and Shea (2012).

Imports in 2012 totalled 5,121 tonnes (t) and re-exports totalled 4,644 t, which shows a decrease from previous data. In total, 59 countries export volumes of over 1 t to Hong Kong; the main countries in order of importance are Japan, Philippines, Indonesia, Fiji, USA and Madagascar. In the previous study, the order was Indonesia, Philippines, Papua New Guinea, Fiji and Japan, which indicates important changes.

Re-exports concern mostly Việt Nam, which was already mentioned in the previous study but which deserves more attention, as this has been apparent from the statistics since 2002 and remains unclear. From the other categories presented in the statistics, the importance of imports from Mexico and Peru seems to be increasing. Singapore and Taiwan still appear as markets exchanging products with Hong Kong as was described by Conand (1993) and Jaquemet and Conand (1999). China (mainland) remains a major importer of frozen and smoked products (code 03081910), but its importance has decreased during the last period.

Table 1. Hong Kong beche-de-mer codes of imports (country of origin), re-exports (country of consignment) and exports in 2012.

Live animals; Animal products (Chapters 1–5)	
HKHS Code	Commodity description (shown by common product name)
03081110	Sea cucumbers (<i>Stichopus japonicus</i> , Holothurioidea), for cultivation
03081190	Sea cucumbers (<i>Stichopus japonicus</i> , Holothurioidea), live (other than those for cultivation), fresh or chilled
03081910	Sea cucumbers (<i>Stichopus japonicus</i> , Holothurioidea), frozen, including those smoked
03081990	Sea cucumbers (<i>Stichopus japonicus</i> , Holothurioidea), dried, salted or in brine, including those smoked
Prepared foodstuffs; Beverages, spirits and vinegar; Tobacco (Chapters 16–24)	
HKHS Code	Commodity description (shown by common product name)
16056100	Sea cucumbers, prepared or preserved

¹ Laboratoire d'Écologie Marine (Ecomar), La Réunion University, and MNHN, Paris, France.

² BLOOM, c/o ADM Capital Foundation, Suite 2406, 9 Queen's Road, Hong Kong

³ World Wildlife Fund 15/F, 8 Kwai Cheong Road, Hong Kong

* Corresponding author: conand@univ-reunion.fr

Table 2. Statistics for sea cucumbers (in kg) in Hong Kong for 2012 (see Table 1 for categories).

Main countries	Category 1190		Category 1910		Category 1990		Category 6100	
	Imports	Re-exports	Imports	Re-exports	Imports	Re-exports	Imports	Re-exports
Total 2012	125,325	44,883	2,743,383	1,675,963	5,121,071	4,644,853	20,656	174
Australia and Oceania					78,199			
Australia			232,442	232,442	76,185	3,045		
Canada	2,496	173	922,101	3,720	104,504	13,131		
Chile	3,135				2,894			
China mainland			254,690	691,670	65,904		14,000	
Croatia					2,894			
Cuba					7,096			
Djibouti					2,748			
Dominican Republic					6,209			
Egypt					45,427			
Fiji					390,221			
Gabon					1,115			
Guatemala					1,150			
Greece					14,367			
Haiti					32,157			
Honduras			33,433					
Iceland			104,940					
India					4,317			
Indonesia					419,483			
Jamaica					2,500			
Japan	23,052		430,977		561,481			
Kenya					20,672			
Korea			21,345		154,853	63,988		
Kiribati					76,778			
Macao						7,393		
Madagascar					311,664			
Malaysia			3,327		38,867	3,256		
Maldives					109,478			
Marshall Islands					48,659			
Mauritania					41,077			
Mauritius					8,382			
Mexico	13,267		121,736		208,549		6,420	
Micronesia*					26,675			
Morocco					9,697			
Mozambique					15,033			
Netherlands			6,400					
New Zealand					2,540			
Nicaragua					6,804			
Pakistan			2,685	4,906				
Panama					20,348			
Peru					214,942			
Philippines					459,112			
Russia					111,741			
Saudi Arabia					22,160			

Main countries	Category 1190		Category 1910		Category 1990		Category 6100	
	Imports	Re-exports	Imports	Re-exports	Imports	Re-exports	Imports	Re-exports
Senegal					1,940			
Seychelles					100,671			
Sierra Leone					10,270			
Singapore			16,500		104,792	26,103		
Solomon Islands					5,679			
South Africa					1,099			
Sri Lanka					246,651			
Sudan					5,258			
Taiwan			23,087	125,013	119,253	149,492		
Tanzania					74,297			
Thailand					47,200	6,903		
Tonga					67,677			
Tunisia					2,119			
Turkey			79,915		24,636			
United Arab Emirates					5,606			
Ukraine					6,613			
Uruguay					1,056			
USA	82,203		464,224	55,683	330,645	15,986		154
Việt Nam		44,710		769,480	2,278	4,353,787		
Yemen					228,312			

* Micronesia = Federated States of Micronesia and Palau
USA = United States of America

A few photos were taken by Kathleen Ho in the Sheung Wan area where the dried seafood street (Des Voeux Road west) is located (Figs. 1 and 2). Drying products in the street occurs occasionally year-round, possibly because the imported product

was not up to the dried standard or because of Hong Kong's relatively humid weather. The authors noted that the quantities of products drying on the street seemed greater than ever before, perhaps because of the approaching Chinese New Year festivities (Fig. 3).



