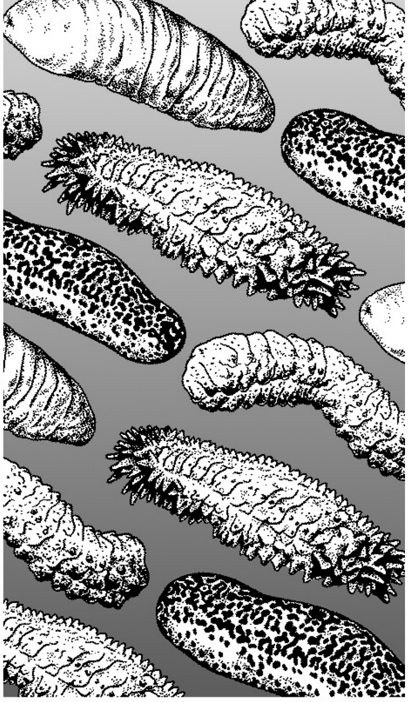

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Editorial

This issue of *SPC Beche-de-mer Information Bulletin* contains eight articles and communications from several countries. It also includes abstracts about sea cucumbers that were presented at the 14th International Echinoderm Conference that was held in Brussels in August.

The first article (p. 3) comes from Tonga. Poasi Ngaluafe and Jessica Lee analyse the change in weight of ten common commercial sea cucumbers. They discuss the possible reasons for the discrepancy they observe between their results and previous ones, and the implications for fisheries management in Tonga.

We are also very pleased to present some insights about sea cucumbers and sea cucumber fisheries in the Colombian Caribbean. The article is from the team of Adriana Rodríguez Forero (p. 9). They report on species that could be new for the Caribbean and conclude with stressing the importance of initiating a management plan for the Colombian fishery resource.

Some news also from Madagascar, where Antoine Rougier et al. (p. 14) talk about the strategies for improving survivorship of hatchery-reared juvenile *Holothuria scabra* in community-managed sea cucumber farms. Their findings indicate that technical solutions must be coupled with active management to maximise the survivorship of juveniles.

From the shallow lagoons of western and southern Mauritius, Katrin Lampe (p. 23) presents statistics on a total of 3411 holothurians, comparing their diversity and population densities in 16 survey sites that had been exploited to different degrees.

Ajith Kumara et al. (p. 30) worked on the breeding and larval rearing of three tropical sea cucumber species, *Holothuria scabra*, *Pseudocolochirus violaceus* and *Colochirus quadrangularis*, in Sri Lanka. They were successful in obtaining juveniles for the three species.

Karim Mezali and Dina Lila Soualili (p. 38) analysed the ability of holothurians to select sediment particles and organic matter. For that, observations on the digestive contents of holothurians from shallow waters in Algeria are presented. The results illustrate the diet specificity of the species.

Mercedes González-Wangüemert et al. (p. 44) assessed the *Holothuria arguinensis* populations inside Ria Formosa (South Portugal) through a volunteer programme. They found high densities but the values oscillated, depending on transects and habitats.

Kalo Pakoa and Ian Bertram (p. 49) summarise the current state of sea cucumber fishery management in 12 Pacific Island countries or territories and the various actions that are taken to establish formal fishery management frameworks.

Finally, we publish several short reports about underwater observations of spawning events of juveniles: from Rodrigue by Alexandre Bédier et al., who also synthesises data recorded in previous bulletins (p. 53); from Papua New Guinea by Jeff Kinch et al. (p. 56); and from India by Hithesh Kardani and Mayurdan Gadhavi (p. 57).

We received many communications, among which was a description of the workshop (SCEAM Indian Ocean) that was held in Zanzibar in November 2012. We would also like to congratulate Thomas Plotieau, who recently had his PhD thesis on *H. scabra*'s diet accepted. He specialised in the bacteria assimilated from the sediment eaten by this species.

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.

Pacific Islands Marine Resources Information System

Change in weight of sea cucumbers during processing: Ten common commercial species in Tonga

Poasi Ngaluafe[1] and Jessica Lee[2]*

Abstract

Accurately estimating the weight of live sea cucumber from the weight of dried beche-de-mer is important for national fisheries data, for standardising data collected from surveys or export records, and for informing management decisions and regulating fisheries quotas. Different sea cucumber species lose different proportions of their body weight through processing, so conversion ratios are best calculated on a species-by-species basis. This study measured the proportional change in weight of ten sea cucumber species in Tonga over the various stages of processing. The aim of the study was to fill knowledge gaps by providing conversion ratios for species for which no relevant data exist, such as *Actinopyga lecanora*, *Bohadschia argus*, *B. similis*, *B. vitiensis* and *Holothuria coluber*. For other species studied, the conversion ratios were compared with the ratios calculated in previous studies, with this study generally producing higher conversion ratios (i.e. less weight lost through processing). We discuss the possible reasons for this discrepancy, the implications for fisheries management in Tonga, and the need for further studies.

Introduction

Sometimes, weight data for sea cucumbers are available for only one stage of processing, whether this be the pre-processing stage (fresh weight), an intermediate processing stage or, more commonly, the fully processed dried product (beche-de-mer). Conversion ratios allow weight data to be compared using a common unit for analysis. If accurate conversion rates are available for a particular species, the processed weight can be used in order to estimate the weight (and numbers, if average weights are available) of fresh sea cucumbers that were processed.

Some previous studies have determined the average change in weight from whole, unprocessed sea cucumbers to dried beche-de-mer for several common tropical species (Conand 1990; Skewes et al. 2004; Purcell et al. 2009; Lavitra et al. 2009). However, there are still knowledge gaps for some commercial species, several of which have been addressed in this study.

In addition to differences between species, the conversion rates for the same species may vary, depending on country/location/environment, and also on the processing standards and methods used. To date, no sea cucumber weight conversion studies have been carried out in Tonga. Comparing the ratios obtained in this study to those reported in previous studies will help the Tongan Fisheries Department to decide whether the ratios currently being used for catch calculations are appropriate to Tonga.

Methods

The methods followed were based on the methods used by Purcell et al. (2009), with some variations. Length conversion information was not considered in this study, as it is not as relevant as weight conversion information for commercial export calculations in Tonga.

The study was conducted in Uiha on the island of Felemea, in the Ha'apai group of islands in Tonga. Sea cucumbers were collected by local fishers and brought to shore in tubs. A sample size of twenty-five individuals was weighed for each species, with the exception of *Thelenota ananas* (prickly redfish), with only 14 individuals recorded, and *Actinopyga* sp. (affinity *flammea*) with only two individuals recorded.

The sea cucumbers were allowed to drain for one minute before being weighed to the nearest 10 g in a plastic bag on a digital hanging scale. They were

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then gutted (although some had already excreted their viscera) in the standard manner for the processor, and were weighed again. Tags were attached by piercing the body wall and attaching numbered labels on plastic zip-ties.

The sea cucumbers were boiled, and then salted for a minimum of three days, with the time of each stage varying for different species according to the standard method of the processor. After salting, they were re-weighed, and then sundried for several weeks before being weighed a final time. The dry weight was recorded at the Fisheries Department in Nuku'alofa, Tongatapu. Figure 1 illustrates some of the stages of processing.

There were some exceptions to the above methods. *Bohadschia marmorata* (chalkfish) were collected by Fisheries staff in Tongatapu and taken to a different processor. Unlike the samples of the other species which were of commercial size, the *B. marmorata* were undersize. One consequence of this was that, once dried, many samples did not register on the hanging scale (i.e. were under 10 g), and so an electronic balance was used to record these weights. Salting is not part of the standard processing method for this species, so this stage was omitted. In addition, the *B. marmorata* in this study were oven-dried, not sun dried, due to a difference in the processing methods of the two processors and the facilities available for this study.

During weighing of the dry product (final stage), some species, the white teatfish and stonefish, were found to be rock-hard. All the other species were quite soft and dry.

Results

This study provided estimates of conversion ratios for ten species (Table 1). The proportion of weight lost at each stage of processing was calculated for each individual separately. These percentages were averaged to give the conversion ratios. This allowed standard errors to be calculated both for the mean weight and for the average percentage of fresh/whole weight represented at each stage.

Although data are provided for each stage of processing, the most relevant conversion ratio for

Figure 1. (A) Sea cucumbers brought to shore in tubs; (B) *Actinopyga* sp. (affinity *flammea*); (C) tagging of *Holothuria fuscogilva*; (D) weighing and recording; (E) boiling stage; (F) salting stage; (G) tagged samples; (H) dried product; (I) standard sun-drying procedure.

Tonga fisheries is the fresh-to-dry ratio, as most exports are in the form of dried beche-de-mer, and it is this final dried product that is weighed. However, knowing the ratio for each stage may be useful in some circumstances, such as a quantity of illegally caught sea cucumbers being discovered during the intermediate stages of processing.

Across all species, the sea cucumbers lost an average of 30% of their initial body weight when they were gutted, a further 24% of initial weight during salting, and another 34% of initial weight during the drying stage, leaving an average of 12% of the initial weight remaining at the end of the process. There was a fair degree of variation of weight loss percentages between species, with the wet-to-dry recovery rate ranging between 5% and 20% for different species (see Table 1).

Note that some specimens had already excreted their viscera when the initial fresh measurements were taken; this is likely to have affected the conversion ratios (see Table 2). Also, it should be noted that sample sizes were smaller for *Thelenota ananas* (14 animals) and *Actinopyga* sp. (two animals), so the conversion rates produced may not be as reliable for these species.

Different species varied in the proportion of weight lost at each stage of processing, as illustrated in Figure 2. The initial weight loss proportion is affected by the fact that in many cases the viscera had already been excreted before gutting (Table 2). In these cases the weight loss in the gutting stage mainly represents water loss.

Table 1. Mean body weight in g (± standard error), and mean percentage of initial whole fresh weight (± standard error), across the different stages of processing. Wet-to-dry conversion ratios are in bold.

Species and sample sizes (n)		Whole fresh	Gutted	Salted	Dried
Stonefish	Mean weight (g)	652.0 (± 39.8)	583.0 (± 21.3)	425.0 (± 14.7)	107.6 (± 19.2)
Actinopyga lecanora (25)	% of fresh weight	100.0 (± 0.0)	92.2 (± 2.4)	67.7 (± 2.1)	**17.2** (± 0.6)
Deepwater (DW) blackfish	Mean weight (g)	554.0 (± 23.1)	521.0 (± 20.5)	368.0 (± 15.0)	110.8 (± 5.7)
A. palauensis (25)	% of fresh weight	100.0 (± 0.0)	94.3 (± 0.7)	66.6 (± 0.9)	**19.9** (± 0.4)
Leopardfish	Mean weight (g)	647.0 (± 60.8)	476.0 (± 25.1)	370.0 (± 21.5)	86.4 (±6.2)
Bohadschia argus (25)	% of fresh weight	100.0 (± 0.0)	80.4 (± 3.8)	54.4 (± 5.1)	**14.3** (± 0.7)
Brown sandfish	Mean weight (g)	583.2 (± 34.8)	428.4 (± 13.0)	357.2 (± 10.8)	67.6 (±3.0)
B. vitiensis (25)	% of fresh weight	100.0 (± 0.0)	77.4 (± 3.4)	65.0 (± 3.2)	**12.2** (± 0.7)
Lollyfish	Mean weight (g)	507.6 (± 26.6)	204.8 (± 11.7)	120.0 (± 7.1)	30.8 (± 2.2)
Holothuria atra (25)	% of fresh weight	100.0 (± 0.0)	40.7 (± 1.5)	23.7 (± 0.8)	**6.0** (± 0.3)
Snakefish	Mean weight (g)	444.0 (± 24.2)	192.0 (± 9.3)	103.2 (± 6.3)	29.2 (±2.0)
H. coluber (25)	% of fresh weight	100.0 (± 0.0)	44.5 (± 1.9)	24.3 (± 1.7)	**6.7** (± 0.4)
White teatfish	Mean weight (g)	2091.0 (± 125.8)	1601.0 (± 66.2)	1241.0 (± 51.6)	384.4 (± 23.3)
H. fuscogilva (25)	% of fresh weight	100.0 (± 0.0)	79.8 (± 2.9)	61.7 (± 2.2)	**18.6** (± 1.0)
Prickly redfish	Mean weight (g)	2901.0 (± 502.9)	2179.0 (± 318.7)	1396.0 (± 222.3)	133.6 (± 23.6)
Thelenota ananas (14)	% of fresh weight	100.0 (± 0.0)	80.9 (± 4.8)	50.1 (± 3.1)	**5.1** (± 0.7)
***Actinopyga* sp.**	Mean weight (g)	1775.0 (± 565)	1155.0 (± 105.0)	760.0 (± 30.0)	205.0 (± 15.0)
Affinity *flammea* (2)	% of fresh weight	100.0 (± 0.0)	70.3 (± 16.5)	47.1 (± 13.3)	**12.5** (± 3.2)
Chalkfish	Mean weight (g)	115.6 (± 2.9)	80.8 (± 3.4)	20.4 (± 1.5)	7.2 (± 0.4)
B. marmorata (25)	% of fresh weight	100.0 (± 0.0)	69.7 (± 2.2)	17.8 (± 1.3)	**6.3** (± 0.3)

Table 2. Status of each species at the time of initial weighing (fresh stage).

All still had viscera	Some had excreted viscera	Most had excreted viscera	All had excreted viscera	Unknown status
Chalkfish	Leopardfish	Stonefish	Deepwater blackfish	*Actinopyga* sp.
Lollyfish	Prickly redfish	Brown sandfish		
Snakefish	White teatfish			

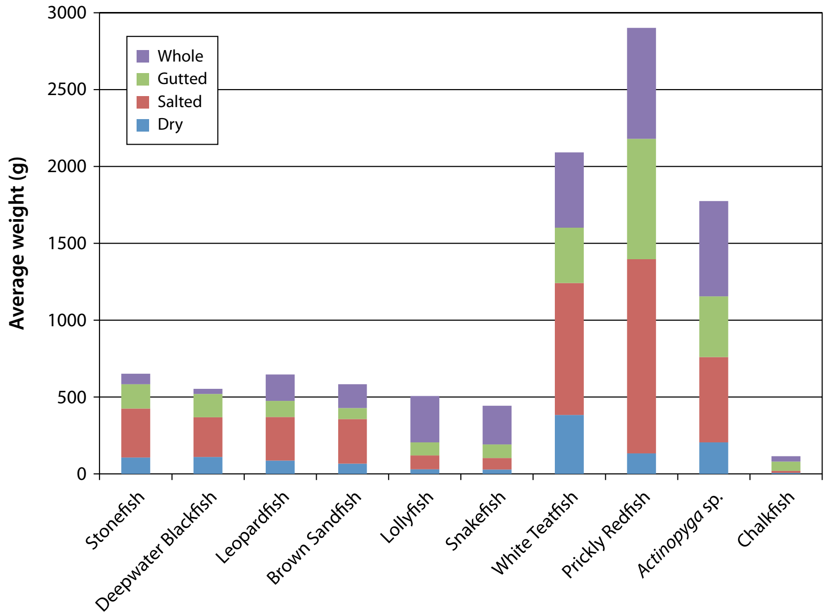

Figure 2. Average weight (g) of each species at different stages of processing.

Discussion

As expected, different sea cucumber species showed marked difference in weight loss through processing. Therefore, as other authors have noted, it is highly recommended that calculations are carried out on a species-by-species basis for the most accurate estimates of weight.

The species that lost the highest percentage of body weight in this study were lollyfish, snakefish, chalkfish and prickly redfish. This may indicate naturally higher water content, but it is also likely to be influenced by the fact that lollyfish, snakefish and chalkfish were the three species that had retained their viscera for the initial weighing, and some prickly redfish had also retained their viscera. This would have resulted in a higher initial fresh weight, making the end/dry weight a smaller proportion compared to species that were initially weighed without their viscera.

The data for chalkfish may also be influenced by other factors. The samples collected were not representative of the common size for commercial harvest, which may have a different percentage of weight loss. In addition, this species was oven-dried, while all other species in this study were sun-dried. This could also contribute to the larger weight loss.

The species that lost the lowest percentage of body weight were stonefish, deepwater blackfish and white teatfish. From observations during this study, these species seemed to have the thickest body wall, which would help explain the lower weight loss. In addition, the samples for these species all contained some individuals that had lost their viscera prior to initial weighing: some white teatfish, most stonefish and all deepwater blackfish.

In addition, in previous research, these species were boiled and dried a second and third time, as part of the processing method to improve the quality. These activities were mostly carried out by the processors as indicated in a survey documented by Purcell et al. (2012) under PARDI/ACIAR sea cucumber project. However, in this study, these species were not boiled and dried a second and third time and it was found, through observation, that a few samples, especially of stonefish and white teatfish, were rock-hard during the final weighing of the dry product. These factors may all contribute to the higher conversion ratios resulting from this study, as shown in Table 3, which provides a compilation of the fresh-to-dry conversion ratios for many sea cucumber species as calculated in previous studies.

Conversion ratios for *Actinopyga flammea* and *Bohadschia marmorata* have not been determined in previous studies, nor were there any conversion ratios for these species recommended for use by the Secretariat of the Pacific Community (SPC). *Actinopyga* sp. is not a common commercial species in Tonga. To our knowledge, conversion ratios for stonefish, leopardfish, brown sandfish and snakefish have not been determined in previous studies, but ratios have been recommended by SPC. It is unclear on which data or studies these recommendations are based. Our calculated conversion ratios for these species were at least double the ratios recommended for use by SPC. Ratios from previous studies and SPC ratios were available for deepwater blackfish, white teatfish, lollyfish and prickly redfish. We calculated a much higher ratio for deepwater blackfish and for white teatfish than previous studies and the SPC recommended ratios, but our ratios for lollyfish and prickly redfish are much closer to the results of previous studies and/or SPC ratios.

Overall, it seems that some of the ratios calculated in this study were comparably large, i.e. not as much weight was lost over the processing stages. There are several possible reasons for this difference. The method of drying – natural sun-drying

Table 3. Compilation of Conversion Rates (CRs) in percent (%) of total whole/fresh weight – from wet to dry product.