Figure 1. Beche-de-mer in Hong Kong: drying in Des Voeux Road west (left) and in a shop (right). (Images: Kathleen Ho/BLOOM)



Figure 2. Beche-de-mer sold in shops, with some prices (in HKD⁴) displayed. (Images: Kathleen Ho/BLOOM)



Figure 3. Advertisement for discounts on Japanese beche-de-mer for the Chinese New Year. (Image: Kathleen Ho/BLOOM)

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⁴ HKD 1.00 = USD 0.13 (as of March 2014)

Alternative product forms, consumer packaging and extracted derivatives of tropical sea cucumbers

Steven Purcell^{1,*}, Poh Sze Choo², Jun Akamine³ and Michael Fabinyi⁴

Abstract

Sea cucumbers have been traded in their dried form, called beche-de-mer or trepang, for centuries. Beche-de-mer is relatively non-perishable and can be transported without refrigeration for long durations, and stockpiled for a year or more. With improved shipping and air freight possibilities, new product forms have appeared in the Asian marketplace. In addition, modern packaging of dried and semi-processed sea cucumbers to attract specialty and household consumers is now commonplace. We provide an exposé of a range of modern product forms and packaging of tropical Indo-Pacific sea cucumbers from various markets. The trade in dried products is still expansive although more non-dried, ready-to-cook sea cucumber products are now widely accepted, with packaging tailored for sale to household Asian consumers in supermarkets and stores. Sea cucumbers, especially those in the genus *Stichopus*, are also used to create a wide range of tonics that are favoured by Malay-speaking countries. For most products, important features are attractive packaging and clever marketing that boasts health, beauty, food safety and authenticity of the sea cucumber products. Most modern product forms will not be options for small-scale fishers but could improve profits for organised export companies. In certain cases, mariculture programmes for tropical sea cucumbers will need to seize these new market opportunities to achieve profitability.

Introduction

Sea cucumbers have long been fished and exported as dried, non-perishable products. The dried form of sea cucumbers is called beche-de-mer in the Pacific and Indian Ocean, trepang in Indonesia and northern Australia, and balat in parts of Malaysia and the Philippines (Akamine 2013). In recent times, several factors have opened opportunities for the trade of new product forms and ways to market sea cucumbers: 1) better shipping of frozen products; 2) affluence of middle and upper-class Chinese who can now afford sea cucumbers more regularly; and 3) a shift in consumer culture in China and other Asian societies towards supermarkets that have the facility to import and sell perishable forms of seafood.

Beche-de-mer in bulk (sacks containing about 40 kg of product) still dominates trade volumes (To and Shea 2012). It appears that a significant proportion of that volume is eventually bought by restaurants, which would not especially be attracted by consumer-friendly packaging and household quantities. While the trade of dried sea cucumbers

in bulk will remain dominant for some time to come, the surge in the demand for small-volume packages of consumer-friendly product presents opportunities worth consideration.

Sea cucumbers have been eaten for centuries by Chinese people for their supposed health benefits (Fabinyi 2012). Recent scientific studies have confirmed that a range of sea cucumber species do have both dietary components (e.g. protein and essential amino acids) and bioactive compounds (see Bordbar et al. 2011 for a review). In recent years, research into the medicinal values of such compounds from sea cucumbers has proliferated in the scientific literature, much more so than biological and ecological studies. Hence, health products from sea cucumbers may be gaining credibility and the trade of such products could offer important options for value-adding of sea cucumbers fished from tropical countries.

In this article, we expose a range of “new” product forms for tropical sea cucumbers from a variety of localities. We finish with a discussion of these

¹ National Marine Science Centre, Southern Cross University, Coffs Harbour, Australia

² Asian Fisheries Society, Laboratory of Marine Biotechnology, Institute of Bioscience, University Putra Malaysia, Selangor, Malaysia

³ Department of Sociology, Hitotsubashi University, Tokyo

⁴ ARC Centre of Excellence for Coral Reef Studies, James Cook University, Townsville, Australia

* Corresponding author: steven.w.purcell@gmail.com

trade opportunities and whether any of them can be realised by artisanal fishers, processors or aquaculture programs in developing countries and island states in the Indo-Pacific.

Gift boxes



Dried *Stichopus naso* (apparently) in gift boxes of 350 g in a store in Chinatown, Sydney, Australia. Retail price is AUD 88 (USD 80) per box. (Photo: S.W. Purcell)



Dried, medium-sized sandfish, *Holothuria scabra*, in 1 kg gift boxes in a store in Haymarket, Sydney. Retail price is AUD 450 (USD 410) per box. (Photo: S.W. Purcell)

Frozen products



Frozen, gutted sea cucumbers unpackaged in a supermarket in Guangzhou (Canton), China. Customers scoop as many as they want into bags and pay by weight. (Photo: S.W. Purcell)



Frozen, gutted *Parastichopus californicus* unpackaged in a seafood market in Beijing, China. Customers scoop as many as they want into bags and pay by weight. (Photo: M. Fabinyi)



Medium-small frozen *Holothuria scabra* in bags in a store in Chinatown, Sydney, Australia. These sandfish most likely come from one of the fisheries in Australia. The sea cucumbers were probably gutted and cooked once, then vacuum-packed in bags. The product is vacuum packed in plain bags with a simple label. Retail price is AUD 25 (USD 23) per 500 g bag. (Photo: S.W. Purcell)



Frozen *Actinopyga spinea* in bags in the frozen seafood section of a supermarket in Guangzhou (Canton), China. The sea cucumbers were probably gutted and cooked once, then vacuum-packed in bags. Retail price is 188 Chinese Yuan (USD 31) for a 400 g bag.



Backside of package of frozen *Actinopyga spinea*, providing information about the product and several suggested ways of cooking the sea cucumbers, written in Chinese at the left and English at the right. (Photos: S.W. Purcell)



Frozen *Stichopus horrens* in a bag in the frozen food section of a supermarket in South Korea. The product was probably boiled once then placed in bags and frozen. It was marketed as “hwangoksam” (yellow jade sea cucumber). Koreans are avid consumers of *S. horrens* and apparently prefer those exported from the Philippines. The bag had 13 sea cucumbers for a weight of 1.6 kg and retailed for KRW 20,000 (approx. USD 19). (Photo: J. Akamine)

Vacuum-packed products



Left: Vacuum-packed *Stichopus hermanni* in a retail store in Hong Kong. The product was semi-processed (cooked once) and not refrigerated.

Right: backside of package with Chinese text referring to product origin (Australia), details of how to prepare the sea cucumber for cooking, and examples of cooking methods and recipes. (Photo: S.W. Purcell)



Isostichopus fuscus in a transparent plastic box in the frozen seafood section of a supermarket in Beijing. Each specimen is individually vacuum-packed, and has been cooked once so they only require reheating. The product sold for CNY 288 (USD 48) for 300 g. They are marketed as “non additive” and “chemical free” to assure consumers that no additives have been used to artificially increase the reconstitution ratio of the product. (Photo: M. Fabinyi)



Frozen and vacuum-packed *Isostichopus badionotus* on sale in a store in Beijing. The packet reads in Japanese, “South American sea cucumber”. Price is CNY 120 (approx. USD 20) for 500 g. They only require reheating, so they are likely to have been cooked once before packaging. (Photo: M. Fabinyi)

Extracted products of sea cucumbers



Gamat water. Believed to heal wounds, reduce swelling, increase appetite, enhance blood circulation and maintain good health. Made at Langkawi and produced by simmering whole *Stichopus* sp. sea cucumbers in water for three days. When preparing gamat water from fresh whole sea cucumbers, the sea cucumbers are allowed to simmer over a low flame for three days without adding water. This pure liquid is then diluted with water and marketed as gamat water. The tonic is supposed to be consumed twice a day, 30 mL each time. Price USD 4 for 200 mL. (Photos: P.S. Choo)

Gamat jelly. Believed to improve general health. About 10 mL of the jelly is mixed with fruit juices, cold or warm water, and taken twice a day; 10 mL of jelly contains 3.48 g of *Stichopus herrmanni*. Price USD 18 for 350 mL. (Photo: P.S. Choo)



Essence of fish and sea cucumber. Believed to help maintain health and energy. Extracted from fresh fish and sea cucumber. Adults and children over 12 years of age drink one bottle (75 mL) a day and children 12 years and under drink ½ bottle (35 mL) a day. Price USD 12.50 for 75 mL. (Photo: P.S. Choo)



Sea cucumber emulsion. Ingredients: sea cucumber (*Stichopus* sp.) extract, honey, omega 3 fatty acid, L-arginine, D-alpha-tocopherol, L-glutamine, chlorella, vitamin B6, vitamin B1, beta-carotene, collagen. Believed to help in wound healing (including gastric wounds), treat haemorrhoids, asthma and diabetes, lower blood pressure, increase blood circulation, nourish the skin, reduce joint and bone pains, and increase libido. Consumed as a tonic; 1–2 tablespoons for adults before breakfast and dinner. Price USD 33 for 500 mL. (Photo: P.S. Choo)



Sea cucumber (gamat) soap. Pictured like an aquatic super hero, the sea cucumber *Stichopus herrmanni* is used to make this fine soap. It costs MYR 15 (USD 4.5) for a 70 g bar. (Photo: J. Akamine)



Two bars of sea cucumber soap sold in a shop in Kota Kinabalu, Sabah, East Malaysia. Each bar is about 70 g and sells for USD 4. They claim they are made from extracts of *Stichopus horrens*. (Photo: J. Akamine)

Discussion

Product forms for whole sea cucumbers

The market for sea cucumbers in China and other Southeast Asian countries has become open to a wider range of sea cucumber product forms. Frozen sea cucumbers are now commonplace in supermarkets in China and other countries such as Korea and Việt Nam. It appears that the sea cucumbers are already cooked once before packaging and the consumer needs only to reheat them and serve in a dish. Low-value species may be exported and sold frozen in bulk and consumers choose quantities and pay by weight. In contrast, moderate-value and high-value species are packaged in convenient quantities for consumers and the packaging may be important to sales.

Gift boxes of sea cucumbers are most common for high-value species but medium-value species can also be packaged this way. Product shape, colour and form are paramount in gift boxes. An especially important time for gift giving is at Chinese New Year or Spring Festival. Red is frequently used as a colour in the packaging of gifts.

Products from sea cucumber derivatives

The processing of sea cucumbers as a medicinal product has come a long way. Among the Malay-speaking countries, only the *Stichopus* species are traditionally used for medicinal purposes and, strictly speaking, gamat refers to species in the genus *Stichopus*. Whereas processed gamat used to be bottled in recycled sauce bottles and marketed as “gamat water” or “gamat oil”, these products are now sold in attractive packaging of many forms. Liquid sea cucumber extracts are sold in Malaysia as an essence or in the form of jelly. In Malaysia, the products are also added into coffee powder, or processed into a product together with the snakehead fish (*Channa striatus*). Many of these products are also marketed on the Internet.

Gamat products are regarded as cures for a wide variety of ailments in Malay-speaking countries, including Malaysia, Indonesia and Brunei. Claims of medicinal benefits are mainly anecdotal (although there are an increasing number of scientific studies supporting these claims — see Bordbar et al. 2011), and include healing of wounds, promoting healing after child birth, cures for epilepsy, herpes, tuberculosis and lowering of blood triglycerides and cholesterol.

Gamat soap has gained popularity abroad, such as in Japan and South Korea, as a souvenir from Malaysia. Gamat soap is produced in both West Malaysia (especially Langkawi Island) and East Malaysia (Kota Kinabalu). The packages claim they use *Stichopus* sp. but other species are sometimes used. In Japan, sea cucumber soap using *S. chloronotus* and *Holothuria atra* from Okinawa has gained popularity among health and nature-conscious consumers, and a 90 g bar can cost about USD 35. The market appears to be open to a variety of value-added products from sea cucumbers, where “beauty” and “health” are keywords.

Producing new product forms in the Indo-Pacific

While the new product forms present opportunities for trade, we doubt that any of these can be produced directly by artisanal fishers. Freezing and vacuum packaging require equipment that is unaffordable to small-scale fishers, and the labelling and marketing of such products requires considerable investment and market contacts. Some of these opportunities will be taken up by large processing and exporting companies, who may or may not pass on improved profits to fishers.

New product forms and marketing might sway buyers in some countries to ask fishers to collect certain sized sea cucumbers or certain species. Demand may increase for certain *Stichopus* species

in artisanal fishers such as those in the Indo-Pacific region if traditional tonics or other products begin to be produced. Such changes in fisheries would need to be monitored and watchfully managed by resource managers.