Species	CRs calculated in previous studies*								CRs Tonga uses (on SPC advice)	CRs calculated in this study
	1	2	3	4	5	6	7	8		
Actinopyga sp. affinity *flammea*										12.5
A. mauritiana (Surf redfish)	6.7				4.9				5.5	
A. miliaris (Blackfish)		5.6			9.7		11.5		5.5	
A. echinites (Deepwater redfish)			11.2	3.0				10.5	5.5	
A. lecanora (Stonefish)									5.5	17.2
A. palauensis (Deepwater blackfish)								11.7	5.5	19.9
A. spinea (Burying blackfish)								7.3		
Bohadschia argus (Leopardfish)									4.0	14.3
B. similis (Chalkfish)										6.3
B. vitiensis (Brown sandfish)									4.0	12.2
Holothuria atra (Lollyfish)		2.6			7.7				3.0	6.0
H. coluber (Snakefish)									3.0	6.7
H. edulis (Pinkfish)									3.0	
H. fuscogilva (White teatfish)			7.6		9.8				8.0	18.6
H. fuscopunctata (Elephant trunkfish)					9.3	12.7			10.0	
H. lessoni (Golden sandfish)								9.8	5.0	
H. whitmaei (Black teatfish)		8.7	9.8		8.1			11.6	7.0	
H. scabra (Sandfish)				5.0			5.1		5.0	
Thelenota ananas (Prickly redfish)		3.0	4.6		5.6	8.0	6.7		5.0	5.1
T. anax (Amberfish)									5.5	
Stichopus chloronotus (Greenfish)					2.7				3.0	
S. herrmanni (Curryfish)								3.3	4.0	
S. horrens (Dragonfish)										
S. variegatus (Variegated/Curryfish)					3.9					

* Authors (note: studies 1–6 as compiled and listed by Skewes et al. 2004).

1 Zoutendyk (1989); **2** Harriot (1984); **3** Conand (1990); **4** Shelley (1981); **5** Vuki and Viala (1989); **6** Conand (1990); **7** Skewes et al. (2004); **8** Purcell et al. (2009).

(with the exception of chalkfish) possibly results in less water loss than oven-drying. There may also be a higher variation in weight loss for sun-drying, as the results are more environmentally-dependent. For example, the week leading up to the dry weighing in this study was very wet and humid in Tongatapu, which may have meant more moisture remained in the product than at the end of a sunny dry period. Unfortunately, most previous studies do not state the drying method used, which makes it difficult to evaluate the differences in ratios found. As previously discussed, the loss of viscera prior to initial weighing is also likely to make ratios larger.

Conclusions and recommendations

The findings of this study have implications for Tonga's export calculations and fisheries management, and managers may need to consider amending the SPC recommended ratios that are currently being used for more accurate calculations and reporting. The ratios calculated in this study are at least double the SPC recommended ratios, with the exception of the prickly redfish ratio.

If our findings do represent the average proportionate weight loss for the species studied within Tonga, then using the SPC rates for conversion (from dried to fresh product) would result in an overestimate of the weight (and numbers, based on the average weight of an individual animal) of freshly caught sea cucumbers. If resources permit it, it would be beneficial to replicate this study using a different location and processor, and to compare the results to the ratios determined in this study. Due to the large differences found between this project and previous studies for several species it would be beneficial to include some other common commercial species in Tonga that were not examined in this study, as they may vary significantly from the recommended ratios currently being used.

If further studies are carried out it is highly recommended that researchers collect their own samples so that sea cucumbers can be weighed fresh before they lose their viscera and excrete excessive water, or alternatively arrange with fishers for animals to be brought for weighing as soon as possible so they do not spend several hours in a warm crowded tub, increasing the chances of viscera loss. Further research into how widely processing methods vary within Tonga, especially with regard to drying methods, would be beneficial, as it may be the case that conversion ratios are significantly different for oven dried product and sun-dried product. A brief survey of the number of processors use oven drying method, for example, and any other potentially significant differences in processing methods and standards (number of weeks of sun-drying etc.), would contribute to a more accurate idea of the suitability of particular conversion ratios, and would be unlikely to require extensive time or resources to complete.

Other issues to consider for the improvement of this study as indicated by socio-economic survey results conducted by Purcell et al. (2012), include some of the high- and medium-value species (i.e. white and black teatfish, stonefish, surf redfish, etc.) had to be re-boiled and re-dried a second or third time in some stages to improve quality.

Acknowledgements

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First insight into Colombian Caribbean sea cucumbers and sea cucumber fishery

Adriana Rodríguez Forero[1], Wensy Vergara Hernández[1] and Vianys Agudelo Martínez[1]*

Abstract

Sea cucumbers are invertebrates that have been marketed legally and illegally for years in Colombia. Little is known of these species, and there is hardly any biological, ecological or market information on the population of the species under commercial exploitation. We present information on the sea cucumbers of the Caribbean coast of Colombia, with data on the fishery, fishermen, trade, species of interest, nutritional contents and reproductive characteristics. We report new species for the Caribbean and conclude with the importance of initiating a management plan for the Colombian fishery resource.

Introduction

As is well known, in many Asian countries sea cucumbers are considered a delicacy. *Trepang* or dried holothurians have been sold for over a thousand years, (a) as a food because of their high-protein content (up to 50%), (b) for pharmaceutical and medical treatment and (c) as an aphrodisiac, as they are considered the *Ginseng* of the sea. Asians believe that the daily consumption of sea cucumbers keeps them healthy. Due to overexploitation, the fishery has expanded to other regions, such as the Galapagos Islands, Chile, Russia and the Caribbean. In the Colombian Caribbean, sea cucumbers have been captured illegally in large numbers on the coasts of La Guajira, Magdalena and Bolivar for about a decade, causing intense pressure on the resource (Fig. 1). This resource is sold by artisanal fishermen at negligible prices (USD 0.5 unit^{-1}, or USD 1–3 kg^{-1}), despite having a high value on the international markets.

Little is known about the sea cucumber species in the Colombian Caribbean, and the dearth of knowledge on species, biology, population dynamics, fisheries management and production in captivity, along with the potential for commercialisation in international markets, indicates the need to begin the development of aquaculture with the aim of: (i) establishing an option of new activities for artisanal fishermen and the regional aquaculture private sector; (ii) diversifying marine aquaculture and possibility re-using abandoned aquaculture facilities; (iii) increasing scientific knowledge; and (iv) establishing programmes for the conservation of endangered and threatened species.

We present recent findings made by the Group for Research and Technological Development in Aquaculture of the University of Magdalena (Santa Marta, Colombia), who have been working on acquiring knowledge of some native species, their fisheries and aquaculture technology. One of the main projects was funded by Colciencias and the University of Magdalena.

Figure 1. Map of Colombia (http://www.worldatlas.com/webimage/countrys/samerica/co.htm).

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Colombian Caribbean sea cucumber fishery

Sea cucumber management in Colombia is inadequate, and in the long term it may threaten the preservation of the species, as has happened in other countries. Currently, there are no studies on population dynamics, ecology, trade or biology of the native species. Since 2005, however, there have been unofficial reports of sea cucumber production. For example, in 2005, 1.646 kg of dry weight sea cucumbers were exported. According to Toral-Granda (2008), in Colombia the fishing of sea cucumber is illegal, is not reported, and is not regulated. In turn, Colombian species are not included in the Convention on the International Trade in Endangered Species (CITES) list or in the Colombian *Red book of invertebrate marine species threatened, vulnerable or endangered*. This does not mean, however, that they are not at risk.

Less than ten years ago, state agencies approved the fishing of species that inhabited shallow water in the Colombian Caribbean and Pacific region. In 2005, commercial exploratory fishing (500 tonnes year^{-1}) of sea cucumbers was allowed by the environment authorities (Ministry of Environment and Sustainable Development) and the fisheries institution (Colombian Institute for Rural Development). At the time, the state agencies had no idea of the targeted species harvested and did not clearly identify criteria for their exploitation (Gutiérrez 2010): they permitted relatively indiscriminate fishing that destroyed much of the fishery resource.

Fishing fleets, mainly Asian, arrived in the Colombian Caribbean. They hired local fishermen and paid them USD 45 per day to collect as many as they could in the working day. There are informal records about the extraction of one tonne of sea cucumbers per day to export to Korea and Japan: In the Guajira, fishermen collected up to one tonne of *Isostichopus* sp. daily, using shovels normally used to extract salt. The fishermen said that on the beaches of the north coast (Guajira Peninsula), sea cucumbers were grouped in columns up to 80 cm in height. One time the Colombian National Navy seized a ship that had 15 tonnes of sea cucumbers, extracted during a short fishing trip that lasted six days.

After the state agencies noticed the problem of the overexploitation of fishery resources, sea cucumber was listed as hydrobiological and the Ministry of Environment confirmed the prohibition on fishing for sea cucumber for commercial and scientific purposes. According to the Code of Renewable Natural Resources and Environmental Protection, a hydrobiological species in Colombia is defined as "the set of plant and animal organisms whose life cycle is fulfilled totally inside the aquatic environment, and their products". Today, only government authorities directly involved in research activities can explore this resource. The commercial harvest of sea cucumbers is totally prohibited.

Sea cucumber fishing model in Taganga (north coast of Colombia)

Taganga is a coastal region that is characterised by the presence of fishermen who have exploited marine resources as a main source of income for centuries (Fig. 2). Its population is estimated at 4200 inhabitants, of whom 19% are active fishermen. Much of the population is made up of women who devote themselves to the commercialisation of the products of the fishing. The quality of life of the population is low; there is a lack of basic human needs, such as water, shelter, infrastructure, access to education, healthcare and employment.

Figure 2. Taganga Bay (Picture by Mendoza Y.).

There are five legal fishermen's organisations in Taganga with a total of 400 members. The other 400 fishermen practise their profession without the support of a formal organisation. Fishing takes place in Taganga (Magdalena) and Cabo de la Vela (La Guajira) (11°16.04′ N, 74°11.24′ W and 12°12.27′ N and 72°10.22′ W, respectively). The fishing fleet consists of 80 vessels, ranging from good quality vessels to primitive, homemade canoes and boats, some with inboard or outboard motors. The main fishing activity involves using *ancones chinchorreros* (a kind of fishing net), but gill nets and longlines are also used for capturing commercial species: fish of the families Carangidae, Scombridae (tuna), Lutjanidae (snappers) and Serranidae (groupers), which have a high commercial value in domestic and international markets.

Sea cucumber fishery is rudimentary: it is performed by free divers. Divers have basic gear consisting of a mask, a snorkel, fins and a marker buoy. They follow the "footprints" of holothurians and easily capture them. They catch between 20 and 80 sea cucumbers in six to eight hours. In one day they can fill seven or eight containers of 20 litres capacity, corresponding to approximately 40 kilos in each one. Currently, fishermen catch only on request as long as the amount they receive from buyers is enough to be "correctly paid" (USD 3 kg^{-1}).

Sea cucumbers are traded in two ways, described below.

(1) On the beach, the fisherman keeps the sea cucumbers in the container until they have expelled all the water from their bodies. He empties the water out of the container until the sea cucumbers remain dry. Once dry, the fisherman weighs the product. It has been established between the fisherman and the buyer (Asians usually), that he discounts a kilo from the total weight and this final weight is the one that the buyer will use to pay to the fisherman.

(2) The fisherman and his wife process the sea cucumbers: the woman washes them in a plastic bowl full of freshwater, then they are cooked on wood stoves placed on the beach and finally they are dried on the roof of their houses. A few days later the buyer weighs and pays for the sea cucumbers and sends them directly to Asians countries.

Fishermen say that Korean and Japanese consumers prefer to buy sea cucumbers from the Magdalena shores, because they taste better than the ones from La Guajira as they remain sheltered on coral surfaces and have different feeding habits.

Commercial species

Official export data are unavailable. In Colombia, studies on sea cucumbers are scarce and refer to the distribution and taxonomic identification. One such is that of Caycedo (1978) who defined the biological classification, habitat and ecology of 14 species of shallow water holothurians on the northern coast of Colombia, including their description and taxonomic keys for identification. The material was collected in Rosario Islands (10° 08.39′ N and 75° 43.21′ W) and Tayrona National Park, northeast of Santa Marta (11° 20′ N and 74° 05′ W). Ten of the species found were new to Colombia – *Isostichopus badionotus*, *Astichopus multifidus*, *Holothuria* (*Thymiosycia*) *impatiens*, *H.* (*Thymiosycia*) *arenicola*, *H.* (*Halodeima*) *grisea*, *H.* (*Halodeima*) *floridana*, *H.* (*Halodeima*) *mexicana*, *H.* (*Selenkothuria*) *glaberrima*, *H.* (*Semperothuria*) *surinamensis*, *H.* (*Platyperona*) *parvula* – and one of these was new to science: *H.* (*Thymiosycia*) *thomasi* sp. *nov.*

Another study is that of Borrero-Pérez et al. (2003), who caught 259 holothurians (Invemar-Macrofauna expedition I), which were distributed in four orders, five families, eight genera and 15 species (with one subspecies). Most of them were recorded for the first time in Colombian Caribbean and ten species are distributed in the Caribbean Sea and in the West Indies. Five species, however, were recorded for the first time in the mainland towns of the Caribbean: *Holothuria* (*Vaneyothuria*) *lentiginosa enodis*, *Amphigymnas bahamensis*, *Mesothuria gargantua*, *Enypniastes eximia* and *Molpadia barbouri*.

Isostichopus badionotus

Our findings confirm the presence of *Isostichopus badionotus* (Selenka, 1867) in the shallow waters of Rodadero beach, Bay of Santa Marta (11°13′22.73″ N – 74°13′32.59″ W), in beaches near the Simón Bolívar Airport (11°09′23.48″ N – 74°13′41.65″ W) and in Taganga bay (11°15′54″ N – 74°12′40″ W). Their habitat is sand or mud. The species presents distinctive taxonomic characteristics: diverse brown colouration, numerous conical warts, twenty peltate tentacles in the buccal area, paired gonads and tubular feet. The presence of spicules prompted us to confirm the species (Fig. 3 and 4). This species is captured in the daily work of the fishermen who sell them to illegal traders. This is the main commercial species because of its abundance, flavour and thickness of the skin.

Figure 3. *Isostichopus badionotus*.

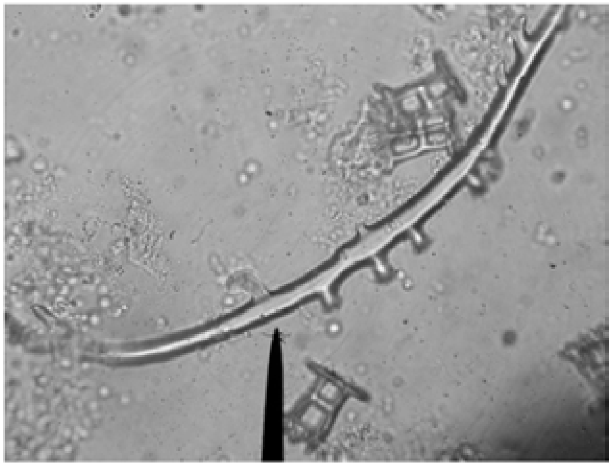

Figure 4. *Isotichospus badionotus* spicules.

During the journeys made to monitor *I. badionotus*, we detected two new species that we registered for the first time in this Caribbean zone – *Stichopus variegatus* and *S. herrmanni* – and also detected the presence of three morphotypes of the genus *Stichopus* (Fig. 5). These species are associated with rocky bottoms. They are easily caught by fishermen because of the traces they leave with their faeces. They are distinctive for their great size (1 kilo per unit), a feature that appreciates their value in the Asian market.

Figure 5. *Isotichospus badionotus* and *Stichopus herrmanni.*

Nutritional composition

Sea cucumbers are classified as commercially important, depending on species, abundance, appearance, smell, colour, thickness of the body wall and also global market demand (Purcell et al. 2012). Processed sea cucumbers are priced according to the dish and the occasion on which they are served (Lo 2004). They are first gutted, then boiled or roasted. They can be preserved by drying, smoking or freezing (Bruckner 2006). In the experience of native fishermen, market buyers prefer small species (*Stichopus* sp.), which has thinner skin, so they are a source of major earnings.

In view of the importance of knowing the nutritional properties of the sea cucumber and the lack of knowledge of these properties in the Colombian sea cucumbers, we are currently undertaking studies to assess the nutritional composition of wild and cultivated sea cucumbers. It is known that the composition of fresh sea cucumbers varies, depending on the species, age and diet. We present a table (Table 1) related to the nutritional content found in *Isostichopus badionotus* compared to the findings of Mehmet et al. (2011).

Reproductive features

Little is known about the reproductive biology of Columbian sea cucumbers. Under controlled laboratory conditions, we obtained natural spawning from *Stichopus* sp. So far we have managed to bring the cycle as far as early auricularia and started methodological adjustments to close the life cycle in captivity. Additionally, we sampled animals monthly in the wild and fixed their gonads for histological examination. We found that *I. badionotus* has a gonad structure similar to other species of the genus.

Conclusions

There is a huge lack of knowledge about Colombian sea cucumbers and therefore great potential for research in various areas related to these invertebrates. There are many species that appear to be suitable for marketing on Asian markets, as is well

Table 1. Nutritional and moisture content (in %) found in *Isostichopus badionotus* compared to the findings of Mehmet et al. (2011).

Species	Humidity	Protein	Lipid	Ash
I. badionotus (from Colombian Caribbean)	87.6	8.9	0.2	2.8
Holothurians (Mehmet et al. 2011)	82–92.6	2.5–13.8	0.9–1.5	1.5–4.3

demonstrated by the large fishing fleets and many buyers who come in search of new products. The work to be done in the near future should include a list of vulnerable species in the *Red book of invertebrate marine species threatened, vulnerable or endangered* as there is no information on the potential danger of extinction. Sustainable aquaculture of sea cucumber should be supported. Environment and fisheries authorities must implement management plans for the species and adjust the legal issues regarding the use of the species for diverse purposes.

Acknowledgments

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Strategies for improving survivorship of hatchery-reared juvenile *Holothuria scabra* in community-managed sea cucumber farms

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Abstract

Community-based aquaculture of the sea cucumber *Holothuria scabra* offers a potentially profitable and ecologically sustainable complementary livelihood activity for coastal communities in the tropical Indo-Pacific region where the species is widespread. However, *H. scabra* aquaculture remains a relatively novel practice. Early efforts to farm the species as an alternative to fishing in coastal communities have commonly faced several practical challenges that have so far prevented the commercial success of the enterprise, such as unacceptably high levels of juvenile mortality during – and even more after – the transfer of juveniles from hatchery to sea pens. This study assesses the impact on survivorship of hatchery-reared juvenile *H. scabra* of a series of technical improvements to community-managed sea cucumber farming practices in southern Madagascar. The improvements included structural modifications to farming pens, better maintenance of the pens and active management regimes that included intensive culling of predatory crabs. The impacts of these improvements on the survival of *H. scabra* juveniles are analysed over three periods spanning pre- and post-implementation phases of these strategies. Results show that, prior to improvement, average juvenile survivorship three months after transfer from hatchery to sea pens was only 40.2%; a level too low to enable the farming system to cover its costs or reach profitability. The technical improvements and active management strategies introduced increased survivorship to 76.6%, a significant jump in productivity that is expected to have significant positive economic implications for the profitability of the enterprise in coastal communities. Our findings indicate that, within community-based farming settings, technical solutions must be coupled with active management to maximise the survivorship of juveniles in the first months of the farming cycle following transfer from the hatchery.