Our article has two important implications for aquaculture. First, aquaculture programmes should seriously look at processing and selling their sea cucumbers for consumer packs (e.g. bags of frozen sea cucumbers or gift boxes) to improve profitability. This is especially true in places such as New Caledonia, where high operating costs make aquaculture profitability marginal (Purcell et al. 2012). Indeed, this is where aquaculture farms should have an advantage because the animals can be harvested at optimal sizes for consumer packs and in a controlled manner to attain a high product quality. Second, aquaculture may move towards certain species that are favoured by Chinese household consumers or for medicinal derivatives. For example, experimental trials have started in Malaysia to develop aquaculture technology for producing *Stichopus horrens* for making gamat tonic, jelly and emulsions.

Perhaps eco-labelling of cultured sea cucumbers could improve sales but we question whether the Chinese and other Asian consumers presently buy into such marketing strategies. Consumer interest in the ecological sustainability of seafood is low in large parts of China, and is unlikely at present to be an important factor that influences purchasing decisions (Fabinyi and Liu 2014). In contrast, however, consumer interest in food safety is very high. In part due to a range of food safety scandals in China, including in the seafood sector. There is a strong suspicion about issues, including the use of antibiotics and other chemicals in the production process, and the use of materials to produce “fake” products (including shark fin and sea cucumbers) (Fabinyi and Liu 2014). Labelling strategies that stress freshness, safety and authenticity are, therefore, becoming more common in China’s seafood sector, and may be one strategy for producers and traders of tropical sea cucumbers to adopt.

Acknowledgments

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Observation of a *Chiridota* sp. juvenile in French Polynesia

Coralie Taquet¹

Species: *Chiridota* sp. (Apodida, Chiridotidae), Östergren, 1898.

Location: Pension "Rose des îles", Motu Tiapaa (16°28'22.00"S, 152°14'38.21W), Maupiti Island, Leeward Islands, Society Archipelago, French Polynesia. The climate is tropical.

Date and time: 13 August 2013, day time (10:00–10:30, local time).

Moon phase: New moon + 7 (waxing crescent).

Observer/Photographer: Alizée Taquet and Coralie Taquet (Fig. 1).

Depth and tide: About 40 cm, low tide (close to an amphidromic point).

Bottom: Sandy bottom (few meters from the beach shore).

Note: Morphology close to adult one (Samyn et al. 2006): worm-like body (cylindrical), smooth reddish translucent body without papillae but with white speckles (ossicle clusters), thin body wall, and lacking tube feet, transparent peltato-digitate tentacles (with a digit-bearing portion forming a disc) with short stalks. Body length: 3 cm.

Acknowledgements: F.W.E. Rowe, F. Michonneau, Y. Samyn and C. Conand are thanked identifying the specimens from photos.

Reference: Samyn Y., VandenSpiegel D. and Massin C. 2006. Taxonomie des holothuries des Comores. *Abc Taxa* 1. 130 p.



Figure 1: Juvenile *Chiridota* sp. observed on a sandy bottom at Maupiti Island in French Polynesia.

¹ UMR 241 Ecosystèmes Insulaires Océaniques, Université de la Polynésie Française, B.P. 6570, 98702 FAA'A Aéroport, Tahiti, French Polynesia. coralie. Email: taquet@gmail.com

Mass spawning of *Holothuria fuscopunctata* in New Caledonia

Emmanuel Tessier and Philippe Letouze

Species: *Holothuria fuscopunctata*.

Location: Tabou Reef, southwest lagoon; GPS point (WGS84): 22°28'56.35 S, 166°26'43.97 E

Date and time: 24 November 2013, 2 p.m. local time.

Moon phase: full + 7 (waning gibbous).

Observer/Photographer: Emmanuel Tessier and Philippe Letouze (Fig. 1).

Observation zone in Tabou Reef (black box).

During the nights of 16–17 and 23–24 November 2013, a mass spawning of coral and black-and-white snapper (*Macolor niger*) in spawning groups was observed in Boulari Pass and in the lagoon.

On 24 November, while scuba diving during the daytime in the western part of Tabou Reef, about 100 specimens of *Holothuria fuscopunctata* were observed releasing gametes. On the trip out at 1:30 p.m., the specimens were positioned normally on the sediment (coral sand). On the return trip at 2:00 p.m., all specimens were beginning to rise up and sway back and forth. They were in groups of two to three, about 4–5 m apart.

The spawn was released from the gonad opening located on the anterodorsal portion of the body. In each group two types of spawn were released:

- Some specimens released white filaments (that looked like poached egg whites) that dissolved fairly readily in the salt water. These were probably the males.
- Others released clouds of transparent liquid that made the sea water murky and in which you could see tiny black dots that seemed to be independent (no connective tissue). This was interpreted as eggs released by the females.

Of the four groups observed more closely, sperm was systematically released before the first eggs were, as is the case in most spawning observations.

The observations lasted about 10 minutes. At the end of the observation period, the specimens were still upright and continued to release gametes.



Figure 1: *Holothuria fuscopunctata* in spawning position.

Communications...

From: *Alexandre Ziegler*

A bit of history on the *Beche-de-mer Information Bulletin*

The *SPC Beche-de-mer Information Bulletin* (BDM) is the only echinoderm-related publication ever published in true journal format (ISSN 1025-4943). As the name suggests, BDM focuses on sea cucumbers, although its content has expanded considerably over the years. It now includes original research papers and review articles, correspondences, abstracts from publications and conference papers, bibliographies, address lists, spawning observations, market news, information on upcoming meetings and workshops, and general data on sea cucumber fisheries resource management.

The first issue of BDM was published in January 1990, the publisher being the Secretariat of the Pacific Community (SPC, formerly known as the South Pacific Commission). SPC is an international, non-profit organisation based in Noumea, New Caledonia that helps Pacific Islanders achieve sustainable development. Publication of BDM is funded by the SPC, the European Union, France, Australia, and other governmental bodies. Since 1990, SPC has published 33 issues of BDM, all of which are available for free download (<http://www.spc.int/coastfish/en/publications/bulletins/beche-de-mer.html>). In addition to the access to individual issues, a database permits searching the contents of all SPC publications, including BDM (<http://www.spc.int/coastfish/en/publications/digital-library.html>).