Keywords: alternate livelihoods, community-based management, marine conservation, sustainable development, natural resource dependence, overfishing, western Indian Ocean.

Introduction

Holothurian aquaculture research and practice have seen considerable progress in recent years, a development that has coincided with broad-scale collapse of many of the world's tropical coastal sea cucumber fisheries. With collection and export markets for beche-de-mer now reaching all but the remotest tropical marine environments (Price et al. 2010; Conand 2008), increased attention is being placed on holothurian farming as a means of cultivating this valuable fisheries resource. We present an overview of juvenile mortality reduction measures that have been integrated into a system of community-based holothurian aquaculture, and discuss the implications of these measures in the context of improving the productivity and profitability of this farming technique as a means of diversifying traditional coastal livelihoods.

Developments in holothurian aquaculture

Holothurian farming at a community level is not economically feasible in many parts of the developing world, as significant capital investment is required to establish the hatcheries that supply the farms with juveniles (Eriksson et al. 2011). However, Madagascar is a pioneer country in holothurian aquaculture with a research programme that started in 1999 (Jangoux et al. 2001), which led to the creation of a commercial hatchery, Madagascar Holothurie SA (MHSA) (Eeckhaut et al. 2008). The presence of this company and its will to support local communities offer a promising opportunity to develop grow-out of *H. scabra* as an innovative economic activity for coastal villages (Eeckhaut et al. 2008; Robinson and Pascal 2009). The availability of *H. scabra* locally solves the need for the communities to invest in a hatchery that requires a considerable

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technical knowhow. Once the source of juveniles is secured, holothurian farming (the grow-out of juveniles in sea pens in natural lagoon habitat) requires an acceptable initial investment, no feeding or nutrient input, and little supervision from farmers other than in safeguarding stocks from environmental disturbances, predation and poaching.

Since 2007, sea pen-based grow-out of hatchery-reared sandfish (*Holothuria scabra*) has been trialled as an alternative livelihood strategy for fishing villages along the coast, including the Velondriake locally-managed marine area (LMMA), a 800 km^2 community-managed marine conservation area (http://www.velondriake.org). Velondriake's holothurian aquaculture model is based on a public-private partnership in which juvenile sandfish are sold to community farming groups at an average size of 15 g by MHSA, which is based in the city of Toliara, approximately 200 km south of Velondriake (Fig. 1) (Eeckhaut et al. 2008). Community groups purchase juveniles from MHSA at a price subsidised by project donors, and are responsible for growing the juveniles to market size (minimum of 350 g). Market-ready adults are then sold back to MHSA for processing and export (Robinson and Pascal 2009).

Communities in southwest Madagascar belong mainly to the Vezo ethnic group, and are almost entirely dependent on seafood protein for food security and income. The Vezo are also amongst the poorest and most economically marginalised people in Madagascar, itself one of the world's poorest countries (World Bank 2011). Recent surveys show mean household income in Velondriake to be USD 0.83 per person per day, with small-scale fisheries employing 87% of the population; generating 82.4% of the incomes and providing 99% of the protein source (Barnes-Mauthe et al. in review). Declining fisheries caused by overexploitation and the widespread use of increasingly unselective and destructive fishing gear, coupled with rapid population growth throughout this region, have led to increased recognition of the need to diversify livelihoods beyond fishing dwindling wild stocks.

Holothurian farming offers an attractive economic opportunity for coastal communities with the high value of the product (approx. USD 3 per kg in the study region in southern Madagascar) compared to reef octopus, the primary source of fishery-derived income in this region,(approximately USD 0.6–1.0 per kg based on 2011 collection prices). Furthermore, the critical ecological niche of holothurians as detritivore "ecosystem engineers" (Coleman and Williams 2002; Wolkenhauer et al. 2010) may even provide positive environmental benefits from farming through recycling of organic material, particularly in locations where wild populations have been effectively extirpated through over-exploitation. For example, growth of seagrass is higher in areas with higher densities of the tropical sandfish *Holothuria scabra*, a ubiquitous but heavily exploited Indo-Pacific species whose high value results in heavy exploitation throughout the tropical and subtropical Indo-Pacific region (Battaglene 1999; James 2004; Hamel et al. 2001; Purcell and Kirby 2006; Purcell and Simetoga 2008; Wolkenhauer et al. 2010).

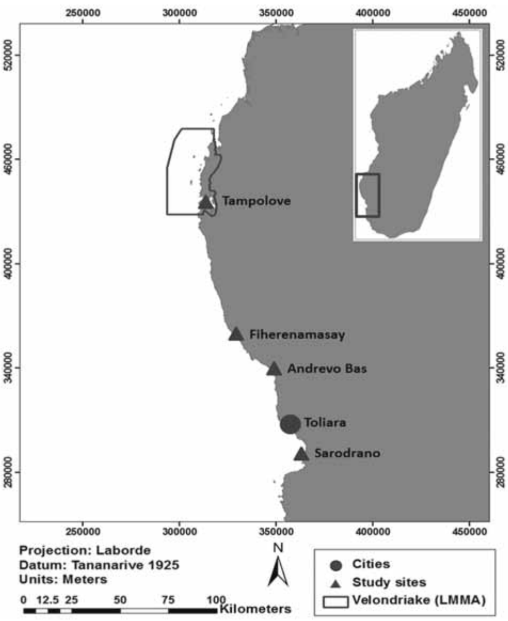

Figure 1. Map of the study area indicating farming sites (villages).

In recent years, considerable research has focused on developing technology for the large-scale hatchery and nursery production and release of *H. scabra*. Sea pens have been used in various stages of sandfish aquaculture, including broodstock holding, (Pitt 2001; Agudo 2006) to assess growth rates and survivorship of hatchery-reared juveniles and to model the effects of restocking overexploited populations (Purcell and Simetoga 2008). Drawing on research developments, a number of hatchery-reared holothurian mariculture initiatives have been established, as far afield as Asia, Southeast Asia, Australia, the Middle-East and the western Indian Ocean (Conand et al. 2004). Their objectives range from farming this valuable fishery resource as private sector ventures to establishing social enterprise initiatives that seek to diversify traditional livelihoods by developing holothurian aquaculture in coastal communities. In the latter case the concept of utilising sea pens for the grow-out of hatchery-reared sandfish juveniles to provide alternative livelihoods for coastal communities is relatively novel, and few studies have been published on this approach (Tsiresy et al. 2011; Robinson and Pascal 2009; Purcell 2010).

Although this aquaculture technique shows considerable promise as an alternative revenue source for Velondriake's Vezo communities, the income-generating potential of the initiative has not yet been realised, in large part because of the very high levels of mortality of juveniles in the period following transfer to community-run micro-farms (Tsiresy et al. 2011). An analysis of mortality rates across 42 pens in four villages during commencement of village-based *H. scabra* farming in Velondriake in the first quarter of 2009 (Robinson and Pascal 2009) showed mean mortality rates of 40.2% in the three months following transfer of juveniles from the MHSA hatchery to community sea pens.

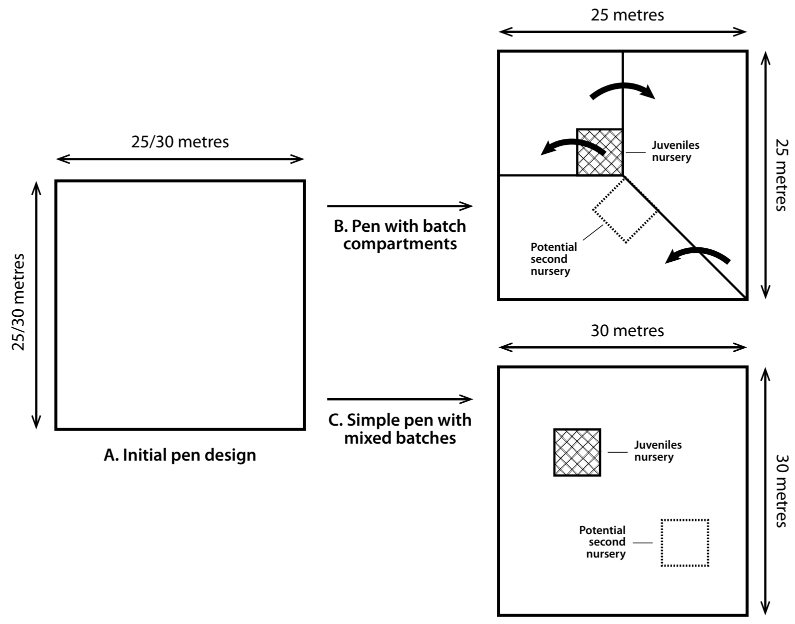

Figure 2. Schematic representation of the sea cucumber growing pens. A: Initial pens prior to improvement; B and C: Pens with a section for juvenile rearing.

Between November 2009 and February 2011, a number of technical improvements in farming and management were undertaken in the community-run holothurian aquaculture sites in order to reduce juvenile mortality in pens after transfer from the hatchery. In this study, we compare juvenile survivorship during the progressive introduction of these interventions, and discuss each intervention in turn with respect to its likely role in reducing juvenile mortality in sea pens. Our findings and recommendations are of relevance to the growing number of sea pen-based sea cucumber farming initiatives developing throughout the world's tropical and sub-tropical coastal regions.

Methods

The production model

Farming is carried out in sea pens, subtidal marine enclosures situated in suitable habitat for *H. scabra* (Fig. 2). These are shallow, sheltered areas with high levels of nutrients, including muddy substrata and seagrass beds (Tsiresy et al. 2011; Hamel et al. 2001; Agudo 2006). When identifying sites for *H. scabra* farming, site selection criteria include adequate sediment depth suitable for pen construction (at least 20 cm), close proximity to the chosen village in order to facilitate maintenance and surveillance of the pens, and a minimum water depth of 10 cm at spring low tide.

Each pen is designed to maximise growth rates by ensuring that the total biomass does not exceed the natural carrying capacity of habitats for *H. scabra*, believed to be 692 g m^{-2} for seagrass habitats near Toliara in southwest Madagascar (Lavitra 2008), which corresponds to about two adult individuals m^{-2} at commercial size.

The farming groups are mainly composed of household groups of between three and eight members, and there are also community groups, including local women's associations, youth clubs and even a local school, managed by teachers, pupils and their parents. Within each community, the pens and stocking regime have been designed to allow for multiple juvenile inputs throughout the year in order to spread both the risk of mortality and loss, as well as the anticipated financial returns.

To assess the improvement of the farming practices from the beginning of the village-based holothurian aquaculture (January 2009) until the end of this study (August 2011), the study period has been divided into three periods: period 1 being the initial situation for which survivorship was considered unacceptably low; period 2 corresponding to the introduction of the first series of juvenile mortality mitigation measures; and period 3 corresponding to a more active level of technical and managerial activities. Table 1 shows the number of farmers monitored during each of these periods.

Two stocking regimes, based around pens of 625 m^2 (Tampolove) and 900 m^2 (three other sites) with four deliveries per year of 195 to 900 juveniles were completed in period 1. In periods 2 and 3, there were deliveries of 300 and 450 juveniles to juvenile nurseries pens of 16 m^2 (Tampolove) and

25 m^2 (three other sites). For the duration of the project period, the villages received between 300 and 450 juveniles, depending on the size of the grow-out pens (between 625 m^2 and 900 m^2), either four or five times per year. Survivorship was evaluated three months after juvenile introductions throughout the project at the different sites of intervention. This three-month threshold is when juveniles reach a critical weight of approximately 50 g, after which they are considered to be markedly less vulnerable to predation (Pascal and Robinson 2011).

Table 1. Number of farmers in four villages (sites) during three periods representing the different maintenance levels.

Village/Site	Period 1	Period 2	Period 3
Andrevo	7	14	6
Fiherenamasay	5	2	0
Sarodrano	4	4	12
Tampolove	15	7	23

Mitigation measures of juvenile losses

The main focus of mortality reduction measures in periods 2 and 3 was the fight against predation – mainly from the swimming crab, *Thalamita crenata*, as well as improvements to pen structure to prevent juveniles escaping from pens. The modifications introduced during period 2 were implemented on 23 pens in four villages (Table 2). Modifications focused on improving pen design and promoting more active management and monitoring of pens by community farming groups.

Improved pen design

Previous designs of sea pens in southwest Madagascar focused on the use of locally sourced materials such as small mesh fishing nets made of soft cotton. These were stretched using polyethylene ropes (4 mm diameter) that were attached to wooden or metallic stakes at approximately 1 m intervals. Within a few months of the pens being built, it became apparent that the soft cotton net was prone to wear and tear, and some of the mesh walls started to collapse after stormy weather. The material was also too flexible to allow proper cleaning and dislodgement of fouling organisms and debris. In addition, the net was not properly fixed to the bottom, allowing some individuals to escape the pens, thereby interfering with proper monitoring of survivorship and growth. Juveniles were also introduced directly into the large farming pens designed for adult sea cucumbers. These pens were too large for effective control of predation.

Improvements made in maintenance period 2 included introduction of rigid plastic mesh of the kind designed as a wind buffer for agriculture. A horizontal wooden frame attached at the seabed and buried in the sediment ensured that animals were unable to escape. The improved durability of this system was immediately noticeable, with sea pen fences remaining in place even during stormy sea conditions. With the integrity of the farming pens assured, farmers could focus on maintenance by making sure the fence mesh remained taught and securely tied to the stakes. Any broken attachment ropes were repaired as quickly as possible. Farmers also cleaned the mesh wall with brushes regularly to remove fouling organisms.

Reduction of juvenile holothurian predation

Juvenile predation by the swimming predatory crab, *Thalamita crenata*, is considered to be the single most important factor influencing the survivorship of farmed juvenile *H. scabra* in the study area, with a single adult crab able to kill up to one *H. scabra* juvenile below 50 g per day (Pascal and Robinson 2011). Improvements to maintenance included the culling of predatory crabs by farmers and aquaculture technicians. Initially, the culling was challenging due to the large size of the pens, and was less successful. Moreover, crab culling could be carried out only during low tide, so pens were open to predators most of the time.

Table 2. Summary of measures undertaken to improve farming techniques.

Limitations in original farming technique	Improvements to address problems
Pen fence was constructed of locally- sourced material of poor durability	Introduction of a rigid plastic mesh wall
Bottom of enclosures was not secure, leading to escape of juveniles, especially during rough weather	Wooden frames tied to the bottom of enclosures and buried in the sediment to stabilise pens, thereby preventing escape of juveniles
High level of juvenile mortality during the first deliveries, mainly from predation by crabs	Introduction of roofed nursery pens housing the juveniles during the first three months after delivery
Lack of maintenance of pens and poor management of crabs	Increased maintenance of pens, particularly before delivery, and intensified culling of crabs

This problem was addressed by placing juveniles in separate enclosures within the adult farming pens. Unlike the adult pens, the surface of these juvenile pens was covered with small mesh net in order to stop predatory crabs entering the juvenile pen from above (Tsiresy et al. 2011). Juveniles were kept in these smaller covered pens (Fig. 2) for three months before transfer to the large pens once they had reached the 50 g threshold size.

The juvenile pens were 16 m^2 (Tampolove) and 25 m^2 (three other sites) and covered approximately 2.5% of the adult pen area, with the remaining area used as a grow-out pen. Each adult cohort was placed in a different compartment of the main pen to allow monitoring of survivorship and weight changes of each cohort separately. The process of transferring each cohort from the juvenile pen into the grow-out pen three to four months after input ensured that the critical stocking biomass of 692 g m^{-2} would not be exceeded in the juvenile or grow-out areas of each pen (Lavitra 2008).

Active management and monitoring

In order to further improve juvenile survival and to optimise the efficiency of the juvenile pens, project staff established farming best practices as part of the training process for farming teams (maintenance period 3). This active and better management introduced in period 3 is aimed at reducing "nursery effect" (Tsiresy et al. 2011), where farmers become over-reliant on technical improvements introduced in our case in period 2 and tend to be more neglectful, resulting in reduce effort in crab culling. Under the supervision of the project technicians, the farming teams were required to spend two to four days during each spring low tide clearing the juvenile pens of crabs before each juvenile delivery. This focus on crab culling within the juvenile pens ensures a predator free environment for the juveniles during the critical first three-month period. Thus, since 2010, crab culling in both juvenile and adult pens has continued during each spring tide, and is coupled with careful maintenance and reparation of the juvenile pens and their covering nets to prevent the entry of crabs. Supervision by project technicians ensured optimal implementation of the above measures and raised awareness among farmers of the importance of maintaining a rigorous maintenance regime.

Transport

The furthest site from the hatchery (Tampolove) is located 200 km from the city of Toliara, over eight hours' drive in an off-road 4x4 vehicle. This distance represents a considerable logistical challenge for farmers. Initial trials of transferring juveniles by sea in speed boats, with fresh seawater pumped through holding tanks during transit, showed very irregular results; on some trips, significant proportions of juveniles were eviscerated or died (up to 10.6% of juveniles arrived dead or eviscerated on the farming site in December 2009, Blue Ventures Conservation unpublished data), probably on account of the high degree of physical agitation experienced during the boat transfer.

Since March 2010, the transfer process has been drastically improved with the introduction of a new procedure, in which groups of 50 to 60 individual juveniles are packed in strong plastic bags designed for the transport of aquarium fish. These are filled with approximately four litres of seawater and pressurised with air. The bags are secured and transported in a vehicle, and care is taken to minimise shock during the road transfer. Delivery is made only during spring low tide, when farmers are able to walk easily to the farm pens, and the juveniles are released immediately after arrival at farming sites. With this procedure, the number of losses due to transportation has become insignificant (fewer than ten individuals per 20,000 juveniles delivered). This mortality level is not significantly different across all the sites, whether near the hatchery or far away.

Data analysis

Comparisons of survival of juveniles over three months after their introduction to the pens were made between each of the three periods. We also compared differences between villages within each period. In some villages, more than one delivery was made for the same maintenance period; and between cohorts, comparisons were made in order to test if variation in survivorship was influenced by delivery and the latter had confounding effects on maintenance responses.