The decision to start the *SPC Beche-de-mer Information Bulletin* was made following a series of meetings in the late 1980s. Sea cucumbers are an important export item for many Pacific nations, and the late 1980s had seen a surge in production associated with increasing levels of imports into mainland China. This development had led to fears among fisheries experts that local Pacific resources might become unable to support such high levels of fishing pressure. The SPC workshop on Pacific Inshore Fishery Resources held March 1988 in Noumea led to the establishment of a number of networks of experts (the so-called special interest groups, or SIGs) on particular resources of interest to Pacific fisheries managers. At the 6th International Coral Reef Symposium held August 1988 in Townsville, Australia, the designated coordinator of the Beche-de-mer SIG, Chantal Conand, met with several holothurian experts and members of SPC to discuss how the exchange of ideas between them could be improved and how future collaboration could be fostered. During a business lunch, SPC announced that it would be capable of funding a journal aimed at achieving the goals of the recently founded Beche-de-mer SIG, in fact the first SIG to become installed under the SPC umbrella. A decision to circulate questionnaires among sea cucumber experts in order to gauge their interest and to identify individuals who might be able to provide future technical information on beche-de-mer fisheries was made during the SPC Regional Technical Meeting on Fisheries held in August 1989 in Noumea. About 60 colleagues responded, and consequently Chantal Conand, as coordinator of the Beche-de-mer SIG, became the first managing editor of the newly founded SPC Beche-de-mer Information Bulletin.

BDM does not constitute a peer-reviewed publication, as all contributions are sent to the managing editor, who then decides whether the article is fit for publication or not. Until issue 27 Chantal Conand acted as the managing editor, before she co-edited issue 28 together with Igor Eeckhaut, who officially became the managing editor of BDM from issue 28 onwards. Technical and editorial aspects of BDM are managed by SPC staff, in particular Aymeric Desurmont and (previously) Jean-Paul Gaudechoux. BDM is a bilingual publication: the original texts are submitted and published in English, but a full translation into French, called *La bêche-de-mer Bulletin d'Information*, is provided by SPC in addition to the English version (<http://www.spc.int/coastfish/fr/publications/bulletins/la-beche-de-mer.html>).

For some time, BDM was published twice annually (i.e. 1990, 1991, 2001, 2002, and 2004–2008), but budget cuts at SPC have led to a reduction to one issue per year from 2005 onwards. Also, printed copies were sent out free of charge to registered members of the Beche-de-mer SIG, but from issue 24 onwards, the distribution was limited to SPC member countries and territories due to budget cuts and environmental reasons. Total page numbers of BDM issues have steadily increased over time, from 14 pages in issue 1 to 76 pages in issue 32. Announcements for the next issue are usually made through the publisher's website as well as through emails sent out to contributors, interested institutions, and all members of the Beche-de-mer SIG.

BDM readership has enlarged considerably over time, now encompassing holothurian and echinoderm scientists, fisheries and coral reef managers, as well as members of various non-governmental organisations. Over the last 20 years, numerous articles published in BDM have been cited in high-ranking research papers, illustrating the importance of the work presented in the *SPC Beche-de-mer Information Bulletin*.

From: Jean Ruffez¹

In Madagascar, sea cucumber harvesting still kills compressor divers

A mission of the Francophone Association for the mutual assistance and the development of life sciences (AFEPS) recently occurred in December 2013. At the request of Grand'air, Reunion's university sports association, a technical internship (Fig. 1) was provided to about 20 students from Reunion and to Madagascar compressor divers from Antsiranana Bay (aka Diego Suarez). During this internship, AFEPS had the responsibility of teaching the students first aid specific to diving, especially the use of the therapeutic recompression by immersion (TRI), also called the "hyperbar room for the poor". This method consists of re-immersing the victim as soon as possible to a depth of 9 m for one hour, and making the victim breathe pure oxygen or, if unavailable, compressed air for a longer time.



Figure 1. Technical teaching: a) Madagascan diver; b) boat used. (Images: Jean Ruffez)



Figure 2. Diego Bay and Ramena in Madagascar.

Dive-fishing has always existed in Madagascar. It used to be performed mostly by free diving, but for a few years, fishing boats owners have equipped their boats and equipped the young divers who work for them with scuba gear. These divers have no knowledge of diving techniques. They just carry on their backs a buoyancy control device with a 12-L tank filled with air. For gear devices, they carry only regulators and manometers. Each diver uses between three and four tanks per dive, diving to depths of 40 m to collect sea cucumbers. Of course, many accidents occur. In this area, there is no hyperbaric room available. Before our arrival, we had been informed that in Antsiranana Bay (Fig. 2) there was at least one dead fisher a week.

The month of December is known as a good period for sea cucumber harvesting in this area of Madagascar. Indeed, as local fishers say, it's protected from the winds and December is the last month before the storms during which sea cucumbers hide in the mud. On the very day of our arrival in Ramena, in Diego Suarez Bay, we were informed that an accident had happened in Sakalava Bay (Fig. 2). A group of 10 fishers from

¹ Coordinator of the "Compressor divers" programme — Francophone Association for the mutual assistance and the development of life sciences; Maison des Associations, BP 1678, rue du Général-Renault — 75011 PARIS; Email: jeanruffez@noos.fr

Diego Suarez was diving to collect sea cucumbers. One of them never surfaced and his body was never found. Another diver became paralysed in his lower limbs while he surfaced; unfortunately, we could not have any contact with the victim. The worst part is that we had full TRI equipment with us, which could have been used to re-immerses the victim with pure oxygen and, therefore, avoided him being paralysed. Only four days later did the victim's brother-in-law contact us. It was too late to intervene. We wanted to contact the victim to understand the conditions in which these fishers dive and what their knowledge is of scuba diving. Unfortunately, this young diver, a 29-year old father, refused to meet us, arguing that he was ashamed of what happened to him. AFEPS is used to this kind of behaviour. It is similar to what is seen in Việt Nam (Ruffez 2008): victims think their accident is due to destiny. It's hard for them to understand what happened. Indeed, they are all used to repeating the same process every day, during each dive. So they do not understand why suddenly one day, one or two of them get paralysed or do not surface.