Survivorship was compared by considering a farming pen as a random variable. Because pens were distributed in the same area and delivery was made on the same day for a particular site, variations within a site would mainly be due to differences in maintenance efforts by individual farmer groups. Assumptions of parametric statistics were tested prior to statistical comparisons. Normality of data was tested using the Shapiro-Wilk Test and homogeneity of variance with Levene's Test. Because the data were not normally distributed (Shapiro-Wilk $W = 0.95$; $P = 0.0008$) and were not of homogeneous variance (Levene's $F = 5.75$; $P = 0.004$), Kruskal-Wallis ANOVA was used in the end, and pair-wise comparisons between sites for the same period and between periods for the same site were made with Mann-Whitney Chi-squared test.

Results and discussion

The study found significant variation in survivorship between maintenance regimes and among sites for a particular maintenance period (Fig. 3; Table 3). Overall, survivorship increased from an average of 40.2% in maintenance period 1 to 76.6% in period 3. By site, comparison revealed that the highest jump in survivorship – from 21.3% to 83% – was observed in Sarodrano between maintenance periods 2 and 3. In Fiherenamasay, where comparison was made between maintenance periods 1 and 2 only, there was no significant difference in survivorship (period 1: 53.8% ± 4.4%; period 2: 52.1% ± 7.0%; $\chi^2 = 0.15$; $P = 0.70$). The lowest difference was observed in Tampolove where survivorship increased by only 29.9% from an already relatively high value (46.3%) in period 1. There was a significant difference between periods 1 and 3 ($\chi^2 = 16.91$; $P = 0.0002$). Period 2 was not significantly different from either period 1 or period 3 ($P > 0.05$).

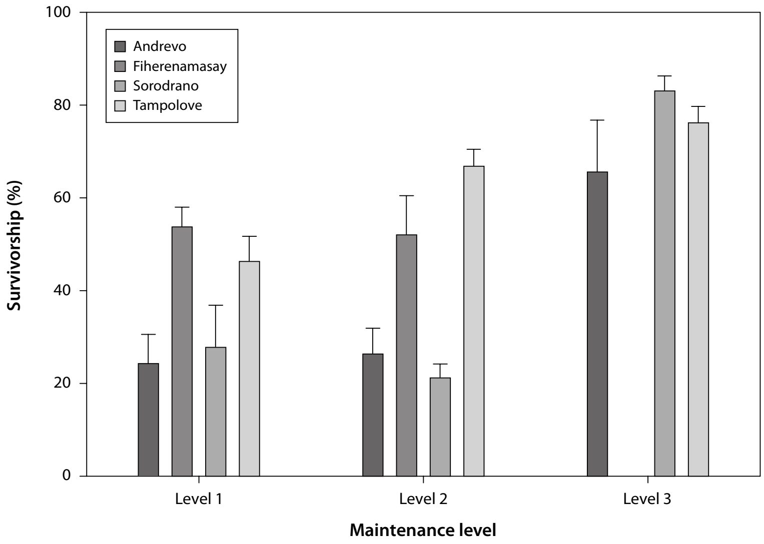

Figure 4. Within site and by maintenance level variation in survivorship.

By period, comparison showed that Fiherenamasay and Tampolove had higher survivorship values than Andrevo and Sarodrano in both periods 1 and 2. No significant difference in survivorship was observed for the three sites where data were available in period 3 (Fig. 4). Fiherenamasay, despite having one of the highest survivorships in periods 1 and 2, withdrew from the holothurian farming programme in period 3 and no comparisons could be made. Comparison between cohorts in the same period within a site showed no significant differences for all sites ($P \geq 0.5$).

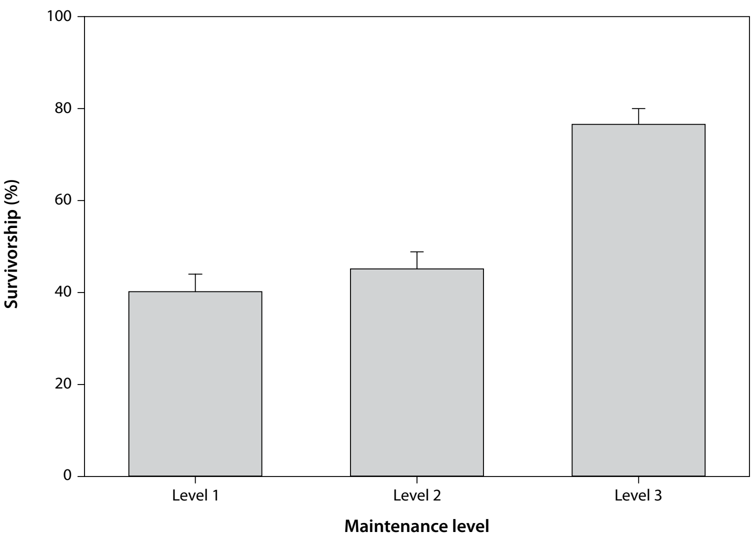

Figure 3. Variation in survivorship by maintenance level.

Table 3. Kruskal-Wallis one way comparison between maintenance periods for each village/site and all sites.

Village/Site	χ^2	*P*	Comparison
Andrevo	7.16	0.03	a, a, b
Fiherenamasay	0.15	0.7	a, a
Sarodrano	13.73	0.001	a, a, b
Tampolove	16.92	0.0002	a, ab, b
All sites	42.98	< 0.0001	a, a, b

The strong jump in average juvenile survivorship from 40.2% to 76.6% is expected to have profound practical and socio-economic implications for community-based holothurian aquaculture in southern Madagascar. The improvement was brought about by a combination of factors, including introduction of active management farming techniques and mitigation of disturbance and predation at a crucial growth stage of farmed *H. scabra*. The study underlines the need for a continuous effort in farm maintenance and control of predation by crabs.

Escape of juveniles to the outside and predation by the crab *Thalamita crenata* were the main causes of high mortality prior to the farming improvements. The replacement of the less stable and less durable cotton mesh fence by a strong plastic mesh that is able to withstand rough sea conditions, and the burial of the fence wall deeper into the sediment stops escape of juveniles to the outside. It is important to note that the new type of plastic mesh is increasing the cost of the fence from approximately USD 2.17 m^{-1} to USD 2.62 m^{-1}, introducing a minimal additional cost for a much longer durability (estimated between five and seven years as against one to two years maximum). The introduction of juvenile enclosures ensures close follow up of juveniles, which otherwise would scatter in a larger area, resulting in a higher source of error during counting and estimation of survivorship.

The small pens also help reduce predation by crabs in two ways. First, crab hunting by farmers and technicians becomes more efficient in smaller, more controllable pens. Secondly, the small mesh roofing in the juvenile pens ensures that entry of predatory crabs into the pens is limited.

In addition to the technical refinements, preparation of the juvenile pens two to three days before juvenile delivery was another important step taken in the farming technique. By closing openings, entry of crabs is reduced. Culling of existing crabs that could become trapped in the enclosures and grow, predominantly feeding on juvenile *H. scabra*, is another important step. At this acclimatisation stage from a hatchery to a farming environment, which also occurs after long transportation (up to eight hours), juveniles are probably most vulnerable to the effects of environmental stress, and predation by crabs would compound the vulnerability.

The lack of difference between maintenance periods 1 and 2 in all sites indicates that improvement of the farming technique through the introduction of roofed nursery pens for the first three months after delivery in itself is not enough to improve survivorship. The results are in agreement with previous findings that show the introduction of roofed juvenile pens is not a "silver bullet" in itself (Tsiresy et al. 2011), but a crucial step that promotes efficiency in minimising predation by crabs. The two sites with an already improved survivorship in periods 1 and 2, had either low natural density of crabs (Fiherenamasay) or maintenance in period 2 had already improved significantly (Tampolove) (unpublished data). Increased management in period 3 in Tampolove resulted in further increase in survivorship. Although no records were kept of the number of crabs culled in all pens and periods, there were instances when up to 150 crabs were killed by a single farmer in Tampolove on a single day (personal observation AR). Culling of crabs following transfer to large pens is less controlled, as maintenance efforts are highest during spring low tides and their effect is less actively controlled during periods between spring tides. However, animals in the growing pens would by then have reached the critical 50 g weight and would be less vulnerable to predation.

The *H. scabra* aquaculture is not a labour-intensive activity, and can be a promising complementary economic activity for the coastal population of southwest Madagascar. But, as described above, the technical solutions offered to maximise production cannot be the only solutions. Even with the reduction of the surface to check and clean, and the intensified physical barrier against crabs offered by the juvenile nurseries offering obvious advantages for the farmers, there is still a need to improve management of the farmed *H. scabra* at the juvenile stage. This study underlines the importance of preparation of farming pens before delivery, and continuous farm maintenance and control of predatory crabs post delivery. Holothurian farming in the region being still at a pioneer stage (Robinson and Pascal 2009), it is expected that it will take some time before continuous maintenance becomes a farming routine. Thorough supervision by trained technicians is required until the economic benefits are fully realised.

The increased survivorship will also mean increased density of large individuals. Based on observation of unexploited wild holothurian populations, a stocking density of 250 g m^{-2} has been recommended for holothurian farms (Battaglene 1999; Purcell and Simetoga 2008). This amounts to less than one individual per m^2, and assuming 100% survivorship is achieved, the density in the pens in this study would be more than two times this value (~ 2 individuals m^{-2}; Lavitra 2008). This value is based on growth study of *H. scabra* in the Toliara area of southwest Madagascar. The large difference between the two optimal density estimates indicates the need for further investigation of sediment type, nutrient content and turnover to sustain long-term holothurian farming.

The community-based holothurian aquaculture aims to provide a complementary source of income for the coastal populations of southwestern Madagascar that are highly dependent on fishing. The project's target is a minimal additional net income of USD 60 $month^{-1}$ per farming group after covering the operational cost of the farm. This would also necessitate achieving financial independence from the current funders and supporting non-governmental organisations. In order for the activity to reach this level of sustainability, and at the current cost of the farming materials and the current price for a farmed adult *H. scabra*, at least 60% of all introduced juveniles must make it to market. The new survivorship values associated with technical improvements and active maintenance exceed this value by a significant margin.

The increased income and socio-economic benefits are also expected to result in increased maintenance efforts by existing farmers and increased interest and buy-in from community members in villages supported by the project. For example, improved survivorship and increased income in the village of Tampolove has resulted in an increased number of farms, including a school farm. With "many hands" involved, the school farm is one of the best maintained, and recorded one of the highest juvenile survivorships during the most recent surveys. Involvement of the school in farming also has significant implications in terms of transfer of skills and knowledge to future generations, and in promoting development and conservation in an area with one of the world's highest poverty levels, as well as extremely high dependence on coastal ecological resources for subsistence and income.

One of the main management challenges in southwest Madagascar has been theft of market-size animals. The farmers have tackled this problem by introducing a rotation system of night guarding, involving all members. This initiative has been supported by building a watchtower to facilitate nightly surveillance. Challenges to meeting increased demand and interest from community members include the limited habitat space available to accommodate new farmers. In addition, a shortage in funding limits the extent to which the project can be expanded during this early 'pre-profit' stage.

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Holothurian density, distribution and diversity comparing sites with different degrees of exploitation in the shallow lagoons of Mauritius

Katrin Lampe[1*]

Abstract

The current study aims to conduct a baseline investigation regarding the abundance, distribution and diversity of holothurians inhabiting shallow lagoons in southern and western Mauritius, comparing sites with different degrees of exploitation. During July and August 2011, 78 day time transects covering an area of 35,550 m^2 recorded a total of 3411 holothurians (152.56 ind. 100 m^{-2}) at 16 survey sites in shallow lagoons in the west (93.50 ind. 100 m^{-2}) and south (59.06 ind. 100 m^{-2}) of Mauritius. These were assigned to 17 species, including ten commercially important ones. The dominant species was *Synapta* spp. (41.6% of the total). The next most common species were *Holothuria atra* (29.14%), *H. leucospilota* (11.93%), and *Stichopus chloronotus* (6.39%). These three species had a commercial value. Overall similar densities of commercial (52.39%) and non-commercial (47.61%) species were assessed. Testing the correlation of habitat diversity, species density and diversity resulted in a patchy picture throughout the lagoons. However, the highest densities, but lowest diversity, were found in sites characterised by a cover that is predominantly sediment and vegetation.

Introduction

Sea cucumbers play an essential role as keystone species, bioturbators and recyclers of lagoons. Changes in their density may even have serious consequences for the survival of other species that are part of the same ecosystem (Birkeland 1988). As well as being ecologically significant, sea cucumbers are also associated with two major economic uses. First, processed sea cucumbers (beche-de-mer) are considered a gourmet food item in Asia, especially in Japan and Korea. Second, holothurians have pharmaceutical properties. Pharmaceutical companies invest in research related to the toxins produced by holothurians. Some compounds that are extracted from the sea cucumber feature antimicrobial activity or act as an anti-inflammatory. Other compounds exhibit antiviral, antitumor, anticancerous and antifertility properties (Bordbar et al. 2011).

Sea cucumber fishery in Mauritius has developed quickly in the past few years and Conand (2004) reported around 11 edible species there. *Bambara*, as sea cucumbers are often called in Mauritius, are easily handpicked by fishermen for local consumption and to be sold to hotels. However, they are mainly being sold to operators, who export the processed products to Asian countries (Luchmun et al. 2001). The current knowledge of sea cucumber diversity and the effect of exploitation in Mauritian waters that appear to be rich in holothurian resources, is virtually unknown (Luchmun et al. 2001). The present work aims to conduct a baseline investigation regarding density, distribution and diversity of holothurians inhabiting shallow lagoons in the south and west of Mauritius, comparing sites with different degrees of exploitation.

Materials and methods

With its total coastline of about 200 km, Mauritius is almost completely surrounded by lagoons that extend over 150 km^2, created by the formation of either barrier reefs or fringing reefs. On the eastern coast of the island, the width of the lagoons, which enclose the area from the shore to the reef crest, varies from 400 m to approximately 7 km. Tides are semi-diurnal, with a mean tidal range of 0.9 m during spring time and 0.1 m during neap time (McClanahan et al. 2005). Lagoons in Mauritius extend from the nearshore to the reef flat. A flat lagoon will generally have homogeneous species composition as opposed to a lagoon floor where there is great variation in bathymetry. The study was limited to two geographically separate areas – the south and the west of Mauritius – where surveys were carried out at a total of 16 sites (Fig. 1). The western lagoons of the island are comparatively calm and protected by the fringing coral reefs, while in the south, the coast is affected by the south-east trade winds and rough sea conditions prevail. However the west region is

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more susceptible to cyclone swells originating in the north and northwest (Padya 1984, 1989).

The survey sites have different degrees of exploitation, i.e. they are differently utilised and affected by, for example, their accessibility to fishermen or fishing activity, and the presence of hotels and tourism.

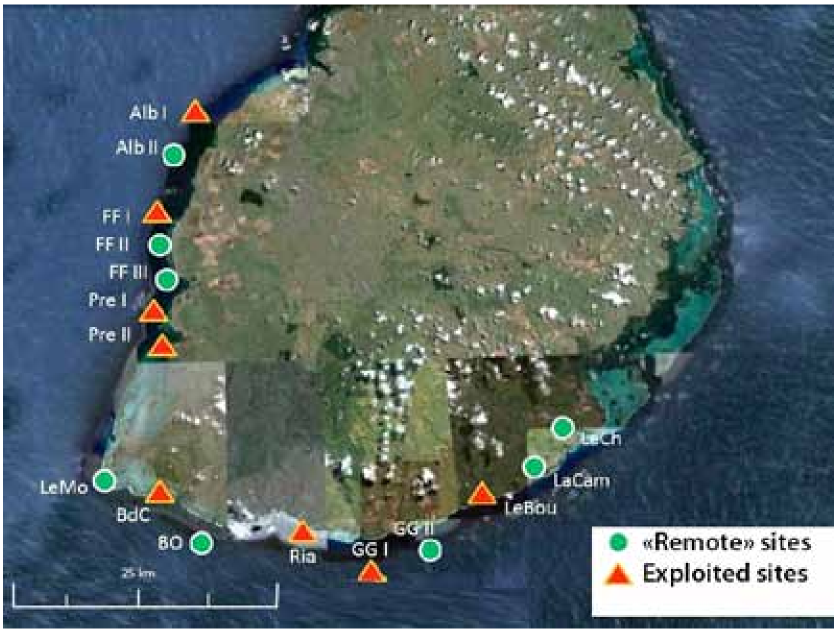

Figure 1. Satellite image displaying the 16 survey sites spread along the shallow lagoons of the west and the south coast of Mauritius. The red sites are exploited, while the green sites are considered "remote" (Snapshot Google Earth 2011).

Figure 2. Example of transects setting for survey of sea cucumber at the site called Flic en Flac II (Snapshot Google Earth 2011).

The surveys were conducted in five belt transects. Each belt transect consisted of a 50 m long main line with five 20 m side transects of 3 m width, thus covering an area of 450 m². According to that, the total covered area per survey site with its five transects was 2250 m² (or 450 m² x 5) (Fig. 2). The five transects were set in a staggered fashion, separated from one another by a minimum distance of 10 m. All surveys were conducted during daylight hours only.

A thorough search for holothurians was carried out snorkelling, starting with the first transect, along the mainline, then working up the side transects. Each individual holothurian found was counted and its species noted down. To understand the effect of habitat type on holothurian distribution and abundance in each of the survey sites, the percentage of different substrate types was also recorded. Substrates were classified into six different types (sand, live coral, coral rubble, seagrass, macroalgae and rocks).

The Shannon-Wiener Index (Nentwig et al. 2004) was calculated in order to measure the dominance and diversity of species and habitats at each of the 16 sites, as per the formula below.

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

Where p_i is the proportion of one species (i) against the total number of species.

The non-parametric Spearman's rank correlation coefficient (R^2) was used to determine the strength of the dependence between the habitat diversity and species density. In this case, a Spearman correlation (R^2) would have a value +1 or -1, stating that the degree of habitat diversity explains the species density.

Table 1. Observed species with their absolute density and commercial value (ranging from 0 in white: no commercial value; to 1 in red: high-commercial value; to 2 in orange: medium-commercial value; to 3 in yellow: low-commercial value, as per Conand 2008) in a survey carried out in July–August 2011 in the lagoons of Mauritius.