In Việt Nam, when we organise trainings for "first aider divers", compressor divers understand that accidents are linked to a lack of knowledge about the science of diving. As soon as they learn that accidents are actually caused by bubbles, and that if they apply the basic safety rules (slow ascent and decompression stops), they no longer have accidents. They have noticed that when someone who had a diving accident (bend or medullary accident) is quickly re-immersed with air, or preferably with pure oxygen according to the Clipperton protocol, articular pains, paralysis and sphincter troubles disappear.

The Grand'air association will continue training young Madagascan divers from Ramena village. Those divers mostly practice free diving and the training will enable them to hunt and collect sea cucumbers deeper. Yet, if we consider precautions and public health prevention, it appears that the idea that this training could be the cause of a marine resources decrease is false. Indeed, with or without training, these divers would be recruited by unscrupulous fishing boat owners who will make them collect sea cucumbers regardless of the depth. Thanks to TRI equipment and a basic training of a few first aider divers, intervention can be performed immediately after diving accidents happen, significantly reducing the rate of death and the amount of consequences. For the last three years, AFEPS's experience in Việt Nam massively proved this method with different flotillas of compressor divers from Ninh Van Bay, close to Nha Trang city, and from Ly Son Island in the center of Việt Nam (Ruffez 2008).

The TRI, Clipperton protocole, developed by Dr J.E Blatteau from the Health Service of the Naval Army's Institute (IMNSSA in French) at the occasion of the Clipperton Island expedition in 2005, is efficient. It has been proved in Việt Nam, where many compressor divers have been saved and have avoided paralysis thanks to this protocol. That is the "decompression chamber of the poor". Indeed, you just need a 40-50-L tank filled with industrial oxygen, a pressure regulator, a 15 meter-long tube and a special device, designed by Dr P. Cavenel, used to connect the tube with a Nitrox Octopus. This gear is easy to find and not very expensive in poor countries.

Re-immersion must be performed as soon as possible, before the diving accident becomes a diving disease. A DVD on first aid methods adapted to diving is delivered to trainers, who use it as a tool to teach first aid methods to divers. Three versions are available: French, English and Vietnamese. The 25-year-long experience of AFEPS enables, modestly but efficiently, the development of training among poor fishers populations, based on technical innovations derived from military research.

Yet, beyond public health matters, the environmental issue of marine resource decrease is also at stake. It raises questions about the ecological, economic and social impacts of fishing methods, and about the possible alternatives to foresee both injured and healthy fishers' reconversion. That is why AFEPS is working on another cooperative project to be carried out with local and foreign partners, for an aquaculture school/ company for the production, transformation and commercialisation of *Holothuria scabra*.

Thanks to the "Help to diving fishers in the inter-tropical zone" APP programme, AFEPS will continue contributing to the training of first aider divers and of voluntary trainers, as it was the case for the projects of diving fishers' reconversion in Việt Nam, Madagascar or elsewhere. Important needs obviously exist in many other developing countries and new initiatives have to be raised to help the most disadvantaged local populations living in vulnerable marine areas. Any voluntary competences are more than welcome to help the association and to participate to the development of these fascinating international solidarity missions.

Reference

Ruffez J. 2008. Diving for holothurians in Việt Nam: A human and environmental disaster. SPC Beche de Mer Information Bulletin 28:42-45.

From: P.A.D. Ajith Kumara¹

Recent training workshop on Artificial Breeding and Larval Rearing of *Holothuria scabra* in Sri Lanka

Sri Lanka's beche-de-mer industry has a long history, and includes around 21 commercial sea cucumber species, most of them reported to be overexploited (Dissanayake and Stefansson 2010). As in many other countries of the world, Sri Lanka started a sea cucumber seed production programme. Under this programme, which began in late 2011, sandfish (*Holothuria scabra*) was successfully bred by scientists of the National Aquatic Resources Research and Development Agency (NARA), which is the research part of Sri Lanka's Ministry of Fisheries and Aquatic Resources Development.

To disseminate this technology to interested local parties, NARA conducted a two-day residential training workshop on artificial breeding and larval rearing of sandfish at NARA Regional Research Center in Kalpitiya on 14 and 15 December 2013. Private sector participants, including hatchery owners, hatchery managers and officers from government agencies as well as non-governmental organisations, were trained through this workshop. This was the first training workshop carried out in Sri Lanka on the breeding and larval rearing of any sea cucumber species, and NARA wishes to conduct few more training sessions in 2014. This training workshop was conducted by Mr P.A.D. Ajith Kumara, Senior Scientist of Inland Aquatic Resources and Aquaculture Division of NARA and A.L.M Rifky, Officer-In-Charge of NARA Regional Research Center, Kalpitiya.



Participants with resource persons (upper left photo);
The selection of broodstock for artificial breeding (upper right photo);
Participants being instructed during a breeding session (lower left photo);
Participants being instructed on broodstock feed (lower right photo).

¹ National Aquatic Resources Research and Development Agency (NARA), Crow Island, Colombo 15, Sri Lanka;
Email: padajithkumara@yahoo.com

Abstracts and new publications...

CITES Notification (Geneva, 1 March 2013)

No. 2013/007 Concerning: *Sea cucumbers*

Convention on the International Trade in Endangered Species Of Wild Fauna And Flora