Species	Commercial value	Absolute density	Total west (ind. 100 m^{-2})	Total south (ind. 100 m^{-2})
Holothuria nobilis	1	3	0.04	0.08
Actinopyga echinites	2	37	0.31	1.87
A. mauritiana	2	2	0.00	0.08
Stichopus chloronotus	2	218	8.98	0.71
S. herrmanni	2	1	0.04	0.00
Bohadschia atra	3	7	0.18	0.19
B. marmorata	3	110	3.35	1.24
Bohadschia sp.	3	8	0.27	0.07
Holothuria atra	3	994	38.73	5.39
H. leucospilota	3	407	14.13	4.67
Subtotal		**1787**	**66.04**	**14.31**
Holothuria hilla	0	120	0.76	4.58
Holothuria pervicax	0	68	1.29	1.73
Stichopus monotuberculatus	0	10	0.31	0.13
Stichopus sp.	0	6	0.27	0.00
Synapta spp.	0	1419	24.81	38.31
Unidentified species	0	1	0.03	0.00
Subtotal		**1624**	**27.46**	**44.76**
Total		**3411**	**93.50**	**59.06**

Results

During July and August 2011, 78 day time transects in 16 survey sites covering an area of 35,550 m² recorded a total of 3411 holothurians (152.56 ind. 100 m^{-2}) inhabiting the shallow lagoons in the west (93.50 ind. 100 m^{-2}) and the south (59.06 ind. 100 m^{-2}) of Mauritius (Table 1).

The relative proportion of the different habitat characteristics of the 16 survey sites was computed. The most common substrate types along each transect set were sandy patches (39.7%), followed by seagrass patches (20.9%). Coral rubble and live coral patches had similar proportions (15% and 12.2% respectively). The least represented habitat types were macroalgae and rocky patches, both with less than 8%. Nine out of 17 species had ten or more individuals found throughout all survey sites (Table 2) whereas species such as *Bohadschia* sp., *B. atra*, *Stichopus* sp., *Holothuria nobilis*, *Actinopyga mauritiana*, *Stichopus hermanni* and one unidentified species occurred very rarely in all survey sites, with fewer than ten individuals surveyed.

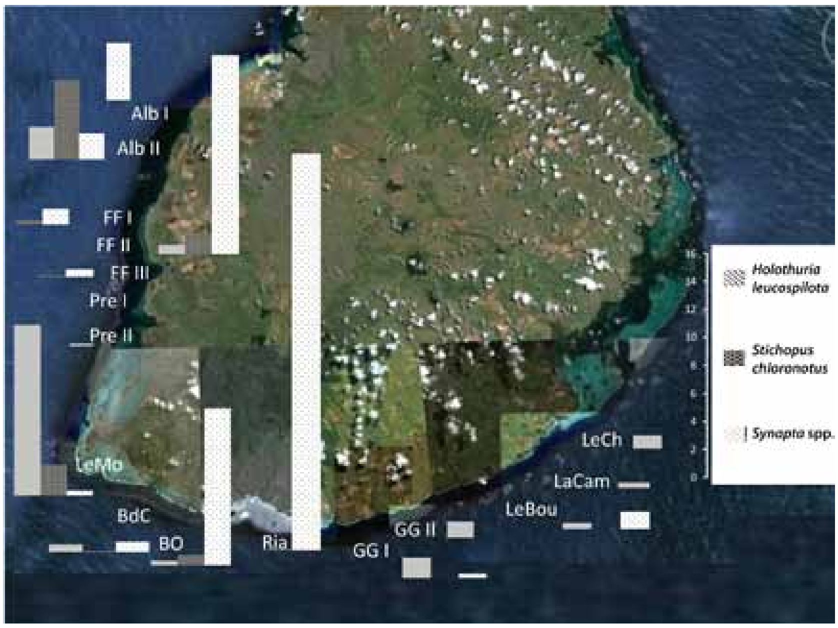

Figure 3. Map of the survey sites in the west and south shallow lagoons of Mauritius with the holothurians densities (ind. 100 m^{-2}) of *Holothuria leucospilota*, *Stichopus chloronotus* and *Synapta* spp. (Google Earth 2011).

Individuals from the genus *Synapta* were shown to be the most abundant, with a relative density of 42% and 1419 counted individuals (Table 2). As for their relative frequency (81%), they were observed in 13 out of 16 sites, most abundantly in Riambel, Flic en Flac II and Bel Ombre (Fig. 3). However, this percentage was less than the most frequently occurring species *Holothuria atra* with 94%, which was also the most abundant species with a total number of 994 individuals (Table 1; Fig. 4), featuring a relative abundance of 29% (Table 2), mostly in Le Morne, Bel Ombre, and Albion II (Fig. 4).

Table 2. The absolute density of each holothurian species and its relative density (%) and observation frequency (%), in the 16 different sites covering a total area of 35,550 m².

Species	Number of individuals	Relative density(%)	Observation frequency (%)
Actinopyga echinites	37	1.08	43.75
A. mauritiana	2	0.06	12.50
Bohadschia atra	7	0.21	18.75
B. marmorata	110	3.22	56.25
Bohadschia sp.	8	0.23	18.75
Holothuria atra	994	29.14	93.75
H. hilla	120	3.52	25.00
H. leucospilota	407	11.93	75.00
H. nobilis	3	0.09	18.75
H. pervicax	68	1.99	31.25
Stichopus chloronotus	218	6.39	50.00
S. herrmanni	1	0.03	6.25
S. monotuberculatus	10	0.29	18.75
Stichopus sp.	6	0.18	12.50
Synapta spp.	1419	41.60	81.25
Unidentified species	1	0.03	6.25
Total	**3411**		

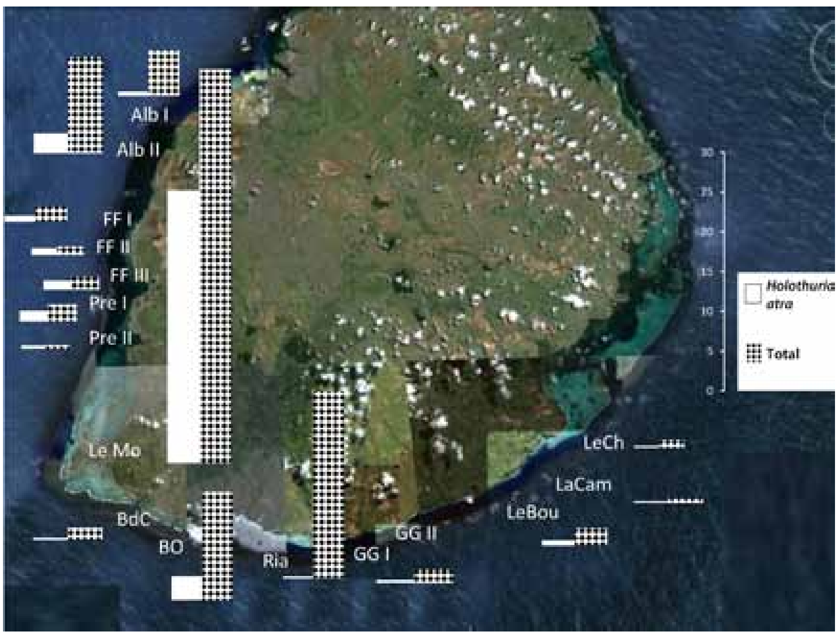

Figure 4. Map showing the survey sites in the shallow lagoons of Mauritius with the densities (ind. 100 m^{-2}) of *Holothuria atra* compared to the overall species density (Google Earth 2011).

Holothuria leucospilota and *Stichopus chloronotus* were the next most common species, constituting 12% and 6% of the total count, featuring 407 and 218 individuals respectively (Table 1; Fig. 3). But *H. atra* was observed at 12 sites (relative frequency of 95%), whereas *S. chloronotus* was less widespread, being found at eight sites only (50%) (Fig. 3 and 4).

In almost the same abundance, species such as *Bohadschia marmorata* and *Holothuria hilla* were found, featuring a total of 110 individuals (relative density of 3.22%) and 120 individuals (relative density of 3.52%) respectively, the former being more frequent than the latter (observation frequency 56.25% and 25% respectively) (Table 2). Some rare species, despite their low relative density as *Actinopyga echinites* (1.08%) and *Holothuria pervicax* (1.99%), were relatively widespread, with observation frequencies of 43.75% and 31.25% respectively, ranking just after the four most widespread species (Table 2). Rather rare species, featuring less than 1% of the relative density were *Actinopyga mauritiana*, *Bohadschia atra*, *Bohadschia* sp., *Holothuria nobilis*, *Stichopus herrmanni*, *S. monotuberculatus* and *Stichopus* sp. They were recorded at either three or two of the 16 sites and sometimes at just one site.

Abundance of commercial and non-commercial sea cucumber species

Ten species were identified as commercially important [key of Conand (2008)].

Holothuria nobilis ranked as being of a high-commercial value, while four other species were of medium-commercial value and five species of rather low-commercial value. The remaining six species (including one genus group) were designated as being of no commercial value. Whereas in the western sites there was a high absolute density of species of no commercial value of 93.5 ind. 100 m^{-2}, in the southern sites the density was 59.06 ind. 100 m^{-2}. The western sites also had the higher density of commercial species (66.04 ind. 100 m^{-2}) (Table 1).

There is one outstanding observation to be made when having a closer look at the western survey sites, and that is the comparatively high abundance of *Holothuria atra* and *H. leucospilota* at those sites. In the four survey sites classified as remote, an average of 79.87 ind. 100 m^{-2} was observed. *Holothuria atra*, which holds a low-commercial value (value of 3), was the species responsible for the high density, especially in Le Morne (Fig. 5). Moreover, the second most commercially important species, *Holothuria leucospilota*, was observed with a density of 11.38 ind. 100 m^{-2} exclusively in Le Morne.

Having compared the relation between the habitat differences to species density; the habitat differences to the respective Shannon-Wiener indices of the species; the Shannon-Wiener indices of the habitats to the species density as well as the Shannon-Wiener indices of the habitats to the Shannon-Wiener indices of the species, the highest correlation coefficient was revealed to be 0.6359, in the southern sites. The others featured a coefficient less than 0.5.

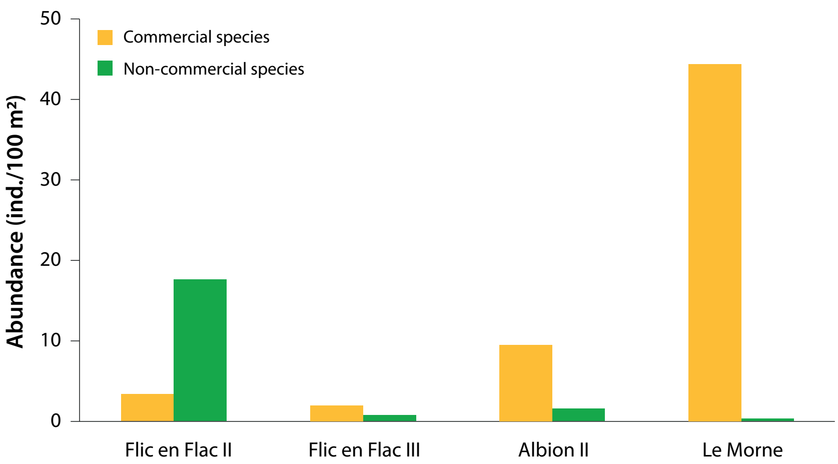

Figure 5. Holothurian densities at remote survey sites, distinguishing between commercial and non-commercial species in the shallow lagoons of western Mauritius, July–August 2011.

Discussion

Species richness and species composition

The results of the present study show a higher diversity of species than any previous studies done in Mauritius (Müller 1998; Luchmun et al. 2001; AFRC 2011). The shallow lagoons of Mauritius and Rodrigues are inhabited mainly by four species of holothurians in great abundance, although they are distributed in a heterogeneous manner in the lagoon. These four species are *Holothuria atra*, *H. leucospilota*, *Stichopus chloronotus* and *Bohadschia marmorata*, which are considered important commercial species. However, certain species of commercial value such as *Thelenota anax*, *T. ananas* and *Holothuria scabra*, which were previously surveyed in Mauritius (Luchmun et al. 2001; AFRC 2011), were missing in the current study. Species of non-commercial value, in particular the genus *Synapta*, contributed to the bulk of the individual densities.

Due to the high heterogeneity of species distribution, it is worth noting that there are areas in the lagoons of Mauritius that were not surveyed but which are likely to harbour the holothurians species missing in this study. The field surveys in this study were undertaken only in shallow lagoons, excluding other habitats such as the intertidal and shallow sublittoral zones, deep regions and channels within the lagoon, as well as habitats outside the shallow lagoon. *Thelenota anax* prefers habitats such as outer lagoons and near passes living on hard bottoms, and large rubble and sand patches. Conand (2006) stated that *H. anax* inhabits reef slopes that are not subject to the influence and passages of land runoffs, meaning that this species is therefore found in areas with strong water movement. Furthermore, this species has not been observed above a depth of eight metres but is found in depths of up to 28 m.

Commercial and non-commercial holothurian abundances in sites with different exploitation degrees

As expected, the highest density of sea cucumbers was measured in remote areas in the western sites (13.63 ind. 100 m^{-2} in the exploited sites and 79.87 ind. 100 m^{-2} in the remote sites of the west). Furthermore, the commercially valued species were more abundant in the remote sites.

For example, the density of *Holothuria atra* and *H. leucospilota* at the remote survey site in Le Morne was found to be striking when compared to exploited sites in the west, where these species' densities were exceedingly low. Also *Stichopus chloronotus*, a species of medium-commercial value, is mainly found in quite high densities in the western remote sites. The site of Le Morne, which is located on an extended piece of land in the southwest, is almost separate from the rest of the island. No local people live around this site, as it is exclusively allocated to hotel complexes. Its lagoon is mainly used by tourists for water sports such as kite surfing, discouraging fishermen from collecting holothurians there. This may be one cause of the abundance of holothurians. The high density of commercially important species may also be a result of the organic nutrients in the water, as this site also is the only one with high turbidity and accumulation of detritus.

The abundance of *Synapta* spp. accounts for the overall densities of the non-commercial species in both remote and exploited sites. However, they are more than twice as abundant in the remote sites as they are in the exploited sites. Such a great difference of abundance of non-commercial species between the two different types of site was not expected. Nevertheless this contrast may be explained by habitat composition at the sites where they were sighted, or other conditions such as salinity and nutrients that might affect the species density.

Habitat and shelter associations

In general, it is apparent that holothurian distribution is of a patchy nature, although there are some species where a preferred habitat type can be noted. For example, the highest density of *Synapta* spp. was found on sites characterised by sand and seagrass in very shallow water, ranging from 30–50 cm deep.

As for *Holothuria atra*, it seems that they live in a wide range of habitats. They occurred in high abundance in some habitats, like that at Le Morne (covered with sand and vegetation in deeper waters, a high extent of turbidity, and a muddy floor cover), where it was observed sometimes to be grouped with *Holothuria leucospilota* in one patch. On other sites, featuring more substrate variability, they tended to occur relatively often on coral rubble patches, on sediment and in mainly unsheltered places, slightly covered by sand. This association with sediment was to be expected, as this forms the primary feeding substratum for *H. atra* (Roberts and Bryce1982).

Physical parameters, such as salinity degrees, water temperature, turbidity of the water and depth at which species occur, as well as nutrient composition, may have a direct impact on holothurians distribution and occurrence.

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Artificial breeding and larval rearing of three tropical sea cucumber species – *Holothuria scabra*, *Pseudocolochirus violaceus* and *Colochirus quadrangularis* – in Sri Lanka

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Abstract

Overharvesting of sea cucumber species can now be considered a worldwide phenomenon, and artificial breeding and aquaculture practices are possible alternative sources of sea cucumbers for coastal fishing communities. Induced spawning of *Holothuria scabra*, *Pseudocolochirus violaceus* and *Colochirus quadrangularis* was achieved for the first time in Sri Lanka in late 2011. Wild broodstocks of these species were collected and induced through the application of several methods. Thermal stimulation (ambient temperature ± 3–5°C) was found to be the most successful method for spawning initiation of *H. scabra* whilst addition of microalgae was more effective for *P. violaceus*. Spawning of *C. quadrangularis* was initiated through transportation stress. Larval development stages of these three species were very similar, but juvenile growth was much higher in *H. scabra* than in the other two species. *H. scabra* juveniles with an average weight of 11 ± 4 g were transferred to a lagoon pen and they attained an average weight of 207 ± 56 g within a period of four months. The observed average growth rate was 1.7 g day^{-1} and there was 89% survival after four months. Juveniles of *P. violaceus* and *C. quadrangularis*, however, took more than two months to attain an average length of 5–8 mm.

Key words: *Holothuria scabra*, *Pseudocolochirus violaceus*, *Colochirus quadrangularis*, induced spawning, larval rearing.

Introduction

Sea cucumbers (class Holothuroidea) are a group of marine invertebrates that provide an important source of livelihood for many artisanal fishers throughout the world, particularly in developing countries in tropical and subtropical regions (Choo 2008; Friedman et al. 2010). Due to the increasing demand for raw materials, most sea cucumber species, including undersized animals, have been exploited indiscriminately, resulting in overexploitation and depletion of stocks in many parts of the world (Lovatelli and Conand 2004; Conand 2005; Bruckner 2006). To protect their sea cucumber stocks, many nations have implemented various management actions and have developed alternative methods for producing beche-de-mer. Artificial breeding and aquaculture practices have been introduced as an alternative method for producing beche-de-mer to satisfy the increasing market demand, as well as to enhance wild populations through restocking and sea ranching (Ivy and Giraspy 2006; Agudo 2006).

The sea cucumber fishery was introduced to Sri Lanka by the Chinese and for centuries beche-de-mer appears to have been one of the major commodities taken to China (Hornell 1917). As in many other coastal fisheries off Sri Lanka, the sea cucumber fishery is primarily artisanal but provides significant contribution to the livelihoods of coastal fishing communities off the north, east and northwest coasts. There are around 21 commercial sea cucumber species in Sri Lanka and most of these stocks are reported to be at critical level (Dissanayake and Stefansson 2010). Therefore, developing technologies for seed production and sea cucumber culture activities to reduce the fishing pressure on wild populations is timely.

It has been well documented that spawning of tropical and temperate sea cucumbers is usually induced

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through the application of short-term environmental stresses. Temperature change, light intensity, photoperiod, salinity, tidal flux, food availability and change in food type are believed to be the environmental factors involved for controlling gametogenesis and spawning of holothurians (Smiley et al. 1991). Thermal stimulation is the most commonly used, although mature animals will often spawn spontaneously in response to collection and transportation stress (Tanaka 1958; Smiley et al. 1991; Yanagisawa 1998; Morgan 2000; Eeckhaut et al. 2012).

Reliable techniques for induced spawning in holothurians have, however, been developed for relatively few species (Engstrom 1980; James et al. 1994; Hamel and Mercier 1996; Yanagisawa 1998; Morgan 2000; Eeckhaut et al. 2012). The current study attempts to carry out induced spawning in three tropical sea cucumber species: *Holothuria scabra* (sandfish), *Pseudocolochirus violaceus* (sea apple cucumber) and *Colochirus quadrangularis* (thorny sea cucumber).

This study concerns *H. scabra* because it yields one of the largest sea cucumber catches worldwide (Giraspy and Ivy 2005) and it forms an important fishery in Sri Lanka. Further, *H. scabra* appears to have the most potential for aquaculture (James 1996; Battaglene and Bell 1999; Battaglene et al. 1999). The other two species were selected because *P. violaceus* is listed as a protected species under the Fauna and Flora Protection Ordinance in Sri Lanka and there is a possibility of promoting exports of *C. quadrangularis* as a commodity for marine aquarium.

Material and methods

Broodstock collection and induced spawning

Brooders of *H. scabra* and *P. violaceus* were collected from the wild and transported to the Kalpitiya Regional Research Center of the National Aquatic Resources Research and Development Agency (NARA) in late 2011, while *C. quadrangularis* were collected in early May 2012 (Fig. 1). *H. scabra* and *P. violaceus* were conditioned within the hatchery tanks before inducing artificial breeding.

Spawning initiations of these three species were tried using the methods described by Agudo (2006). These methods include thermal stimulation, a powerful jet of water, dry treatment, transportation stress and the addition of increased quantities of microalgae. In thermal stimulation, the water temperature was raised by 3–5°C by adding warm seawater to the spawning tank and maintaining a uniform temperature. Sandfish brooders were introduced into the tank and after around 45–60 minutes the water was replaced with new water at ambient temperature. When the ambient temperature of the seawater was higher than 32°C, a cold shock treatment was given by putting ice bags into the tank to lower the temperature.

When applying a powerful jet of water, the broodstock was kept dry for about 45 minutes and then subjected to a powerful jet of seawater for 15 minutes. Then they were returned to the spawning tank at ambient water temperature. In the dry treatment method, brooders were kept completely dry for about 45–60 minutes and then the tank was refilled with water at ambient temperature. In the last method, *Chaetoceros* spp. (40,000 cells ml^{-1}) was put into the spawning tank until the water became turbid. After one hour, the water was replaced with new water at ambient temperature.

Once the spawning was over, the animals were put back into the broodstock holding tanks. An egg count was made after each successful breeding trial. Fertilisation occurred inside the spawning tanks and the fertilised eggs were collected and introduced into larval rearing tanks. Observations of egg development stages were carried out at different time intervals.

Figure 1. Three sea cucumber species; *Holothuria scabra* (left), *Pseudocolochirus violaceus* (middle) and *Colochirus quadrangularis* (right) used for artificial breeding.

Larval rearing

Feeding of the larvae was started two days after fertilisation. The initial larval stages of the three species were fed with *Chaetoceros* spp. (20,000–40,000 cells ml^{-1}). The latter larval stages of *H. scabra* were fed with grounded shrimp pellets and fine paste of *Sargassum* spp. The larval stages and juveniles of *P. violaceus* and *C. quadrangularis* were fed with *Chaetoceros* spp. (40,000 cells ml^{-1}) continuously. After one month, *H. scabra* juveniles were transferred into an indoor nursery tank and maintained until they reached 1 g in weight (~ 3 cm) and then they were nursed in outdoor fibreglass tanks.

Figure 2. Spawning behaviour of male *H. scabra* (left) and release of sperm (right).

Figure 3. A small bulge formed by female *H. scabra* before releasing eggs (left) and release of eggs (right).

Water exchange and aeration

Water in the larval rearing tanks was changed once a day, in the morning, and dead algae, faeces and dead larvae that had settled in the bottom of the tanks were removed by siphoning. The water of the larval rearing tanks was aerated continuously but gently. The water temperature was maintained in the range of 26–29°C and the dissolved oxygen was above 5.5 mg L^{-1}. The salinity ranged from 33‰ to 37‰ and the pH from 8.0 to 8.3.

Results

Induced spawning

Thermal stimulation (ambient temperature ± 3–5°C) was found to be the most successful method for spawning initiation of *H. scabra* and three successful breeding trials have been carried out since October 2011. The males spawned before the females and pre-spawning behaviour included rolling and twisting on the substrate. Males raised the anterior end of their bodies perpendicularly prior to spawning and often swayed from side to side, releasing a steady stream of sperm from a single gonopore at the top of the anterior end (Fig. 2). Males remained erect and spawned continuously for several minutes or hours, even when they were disturbed.

Females started spawning about an hour after the first male, by raising their bodies off the substrate, in a similar manner to males. They formed a bulge in the anterior part of their body and released pale yellow eggs in short powerful bursts which lasted for 20–30 seconds (Fig. 3). Immediately after spawning, the females returned to a horizontal position. In *H. scabra*, around 0.7, 0.38 and 1.8 million eggs were produced in the first, second and third breeding trials respectively.

Spawning of *C. quadrangularis* was initiated by transportation stress, while the addition of increased quantities of microalgae (*Chaetoceros* spp.) was more effective for *P. violaceus*.

Two successful breeding trials were carried out for *P. violaceus* in April and May 2012, and one trial for *C. quadrangularis* in May 2012. In both species, males spawned first and females reacted about 40–50 minutes after the first male. Males spawned continuously for around 35 minutes and females for 20–30 seconds. Around 0.52 and 0.09 million eggs were produced by *P. violaceus* in the two breeding trials and around 0.73 million eggs were produced by *C. quadrangularis*. High mortality rates were observed at the end of the larval rearing process and for all these species the survival ranged from 0.7% to 1.5%.

Larval development and larval rearing

After fertilisation, cleavage started and the embryo further developed inside the fertilisation membrane. The cleavage was complete and holoblastic. The blastula stage occurred within an hour after fertilisation and it became a typical gastrula stage after one day. The larval development of *H. scabra* consisted of auricularia larva, which is a feeding stage, and then the non-feeding doliolaria larval stage and finally the pentactula larval stage. Auricularia is a slipper-shaped, transparent larva with ciliated bands around the body. It has a pre-oral loop in the anterior part and an anal loop posterior. Three larval developments stages – early, middle and late auricularia – can be identified. Early auricularia larvae were formed after two days and late auricularia were formed after five or six days and remained for 10–13 days. The digestive tract, comprising foregut, mid gut, hindgut and larval anus, was observed in the late auricularia stage. Auricularia larvae are pelagic in habit and feed on microalgae.

Doliolaria larvae are smaller and more compact than auricularia larvae. They have a barrel-shaped, dark-brown body with five ciliated bands (Fig. 4). In this stage, rapid changes can be observed inside their body and all adult features begin to form. This stage remained for 2–3 days (day 14 to 16 in their life cycle) and plastic sheets (PVC) were transferred to the larval tanks as soon as the first doliolaria larva was observed, as they need favourable substratum to settle on and metamorphose into pentactula larvae.

Pentactula larvae were observed after 16 days. It is a tubular-shaped larva with five tentacles at the anterior end and a single posterior foot. The body colour is dark with a greenish-grey tinge. Tube feet develop all over the body. The pentactula creeps over the sides and bottom of the tank and they actively feed on benthic algae and other detritus. After one month they become typical sea cucumbers with the same body shape as adults, but in the early juvenile stages there are two long tube feet at the posterior end. In this study, they were tightly attached to the settlement substrata but could perform slow activities. The juveniles produced in the indoor hatchery tanks (~ 3 cm length) were nursed in outdoor fibreglass tanks until they reached around 5–10 g (Fig. 4). The nursed juveniles were grown out in a lagoon pen.

The development stages of *P. violaceus* and *C. quadrangularis* are very similar to those of *H. scabra*. In both these species, the non-feeding doliolaria stage appeared around 13–14 days but juvenile growth was very low compared to *H. scabra* juveniles. Juveniles of these species took more than two months to attain an average length of 5–8 mm and *P. violaceus* juveniles attained an average length of 1 cm only after four months (Fig. 5).

Grow-out of juveniles

H. scabra juveniles with an average weight of 11 g ± 4 were transferred into a pen which was constructed in Puttlam lagoon. The size of the pen was

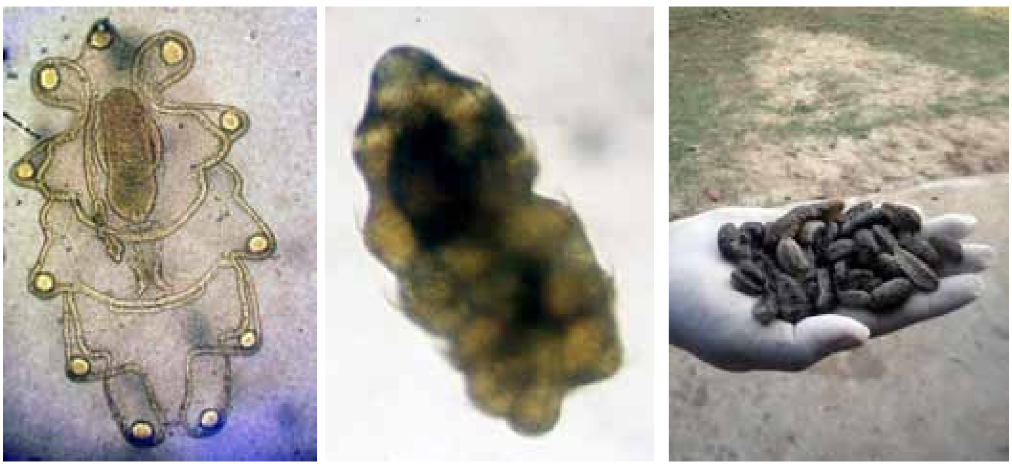

Figure 4.
Different stages of *H. scabra* life cycle: auricularia (left), doliolaria (middle) and juveniles (right).

Figure 5. Larval stages of *P. violaceus* gastrula (left), pentactula (middle) and juveniles (right).

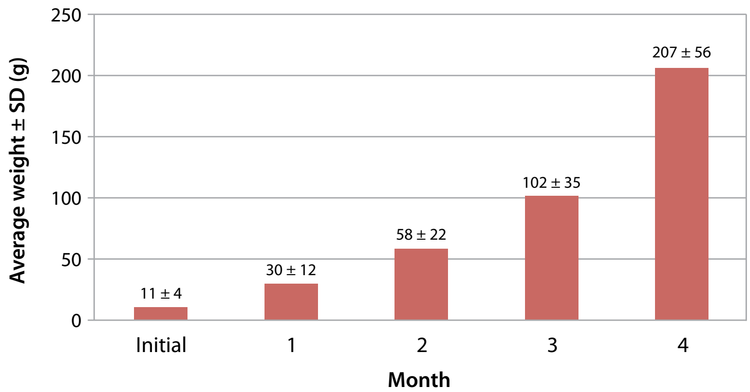

Figure 6. Weight increase of *H. scabra* reared in a lagoon pen.

Figure 7. External appearence of *H. scabra*: initially stocked into pen (left), after one month (middle) and after 3 months (right) of stocking.

56 m^2 and the stocking density was 3 ind. m^{-2}. These juveniles were weighed each month and attained an average weight of 207 g ± 56 within a period of four months (Fig. 6 and 7). There were differences in growth rate with time. In first month the reported growth rate was 0.8 g day^{-1} and this increased gradually, attaining the highest growth rate of 3.6 g day^{-1} in the fourth month. The average growth rate during the four-month period was 1.7 g day^{-1} and the survival rate after four months was 89%.

Discussion

Among the tropical sea cucumbers, *H. scabra* is considered one of the best species for aquaculture

(Battaglene 1999; Battaglene and Bell 1999). Artificial breeding and larval rearing of *H. scabra* have been conducted in several countries, including Australia (Bell et al. 2007; Morgan 2001), Fiji (Hair et al. 2011), India (James 2004), Madagascar (Lavitra et al. 2009), New Caledonia (Giraspy and Ivy 2005), Solomon Islands (Battaglene et al. 1999), Vietnam (Pitt and Duy 2004) and Iran (Dabbagh and Sedaghat 2012). Thermal stress is a well-known practice used to stimulate spawning in sea cucumbers (James et al. 1988; Battaglene et al. 1999, 2002; Morgan 2000; Giraspy and Ivy 2005; Eeckhaut et al. 2012) but in the present study thermal stress was successful only for *H. scabra*. The addition of microalgae and transportation stress are two other methods that can be used to induce spawning of sea cucumbers (Dolmatov and Yushin 1993; Reichenbach 1999) and these methods were successfully adopted for *P. violaceus* and *C. quadrangularis* respectively in this study.

Previous studies have shown that spawning of sea cucumbers can be seasonally limited. For an example, in Vietnam, *H. scabra* broodstock could be induced to spawn throughout the year (Pitt and Duy 2004) but in Iran spawning peaks are in early and late summer. It is, however, difficult to conclude reproductive periodicity of *H. scabra*, *P. violaceus* and *C. quadrangularis* in Sri Lanka as we did not make any attempt to induce them throughout the year.

In all our spawning trials, *H. scabra* males spawned first and the females reacted around one hour later. The time between the first spawning males and females among the three species that we studied was usually less than one hour. This is in accordance with previous observations made on several sea cucumber species. According to James et al. (1994), females are stimulated by the presence of sperm in the water column. As observed in our experiments, most aspidochirotids lift the anterior end of the body from the substratum during spawning to facilitate dispersal of gametes and fertilisation (McEuen 1988). Releasing of the eggs in short powerful bursts is typical of many holothurians; it aids the release of eggs into the water column, their dispersion and fertilisation (Battaglene et al. 2002).

The larval development stages of these three species seem to be very similar. However, according to Agudo (2006), there may be differences in the length of the larval cycle from species to species and even within the same species in relation to geographical location. In tropical waters, *H. scabra* (James et al. 1988), *H. spinifera* (Asha and Muthiah 2002) and *Actinopyga echinites* (Chen and Chian 1990) have taken less than 15 days to reach the non-feeding doliolaria stage and, in this study, the doliolaria of these three species also appeared in less than 15 days. As this is the first report of induced spawning and larval rearing of *P. violaceus* and *C. quadrangularis*, there are no published works to make any comparison of larval development stages, larval rearing, growth and survival of these species.

Previous studies have reported that settlement of sea cucumber larvae can be induced by adding suitable food items. Algamac has been identified as a potential settlement cue and food for settled pentaculae of *H. scabra* (Battaglene 1999). Furthermore, Asha and Muthiah (2002) have observed that Algamac and periphytic diatoms acted as good settlement cues for *H. spinifera*. However, in our experiments we did not use this kind of settlement cue and this may be a reason for the observed high larval mortality rates.

In Vietnam, *H. scabra* juveniles with an average weight of 84 g stocked at 0.73 juveniles m^{-2} grew at a rate of 1.05 g day^{-1} over five months (Agudo 2006). This study revealed a much higher growth rate (1.7 g day^{-1}) for this species with stocking density of three juveniles m^{-2}. However, in Iran, *H. scabra* juveniles reared in a sea pen attained up to 22 g after one year (Dabbagh and Sedaghat 2012).

According to preliminary observations, there is a high potential for commercial sandfish culture in Sri Lanka. However, as this is the first attempt to breeding and rear the larvae of any sea cucumber species in Sri Lanka, there needs to be more research to improve the larval rearing and grow-out facilities before starting any commercial activity.

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The ability of holothurians to select sediment particles and organic matter

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Abstract

Particle selectivity by deposit feeders is an important concept in the ecology of benthic species. The holothurians, as deposit feeders, utilise the organic matter that coats sediment and detritical particles as food. Thus, particle size has been proposed as one resource axis along which niche separation can occur in optimal foraging strategy. Interspecific differences in particle size preference are thought to reduce the interspecific competition among benthic deposit-feeder species.

The analyses of the digestive contents of the holothurian species that were sampled in two localities of Algerian shallow water areas are presented. The results illustrate the specificity of each species: holothurians ingesting the coarse and fine sediment [*Holothuria* (*Holothuria*) *tubulosa*, *H.* (*Roweothuria*) *poli* and *H.* (*H.*) *stellati*], and holothurians selecting fine and very fine sediment [*H.* (*Panningothuria*) *forskali* and *H.* (*Platyperona*) *sanctori*]. Concerning the selectivity of organic matter, *H.* (*P.*) *forskali* is the most selective species followed by *H.* (*Platyperona*) *sanctori*, *H.* (*H.*) *tubulosa*, *H.* (*H.*) *stellati* and *H.* (*R.*) *poli*. This feeding behaviour is discussed between species and sites.

Keywords: Aspidochirotid Holothurians, Algerian basin, organic matter, *Posidonia oceanica* meadows, optimal foraging.

Introduction

Deposit-feeding holothurians belonging to the Aspidochirotid group ingest non-living sediment and detritus material (Coulon et al. 1991; Coulon and Jangoux 1993) for the nutritive particles it contains and for micro-organisms, such as bacteria (Yingst 1976; Moriarty 1982; Birkeland 1989; Plotieau et al. in press), cyanobacteria (Sournia 1976), meiofauna (Berthon 1987), microalgae and fragments of marine phanerogams (Massin and Jangoux 1976; Traer 1980; Verlaque 1981). This behaviour includes processes such as food selection, handling, ingestion, digestion and assimilation (Massin 1982b).

By their feeding activity, holothurians influence microbiological processes at the water-sediment interface (Amon and Herndel 1991a, 1991b) and the bio-accumulation of chemical and organic particles (Lappanen 1995). In addition, rejection of fecal pellets enriches the marine sediment with organic matter; this makes the substratum more attractive for other deposit-feeders (Amon and Herndel 1991a, 1991b). By their selective activity, deposit-feeding holothurians can affect the physicochemical properties of the sediment (Taghon 1982). In fact, they alter the sediment actively and deteriorate the stability of the bottom (Massin 1982a, 1982b). This process, called "turn over" has an effect on the incorporation of organic matter into sediment in finely divided form (Roberts and Bryce 1982; Francour 1989), which is available for the meiobenthos and the microbenthos (Mann 1978).

This study focused on the granulometry of the particles ingested by sea cucumbers and also on the organic matter found throughout their digestive tract. We analysed and compared the contents and the rates of organic matter assimilation of the digestive tract with those of the ambient sediment. Particle selection during foraging was studied by comparing the grain size distribution of the ambient sediment with that of the gut sediment of five holothurian species inhabiting the *Posidonia oceanica* meadows of two contiguous Algerian areas.