1. At its 26th meeting (AC26, Geneva, 15–20 March 2012), the Animals Committee requested the Secretariat to issue a notification drawing the attention of the Parties to publications of the Food and Agriculture Organization of the United Nations (FAO) on sea cucumbers.
2. The following provides a list of recent publications by FAO on sea cucumbers, with links to online versions:
 - 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. 425 pp.
<http://www.fao.org/docrep/007/y5501e/y5501e00.htm>
 - Toral-Granda V., Lovatelli A. and Vasconcellos M. 2008. Sea cucumbers. A global review of fisheries and trade. FAO Fisheries and Aquaculture Technical Paper no. 516. Rome, Italy: Food and Agriculture Organization. 317 p.
<http://www.fao.org/docrep/011/i0375e/i0375e00.htm>
 - Food and Agriculture Organization. 2010. Putting into practice an ecosystem approach to managing sea cucumber fisheries. Rome, Italy: Food and Agriculture Organization. 81 p.
<http://www.fao.org/docrep/013/i1780e/i1780e00.htm>
 - 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. 150 p. + colour plates.
<http://www.fao.org/docrep/017/i1918e/i1918e.pdf>
 - Food and Agriculture Organization. 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. 44 p.
<http://www.fao.org/docrep/015/i2658e/i2658e00.htm>
 - Purcell S.W. Managing sea cucumber fisheries with an ecosystem approach. 2012. Edited/compiled by Lovatelli A., Vasconcellos M. and Yimin Y. FAO Fisheries and Aquaculture Technical Paper no. 520. Rome, Italy: Food and Agriculture Organization. 157 p.
English: <http://www.fao.org/docrep/012/i1384e/i1384e00.htm>
Spanish: <http://www.fao.org/docrep/013/i1384s/i1384s00.htm>
3. The Animals Committee encourages sea cucumber range States to:
 - promote the conservation and management of sea cucumbers that occur on their territories, taking advantage of the information in the publications above and other documents available from FAO, as well as in the reports of the CITES-related workshops on Sea Cucumbers in 2003 and 2004 (see documents AC22 Inf. 1 and CoP14 Doc. 62), and other publications.

Some conferences to come

North American Echinoderm Conference, 1–6 June 2014

The conference will take place at the University of West Florida, Pensacola, FL, USA. The website is: <http://uwf.edu/naec2014>

The conference is being dedicated to the career of David Pawson. As part of the dedication, we have several student “scholarships” to help offset the cost of attending the meeting.

While the meeting is being held in North America, anyone interested in the meeting is invited to attend regardless of where you are from. Please help spread the word.

3rd Annual World Congress of Aquaculture and Fisheries — 2014 (WCAF-2014)

The meeting will be held from 16–18 October in Dalian International Conference Center, Dalian, China.

For more info please visit: <http://www.bitcongress.com/wcaf2014/default.asp>

Next European Echinoderms Conference

The next European Echinoderms Conference will take place in Portsmouth, England between 20 and 24 July 2014. We look forward to welcoming you there so please pass this message on to anyone who might be interested.

A website will be developed shortly giving details of the meeting and how to register, but for early planning registration covering all costs except the conference dinner and post-conference excursions will be around £ 110 (€ 130) and accommodation will be available in the university halls of residence bed and breakfast £ 44 (€ 51.3) per night.

Dr Andrew B. Smith FRS FRSE: a.smith@nhm.ac.uk

Books in press**I. Sea cucumbers in the western Indian Ocean: Improving management of an important but poorly understood resource**

N. Muthiga and C. Conand

2014 – *WIOMSA Book Series No. 14. viii + 74 (in press)*

Across the western Indian Ocean, the harvesting of sea cucumbers is predominantly carried out by artisanal fishers. Although sea cucumbers have been traded for centuries in the region, little is known about stocks, fishing practices and the socioeconomic factors driving this fishery. This, coupled with declining stocks led to the initiation of a three-year, multi-country regional research project funded by the Marine Science for Management programme of the Western Indian Ocean Marine Science Association. The project aimed to document and evaluate the knowledge available on sea cucumbers in the region and conduct studies to fill key information gaps in five countries Kenya, Madagascar, Reunion (France), Seychelles and Tanzania. This volume provides a summary of key research findings of the project and recommendations for the effective management of the sea cucumber fishery in the western Indian Ocean. Information is summarised in chapters discussing ecological assessments and species inventories; studies on the reproductive biology of the key commercial species; studies to assess the effectiveness of marine protected areas in the management of sea cucumbers; and studies on the socioeconomics and management of the fishery. The volume is targeted at institutions that have a stake in maintaining the long-term productivity and sustainability of fisheries and natural resources, fisheries and conservation managers, local communities that depend on these resources and donors especially those who have an interest in coastal community resource management and alternative livelihoods. The main findings of the project were that the sea cucumber fisheries in most of the studied countries continued to decline due to overexploitation and persistent and systemic governance challenges. The key recommendations detailed in this report include improving management capacity and planning, addressing the ecological and socioeconomic knowledge gaps, exploring alternative livelihoods and diversification, and improving stakeholder engagement and regional coordination. Copies of this volume can be obtained from the Executive Secretary WIOMSA (secretary@wiomsa.org).

II. FAO Publications

The two publications below are available online and hard copies are available by contacting Alessandro Lovatelli. Simply contact him and provide your contact details and mailing address and indicate what you are doing in the field of sea cucumbers. Link: <http://www.fao.org/docrep/011/i0375e/i0375e00.htm>

Sea cucumbers. A global review of fisheries and trade.

Toral-Granda V., Lovatelli A. and Vasconcellos M.

FAO Fisheries and Aquaculture Technical Paper. No. 516. Rome, Italy: Food and Agriculture Organization. 317 p. 2008.

This paper reviews the worldwide population status, fishery and trade of sea cucumbers through the collection and analysis of available information from five regions, covering known sea cucumber fishing grounds: temperate areas of the Northern Hemisphere; Latin America and the Caribbean; Africa and the Indian Ocean; Asia; and the western central Pacific. In each region a case study of a “hotspot” country or

fishery is presented to highlight critical problems and opportunities for the sustainable management of sea cucumber fisheries. The hotspots are Papua New Guinea, Philippines, Seychelles, Galapagos Islands and the fishery for *Cucumaria frondosa* in Newfoundland, Canada. Together they provide a comprehensive and up-to-date evaluation of the global status of sea cucumber populations, fisheries, trade and management, constituting an important information source for researchers, managers, policy-makers, and regional and international organisations interested in sea cucumber conservation and exploitation.

Commercially important sea cucumbers of the world.

Purcell S.W., Samyn Y. and Conand C.

FAO Species Catalogue for Fishery Purposes no. 6. Rome, Italy: Food and Agriculture Organization. 150 p. + 30 colour plates. 2012.