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Materials and methods

Sampling sites

Investigations were carried out at two sites, the first situated in Algiers Bay (Tamentefoust) and the second in Bou-Ismail Bay (Sidi Fredj), at a depth of 1–9 m (Fig. 1). The site of Tamentefoust, located in the eastern part of Algiers Bay, is in a half closed creek, an area well protected from the dominant winds and influenced by the Oued El-Hamiz. Holothurians inhabit the rocky bottom, with photophile algae dominated throughout the year by *Colpomenea sinuosa*, sparse *Posidonia oceanica* beds (Semroud 1993) and scattered benthic fauna: seasonally by *Fosliella* sp. and *Ulva rigida*. It is a polluted area with harbour activities and the discharge of domestic waste water.

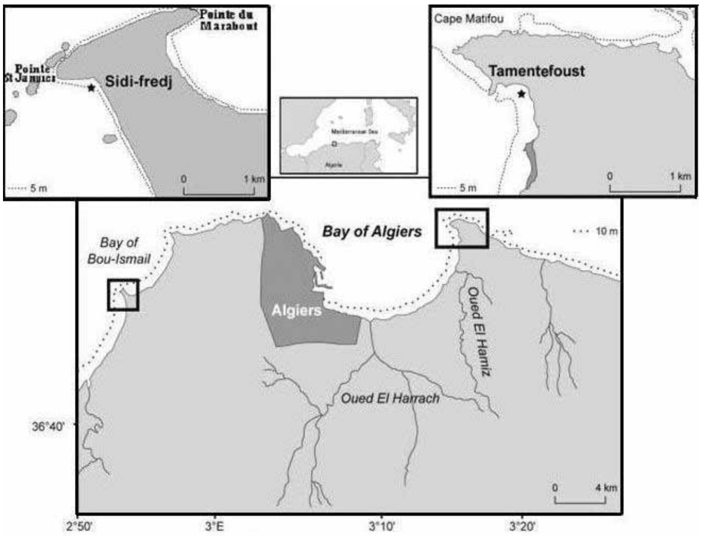

Figure 1. Location of the two sampling sites: Tamentefoust and Sidi Fredj.

Table 1. Mean densities [standard deviation] of the studied holothurian species in the two sites, evaluated for 240 m² (Mezali 1998, 2008).

Species	Sidi Fredj	Tamentefoust
Holothuria (*Holothuria*) *tubulosa*	0.942 [0.113]	0.396 [0.045]
Holothuria (*Roweothuria*) *poli*	0.400 [0.068]	0.096 [0.022]
Holothuria (*Holothuria*) *stellati*	0.050 [0.017]	0.038 [0.014]
Holothuria (*Panningothuria*) *forskali*	0.225 [0.036]	0.054 [0.024]
Holothuria (*Platyperona*) *sanctori*	0.250 [0.051]	0.050 [0.026]

The sampling site of Sidi Fredj is further from the much industrialised area of Algiers and is located in Bou-Ismail Bay, an area much less exposed to domestic waste water than Tamentefoust, and considered less polluted (Soualili et al. 2008) but more exposed to the dominant winds (Guettaf et al. 2000). The site is in a semi-protected area (enclosing a marine medical centre) on a rock ledge interrupted by sandy and heterogeneous block bands where marine phanerogams are dominant. *Posidonia oceanica* meadow is in better health here than in Tamentefoust. A *Cymodocea nodosa* meadow is also present.

Collection and preparation of samples

In the Mediterranean *Posidonia* meadows, three deposit-feeding holothurian species [*Holothuria* (*Holothuria*) *tubulosa*, *H.* (*Roweothuria*) *poli* and *H.* (*Panningothuria*) *forskali*] are common. Within the Algerian *Posidonia* meadow, these three species are indexed with two others species [*H.* (*Platyperona*) *sanctori* and *H.* (*Holothuria*) *stellati*]. The mean densities of these species are shown in Table 1 for Sidi Fredj and Tamentefoust sites (Mezali 1998, 2008).

The holothurians were collected by scuba diving at a depth of 1–9 m during spring. Batches of samples, each batch composed of ten individuals of each species (larger than 150 mm contracted length), were collected from each site, measured and isolated individually into small plastic bags, together with some sediment taken from the study area. A Plexiglas box closed in one of its ends was used to sample the first millimetres of the bottom sediment. In the laboratory, each animal was dissected longitudinally and its digestive tract carefully collected. To calculate the percentage of organic matter, the sediment collected from the gut of the ten individuals of each species was pooled. We used the following relation: % OM = (1-AW/DW) x 100, where DW = Dry Weight; AW = Ash Weight and OM = Organic Matter (Massin 1980). The same protocol was used for the bottom sediment. The percentage of organic matter in the gut sediment was compared with that of the ambient sediment in each site.

The granulometric technique used is indicated in Figure 2. For each species, the sediment from the gut of the ten individuals of that species was pooled in order to provide samples of a size suitable for granulometric analysis (≥ 150 g) (Roberts 1979). The obtained sediment was oven dried (for 24 hours at 105°C), then weighed (initial weight = 150 g). A fine fraction was obtained by sifting under running water using a 40 μm mesh sieve (Fig. 2). The rest of the sediment was dried, weighed (final weight), then sieved mechanically using a series of AFNOR sieves. What

remained in each sieve was weighed and expressed as a percentage of the initial weight. Percentages of the various fractions, coarse (600–2000 µm), average (200–600 µm), fine (60–200 µm) and very fine (40–60 µm) were thus determined (Berthois 1975).
A multiple comparison of average rates was carried out using a non-parametric statistical test [Kruskal-Wallis one-way analysis of variance by ranks ($P < 0.05$) (Statistica 6.0)]. Prior to this analysis, an arcsin transformation was used for the percentages ($x' = \arcsin\sqrt{x}$).

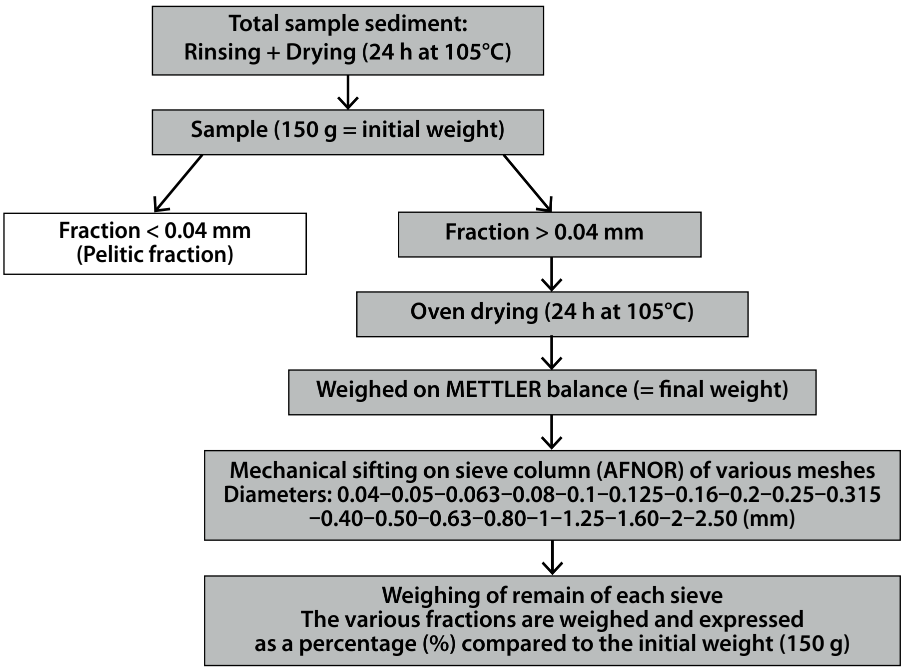

Figure 2. Grain size analysis of the holothurians guts and bottom sediments.

Results

Size selection of sediment particles

The percentages of the size classes of the surrounding sediment in both sites differed from those found in the guts of holothurians. The bottom sediments were characterised by high rates of fine fraction (59.87% and 55.13% respectively in Sidi Fredj and Tamentefoust sites, Table 2). This phenomenon was observed at Sidi Fredj site for all holothurians species that have a tendency to select in preferential way the fine fraction (42.76–57%, with an average of 49% ± 5.7, Table 2). At that site, *Holothuria* (*R.*) *poli* was the most significantly selective for this fraction ($P < 0.01$).

Holothuria (*R.*) *poli* at Tamentefoust site also selected the fine fraction (31.92%, Table 2). At Sidi Fredj site *H.* (*P.*) *forskali* and *H.* (*P.*) *sanctori* had a tendency to select the very fine fraction (22.09–31.32%, Table 2), this was also observed at Tamentefoust site for *H.* (*H.*) *tubulosa* and *H.* (*R.*) *poli*, which showed the highest

Table 2. Grain size distribution in percentages of dry weight per size class of sediment taken from the holothurians guts and the surrounding sediment. *: classification according to Berthois (1975).
T = Tamentefoust; SF = Sidi Fredj. The first line in size classes refers to the mean, the second line to the standard deviation.

	Substratum	*Holothuria* (*Holothuria*) *tubulosa*	*Holothuria* (*Roweothuria*) *poli*	*Holothuria* (*Holothuria*) *stellati*	*Holothuria* (*Panningothuria*) *forskali*	*Holothuria* (*Platyperona*) *sanctori*
Fraction* (µm)	**T/SF**	**T/SF**	**T/SF**	**---/SF**	**---/SF**	**---/SF**
< 40	3.50/4.59	4.81/6.05	2.89/4.32	6.86	5.06	6.16
	[1.20/2.40]	[1.00/2.30]	[2.30/2.70]	[2.00]	[2.30]	[2.70]
40–60	3.70/18.80	1.75/9.81	9.10/10.20	8.96	22.09	31.32
	[2.40/2.50]	[3.30/2.50]	[1.70/2.10]	[2.50]	[2.50]	[2.10]
60–200	55.13/59.87	17.32/42.76	31.92/57.09	47.21	52.56	45.64
	[3.50/2.30]	[4.00/3.50]	[2.10/3.40]	[2.30]	[2.50]	[1.40]
200–600	35.12/4.54	60.26/13.35	40.36/11.34	9.57	11.00	10.68
	[2.10/2.34]	[5.50/2.80]	[3.10/2.20]	[2.34]	[2.80]	[2.20]
600–2000	2.55/12.20	15.86/28.03	15.73/17.05	27.40	9.29	6.20
	[2.20/2.30]	[2.70/2.30]	[1.20/2.70]	[2.10]	[3.40]	[2.20]

percentage of this fraction (200–600 µm) with respective percentages of 60.26 and 40.36% compared with 35.12% in the ambient sediment (Table 2). At Tamentefoust site, *H.* (*H.*) *tubulosa* and *H.* (*R.*) *poli* had significant selectivity for the average fraction (40.36–60.26%, Table 2) with, however, *H.* (*H.*) *tubulosa* the more selective compared to *H.* (*R.*) *poli* ($P < 0.01$). This selectivity for the average fraction was not observed for these species at Sidi Fredj site. We noted, by comparing the sediment fractions in the holothurians guts and the surrounding sediment of the two sites, that *H.* (*R.*) *poli* presented an adaptation to its environment. At Sidi Fredj site the highest fraction was between 60 and 200 µm and at Tamentefoust site it was between 200 and 600 µm (Table 2).

Organic matter assimilation

The high rate of organic matter in the gut sediment of *Holothuria* (*R.*) *poli* and *Holothuria* (*H.*) *tubulosa* at the Tamentefoust site [6.67 and 8.70% respectively for each species (Kruskal-Wallis, $P < 0.01$), Table 3] shows that both species have a tendency to select organic matter from the bottom sediment (3.18%, Table 3). This result was true for *Holothuria* (*P.*) *forskali* and *H.* (*P.*) *sanctori* at Sidi Fredj site (8.58 and 7.72% respectively, Table 3) ($P < 0.01$), but not observed for *H.* (*R.*) *poli*, *H.* (*H.*) *tubulosa* and for *H.* (*H.*) *stellati* (2.49, 4.31 and 3.55% respectively, Table 3). *Holothuria* (*H.*) *tubulosa* at Sidi Fredj site presented a percentage in organic matter (4.31%) closer to that of the substratum (4.77%) (Table 3). However, the percentage of organic matter of *H.* (*P.*) *forskali* at Sidi Fredj site did not differ significantly from that of *H.* (*H.*) *tubulosa* at Tamentefoust site ($P > 0.01$). *Holothuria* (*H.*) *tubulosa* at Tamentefoust site was able to concentrate approximately three times the organic matter compared to that of the bottom sediment. *Holothuria* (*P.*) *forskali* at Sidi Fredj site was able to concentrate approximately two times the amount of organic matter that the bottom sediment could (Table 3).

Discussion

The high rate of fine fraction found in the bottom sediment is related on the one hand to the exposition of the sampling area (quiet mode of both sites) and on the other hand to the organic matter concentration. In fact, according to Berthois et al. (1968), the rate of organic matter increases with the importance of the fine fraction of the sediment. This is observed for *H.* (*R.*) *poli* at Tamentefoust site, which has a tendency to select this fraction (31.92%). Indeed, Plotieau et al. (unpublished results) suggested that the nutritional value of the fine sediments would be higher than that of the coarse sediments because of their higher number of nutritive microorganisms. It is also noticed that *H.* (*H.*) *tubulosa* and *H.* (*R.*) *poli* have a significant preference for the average fraction (200–600 µm).

The results obtained corroborate the observations of Massin and Jangoux (1976) on *H.* (*H.*) *tubulosa*, which can accumulate approximately three times more organic matter than the bottom sediment can. The difference in organic matter noted in the gut sediment of holothurian species could be related to their micro-distribution in *Posidonia oceanica* meadow (preferred biota and its organic matter richness). *H.* (*H.*) *tubulosa* was observed between *Posidonia* leaves (30% of individuals, Mezali 2004). In fact, Blanc (1958) demonstrates that the length of *Posidonia* leaves is responsible for the decantation and accumulation of a great quantity of biodetritical and terrigenous material. *H.* (*H.*) *tubulosa* was also observed between the blocs mixture (33% of individuals, Mezali 2004) where food is stocked. *H.* (*R.*) *poli* prefers the sandy bottom (40% of individuals, Mezali 2004) influenced by hydrodynamism that disperses food.

The difference in organic matter noted in the gut sediment is also due to the difference in the texture of the tentacles. Indeed, according to Massin and Jangoux (1976), *H.* (*H.*) *tubulosa* is able to recognise particles covered by organic matter.

Table 3. Percentages (%) of organic matter (OM) in the gut sediment of holothurians and the surrounding sediment at both sites.
T = Tamentefoust; SF = Sidi Fredj; SD = standard deviation.

	Substratum	*Holothuria* (*Holothuria*) *tubulosa*	*Holothuria* (*Roweothuria*) *poli*	*Holothuria* (*Holothuria*) *stellati*	*Holothuria* (*Panningothuria*) *forskali*	*Holothuria* (*Platyperona*) *sanctori*
OM	**T/SF**	**T/SF**	**T/SF**	**---/SF**	**---/SF**	**---/SF**
Means	3.18/4.77	8.70/4.31	6.67/2.49	3.55	8.58	7.72
SD	---/---	4.83/2.92	2.34/1.67	2.82	6.05	4.46

We can conclude that these aspidochirotid holothurians species are deposit feeders, feeding on materials present at the water-sediment interface. They feed selectively and are able to discriminate between the rich and poor particles in nutritive elements, and select the rich ones. This recognition is undoubtedly due to the gustatory receivers located on their tentacles. The food preferences are related to the size of individuals (Paine 1976). This last point has great implications for the distribution and abundance of nutritive matter.

The aspidochirotid holothurians' capacity to select food was studied by comparing the composition of their digestive tract sediment and the bottom sediment. This comparison gives a valid indication, since the studied sites are relatively homogeneous (Khripounoff and Sibuet 1982). The detritus (i.e. degrading or dead organic matter) represents the essential nutritive source for these benthic animals: *Holothuria* (*R.*) *poli* at Tamentefoust site is the more selective for the organic matter.

The granulometric analysis of the digestive contents illustrates the feeding specificity of *H.* (*H.*) *tubulosa* and *H.* (*R.*) *poli*. Both species ingest the average and fine sediment fraction. The granulometric analysis of guts contents allowed us to classify the holothurians in two groups: (1) holothurians that ingest the coarse and the fine fractions of sediment (600–2000 µm and 200–60 µm): *H.* (*H.*) *tubulosa*, *H.* (*R.*) *poli* and *H.* (*H.*) *stellati*; (2) holothurians that have a tendency to select the fine and very fine fractions of the sediment (40–200 µm and < 40 µm): *H.* (*P.*) *forskali* and *H.* (*P.*) *sanctori*. The two groups react in a different way in polluted and less polluted areas and their physiological answers may be interpreted in the light of optimal foraging theory.

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Volunteer programme assesses the *Holothuria arguinensis* populations in Ria Formosa (southern Portugal)

Mercedes González-Wangüemert[1], Tiago Braga[1], Mariana Silva[1], Sara Valente[1], Fernanda Rodrigues[1] and Ester Serrao[1]*

Abstract

The population status of *Holothuria arguinensis* in Ria Formosa (southern Portugal) was assessed using a visual census conducted by a volunteer programme, the CUMFISH project. We found high densities of this species (267 ± 152 ind. ha^{-1}) in Praia de Faro, but the values oscillated, depending on transect and habitat. *H. arguinensis* seems to prefer a bottom covered with seagrass, mainly *Cymodocea nodosa* and *Zostera marina*. Its size-frequency distribution was multimodal, showing lengths ranging from 7 to 33 cm. During the sampling last March (data not included), we found a high percentage of juveniles smaller than 6 cm, which indicates good recruitment inside the Ria.

Introduction

Holothuria genus is the only Holothuriidae present in the Mediterranean Sea and north-eastern Atlantic. It is found in various marine habitats in shallow coastal waters. They are found in high density, providing important ecosystem services and enhancing nutrient cycling and local productivity in oligotrophic carbonate sediments through their bioturbation and deposit-feeding activities (Byrne et al. 2010).

Holothuria (*Roweothuria*) *arguinensis* (Koehler and Vaney, 1906) belongs to this genus and, in the last few years, has been considered a target species in the growing sea cucumber fishery (Aydin 2008; Sicuro and Levine 2011). This species had been considered a north-eastern Atlantic species, distributed from Portugal to Morocco and Mauritania, including the Canary Islands (Thandar 1988). It has not been found in other Macaronesian Islands such as Açores, Selvagens or Madeira, nor in the Cape Verde Archipelago (Borerro-Pérez et al. 2010; Micael et al. 2012). However, its geographical distribution is changing, including its colonisation of the Mediterranean Sea, where it was registered in the Alicante coast in southern Spain (González-Wangüemert and Borrero-Pérez 2012), and its extension to the northern Portugal coast in the Berlengas Islands (Rodrigues 2012). However, information about this species is scarce (density, abundance, habitat and reproduction) in spite of its high potential as a fishery target and its very restricted geographic distribution. Under the CUMFISH project (PTDC/MAR/119363/2010, http://www.ccmar.ualg.pt/cumfish/), we are carrying out a volunteer programme to assess the *H. arguinensis* populations inhabiting the Ria Formosa (southern Portugal) using a visual census that will continue for two more years. This study will provide useful information concerning density patterns, habitat preferences, distribution of size classes and some observations *in situ* about its recruitment inside Ria Formosa.