Sea cucumbers are harvested and traded in more than 70 countries worldwide. They are exploited in industrialised, semi-industrialised and artisanal fisheries in polar regions, temperate zones and throughout the tropics. In some fisheries, more than 20 species are exploited by fishers. The processed animals are exported mostly to Asian markets and need to be distinguished to species level by customs and trade officers. This book is intended as an identification tool for fishery managers, scientists, trade officers and industry workers to distinguish various species exploited and traded worldwide. This book provides identification information on 58 species of sea cucumbers that are commonly exploited around the world. There are many other species that are exploited either in a small number of localities or in relatively small quantities, which are not presented. Species in some regions with active fisheries are also not represented due to limited available information (e.g. Mediterranean species). The accounts are based on more than 170 reports and research articles, and by comments and reviews by taxonomists and field workers. Two-page identification sheets provide sufficient information to allow readers to distinguish each species from other similar species, both in the live and processed (dried) forms. Where available, the following information for each species has been included: nomenclature together with FAO names and known common names used in different countries and regions; scientific illustrations of the body and ossicles; descriptions of ossicles present in different body parts; a colour photograph of live and dried specimens; basic information on size, habitat, biology, fisheries, human consumption, market value and trade; geographic distribution maps. The volume is fully indexed and contains an introduction, a glossary, and a dedicated bibliography. Readers are encouraged to base their identifications on a combination of morphological features, samples of ossicles from different body parts and information on what habitat and locality the species was found.

III. A manual on hatchery of sea cucumber *Holothuria atra* in the sultanate of Oman

The manual is available for download at:

http://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CDAQFjAA&url=http%3A%2F%2Fwww.sarnissa.org%2Fdl679&ei=4q3HUoLSOq-U0QXUuYGIDQ&usg=AFQjCNGS2t22HZ3XGzrZR-rALnzWcMcm_g&sig2=EiKRE08_ncc_2kKBOZ000g&bvm=bv.58187178,d.bGQ

Oral presentations and posters from the Eighth WIOMSA Scientific Symposium held in Maputo, Mozambique (28 October–2 November 2013) communicated by C. Conand.

Oral presentations

Analysis of the incomes generated by community-based sea cucumbers farmers within an NGO–private sector partnership in the Velondriake Locally Managed Area (LMMA) in southwestern Madagascar, case of the village of Tampolove.

Razafimana H., Lanting M., Rougier A. and Harris A.

Lost values of insufficiently managed sea cucumber fishery resources.

Eggertsen M., Eriksson H. and de la Torre-Castro M.

Science to policy and the road ahead for western Indian Ocean sea cucumber fisheries management and research.

Eriksson H., Purcell S., Conand C., Muthiga N. and Lovatelli A.

Effect of the size release of sea cucumber juveniles on their survival and growth during the three first months of rearing in pens (case of Tampolove site).

Lavitra T., Tsiresy G., Rasolofonirina R., Rougier A. and Eeckhaut I.

Poverty eradication through community-led, integrated multi-trophic aquaculture of sea cucumber *Holothuria scabra* and red seaweed *Kappaphycus striatum* in Tanzania.

Mgaya Y., Beltran-Gutierrez M., Ferse S.C.A., Kunzmann A., Msuya F.E., Slater M.J. and Stead S.M.

The hidden part of the iceberg: Fifteen years of malgacho-belgian researches to sustain the development of sea cucumber farming.

Eeckhaut I., Jangoux M., Rabenevanana M.W., Rasolofonirina R. and Lavitra T.

Poster presentations

Management strategies in sea cucumber fisheries in Tanzania.

Mmbaga T. K.

Abundance and distribution of *Thallamita crenata* crabs (redoubtable predator of sea cucumber *Holothuria scabra*) in Sarodrano and Tapolove (two main sea cucumber farming villages in SouthWestern coast of Madagascar) and identification of the best trap system and bait to catch them.

Lavitra T., Tsiresy G., Rasolofonirina R., Rougier A. and Eeckhaut I.

AMPA/HOLOTHURIE: A new project funded by the Malagasy Government to promote sea cucumber farming in Madagascar.

Lavitra T., Tsiresy G., Rasolofonirina R., Rougier A. and Eeckhaut I.

The use of food compound to rear juveniles of sea cucumber *Holothuria scabra* in the external pond.

Lavitra T., Tsiresy G., Rasolofonirina R., Rougier A. and Eeckhaut I.

The holothurian (Echinodermata) biodiversity of the Scattered Islands (France, Mozambique channel): Glorioso Islands.

Mulochau T., Conand C. and Chabanet P.

Production *Holothuria scabra* seeds for farming: Experience from Tanzania.

Mmbaga T.K. and Mgaya Y.D.

Abundance and composition of sea cucumbers in Bongoyo Island, Dar es Salaam.

Kaiza V.E.

Sea cucumbers recruitment: A poorly understood stage in life history.

Conand C. and Bourjon P.

Sea cucumbers in the shallow lagoons of Mauritius: Abundance, diversity and size distribution.

Lampe K. and Moothien Pillay R.

Rehabilitation of natural stocks of the holothuroid *Holothuria fuscogilva* (Cherbonnier, 1980) at the Gulf of Aqaba, Red Sea.

Hasan M.H.

From Mercedes Gonzalez-Wanguemert: Masters theses conducted under her supervision

Fernanda Rodrigues. 2013. Role of coastal lagoon on genetic diversity: Are they hotspots of biodiversity? Msc thesis (EMBC: International Master of Science in Marine Biodiversity and Conservation). CCMAR, Universidade do Algarve (Portugal). Supervisor: Dr Mercedes Gonzalez-Wanguemert. 40 p.

Andjin Siegenthaler. 2013. Spatial distribution patterns and population structure of *Holothuria mammata* and *Holothuria arguinensis* in the Ria Formosa (Portugal). Master's thesis (EMBC: International Master of Science in Marine Biodiversity and Conservation). CCMAR, Universidade do Algarve (Portugal). Supervisor: Dr Mercedes Gonzalez-Wanguemert. 55 p.

Recent publications

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Secretariat of the Pacific Community, Fisheries Information Unit, BP D5, 98848 Noumea Cedex, New Caledonia
Telephone: +687 262000; Fax: +687 263818; cfpinfo@spc.int; <http://www.spc.int/coastfish>