Materials and methods

Ria Formosa is a large tidal lagoon extending for 55 km along the south coast of Portugal with a total area of 170 km^2. A strongly branched system of creeks and channels is connected to the ocean by six outlets. The system has semi-diurnal tides, with 50–75% of the water volume exchanged during each tide. The lagoon shows a salinity around 35.5–36.9 PSU and water temperatures range from 12–28°C.

The visual census was carried out in Praia de Faro (36° 59' 0'' N, 7° 55' 0'' W) on both sides of the main bridge (Fig. 1). The census was conducted during low tide at least twice a month. The results described here were obtained between November 2012 and February 2013.

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Figure 1. Sampling sites in Praia de Faro (Ria Formosa, southern Portugal). A: East side of the bridge; B: West side of the bridge.

Figure 2. Transect outside water during low tide with two individuals of *Holothuria arguinensis.*

To carry out the visual census, we used two transects of 100 x 2 m with three replicates for each one (Dissanayake and Stefansson 2010) on two different scales, considering the level of maximum low tide (Transect 1: outside water, transect 2: inside water) (Fig. 2).

We established the sampling date, considering the best low tides, from local tide tables (http://www.hidrografico.pt/previsao-mares.php). For each transect, we obtained information about the identity of the sea cucumber species, the total length, external marks, bottom and habitat types (sand, clay, pebbles, rocks, seaweeds, seagrass), and position in the transect. Some photos were taken during samplings.

Results and discussion

H. arguinensis was observed in all of the sampling sites, with an average density of 267 ± 152 ind. ha^{-1}, although the density ranged from 140 to 480 ind. ha^{-1}, depending on the transect and habitat. During the samplings, we registered the presence of another sea cucumber species, *H. mammata*, but its density was very low. In general, *H. arguinensis* densities were higher on the west side of the bridge and along transect 2 (inside water) (Fig. 3).

These results are logical, considering the presence of dense and continuous *Zostera marina* and *Cymodocea nodosa* seagrass on the west side, while on the east side there is a heterogeneous habitat of small patches of seagrass, sand and mud. *Holothuria arguinensis* seems to prefer a bottom covered with seagrass. The data showing higher densities in transect 2 (inside water) are also understandable because sea cucumbers minimise the

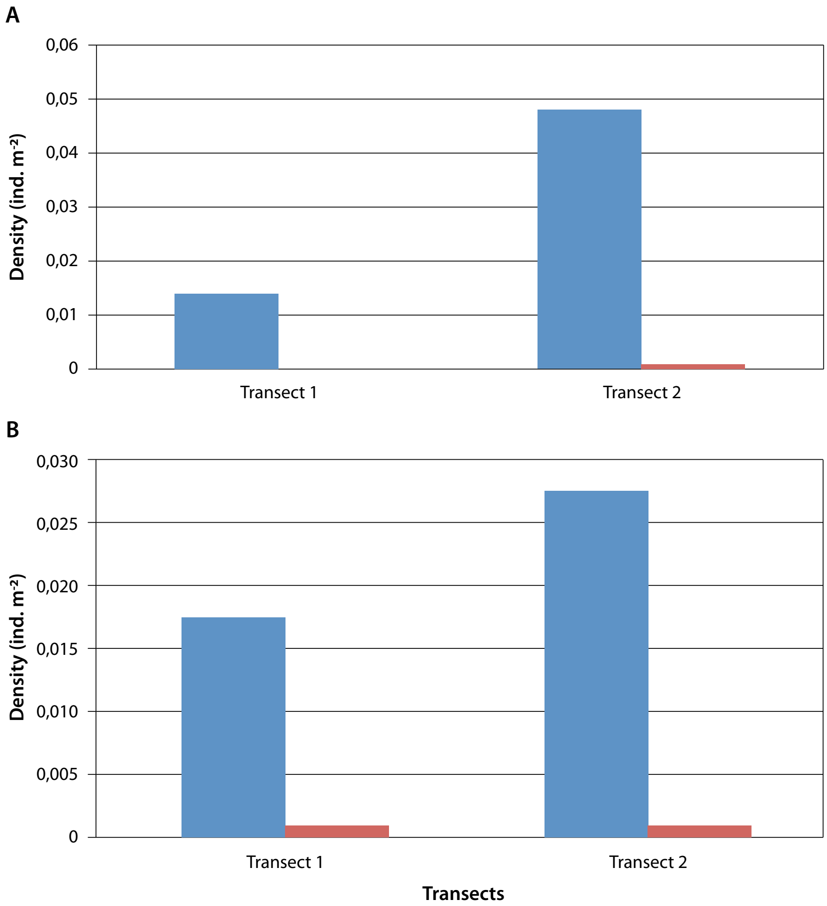

Figure 3. Density (in ind. m^{-2}) of *Holothuria arguinensis* (in blue) and *Holothuria mammata* (in red) over a period of four months in Praia de Faro for the different transects (transect 1: outside water; transect 2: inside water). A: Densities on the west side of the bridge; B: Densities on the east side.

Figure 4. *Holothuria arguinensis* damaged by exposure.

risk of phototoxicity by maintaining themselves under water or covered with leaves of seagrass. In fact, some of the sea cucumbers that were not covered with water during low tide on days of high radiance (ultraviolet light) showed a sickly and mucilaginous aspect (Fig. 4).

H. arguinensis individuals from Praia de Faro ranged in length from 7 cm to 33 cm and showed a multimodal size-frequency distribution, with the higher abundances 19–20 cm in length (Fig. 5). It is important to note that during the last samplings we found many juveniles, mainly on the west side in the seagrass (Fig. 6).

During the next two years, we will continue to carry out the visual census in Praia de Faro and three other localities inside Ria Formosa (Tavira, Fuseta and

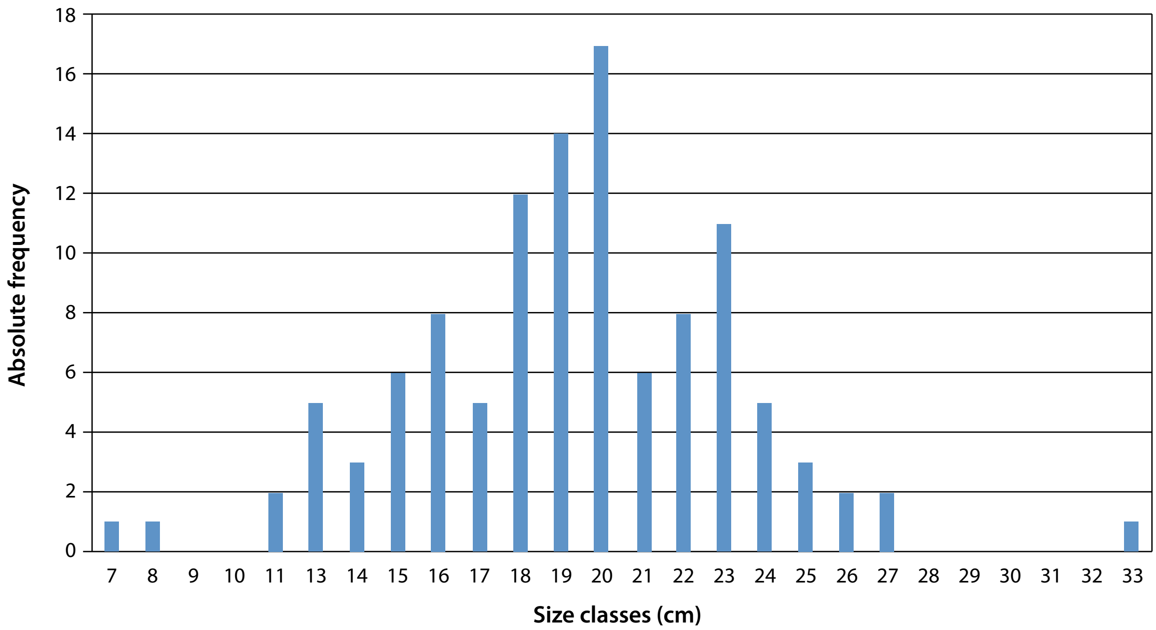

Figure 5. Length-frequency distribution of target species (*Holothuria arguinensis*) over a period of four months from Ria Formosa.

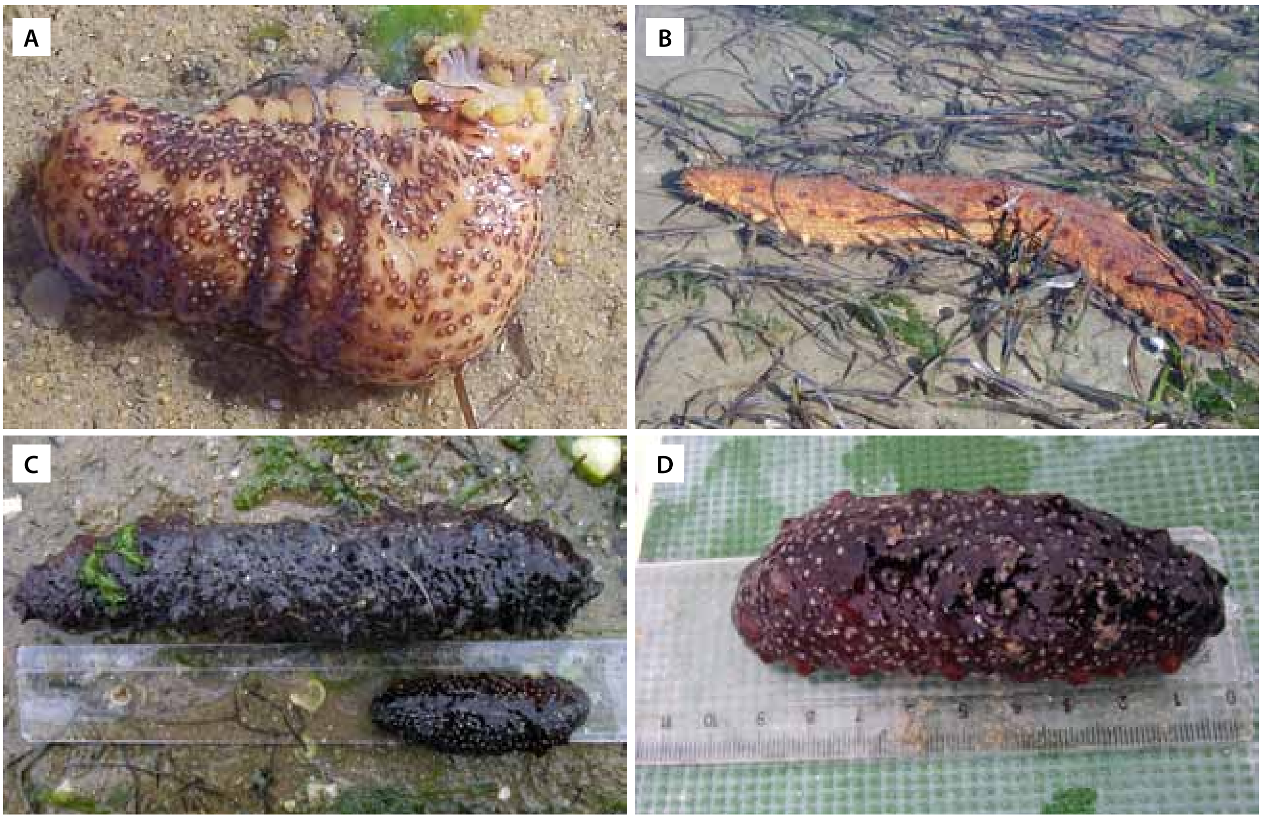

Figure 6. Different specimens of *Holothuria arguinensis* sampled in Ria Formosa. A: *H. arguinensis* juvenile found inside seagrass (5 cm); B: Adult of *H. arguinensis* sampled on a patch with *Cymodocea nodosa* and *Ulva* sp; C: Juvenile and adult of *H. arguinensis*; D: *H. arguinensis* juvenile with 9 cm of length.

Culatra), recording the same parameters and supplementary ones, such as seagrass covering, irradiance, water and air temperature and granulometry of sediment. This information, obtained through the volunteer programme, together with the studies of the genetic diversity, ethology, reproduction and nutritional profile, which are accomplished at the same time by MSc students, will allow us to have a better picture of *H. arguinensis* populations in Ria Formosa for future fishery management.

Acknowledgements

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Management state of Pacific sea cucumber fisheries

Kalo Pakoa[1] and Ian Bertram[1]

Many of the sea cucumber fisheries in Pacific Island countries and territories (PICTs) are in a poor state and in need of rehabilitation. Many are closed as countries attempt to take drastic action to prevent further collapse. Persistent pressure from buyers to supply sea cucumber products is creating an uphill battle for many PICT fisheries as they try to control sea cucumber exploitation. There is also a lack of effective fisheries management frameworks, regulatory measures and enforcement capacities in many countries. In this article we summarise the current state of sea cucumber fishery management in several countries as of March 2013, and progressive action being taken, with SPC collaboration, to establish formal fishery management frameworks. In Figure 1, a coloured code is used to indicate the state of sea cucumber fisheries in the Pacific Islands region.

Vanuatu extends closure to ten years

The Vanuatu Fisheries Department, sea cucumber resource owners and those interested in rehabilitations of stocks are relieved: the fishery will remain closed for another five years. There was mounting pressure to open the fishery towards the end of the first five-year closure (2008–2012), the national general election added fuel to pressures to open the fishery as traders tried to influence decisions to lift the ban on harvest and exports. The Fisheries Department organised an awareness meeting that targeted interested politicians who at the end understood the low status of the resources in the country and the need to keep the fishery closed to allow full recovery of stocks. Vanuatu Fisheries followed SPC's advice, based on the results of surveys undertaken in 2011 and 2012, to extend

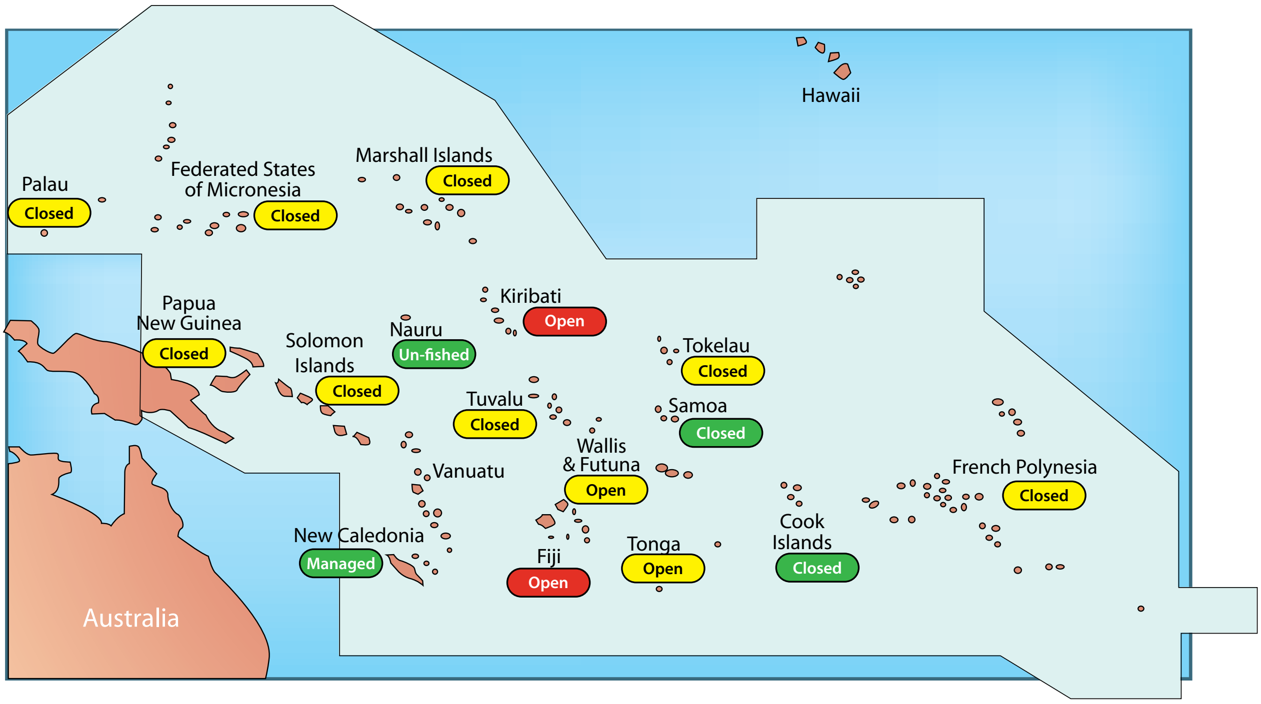

Figure 1. State of sea cucumber fisheries in PICTs.
Red: countries that have relatively few measures in place to control the fishery ; Yellow: fisheries closed in the past five years or where an open season is implemented with management plans being developed or reviewed; Tonga and Wallis-Futuna implement annual open seasons; Green: relatively well-managed fisheries, fisheries that have been closed for the last 20 years and the unfished fishery of Nauru.

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the five-year ban. This new amendment, dated 19 December 2012, took effect from 1 January 2013. SPC had, in 2006, advised Vanuatu Fisheries to close the fishery, based on 2003 assessments. This resulted in the decision to close the fishery in 2008. This extended ban is necessary to allow stocks to recover, and other assessments will be undertaken during the next five years to evaluate the status of the resource. It will also give time to finalise the draft national fishery management plan and prepare the opening of the fishery. Trials will also be conducted to assess the value of other products besides the traditional boiled and dried beche-de-mer.

Papua New Guinea extends current moratoria for another three years against pressure to lift the ban

Papua New Guinea (PNG) was the region's largest sea cucumber fishery and contributed around 10% of global sea cucumber production. In the 1990s, PNG developed and introduced a national sea cucumber fishery management plan, but, catch rates of some species continued to decline and localised depletions were observed. A three-year moratorium was therefore enforced in 2009. A survey undertaken by the National Fisheries Authority (NFA) in 2012 showed that resources had not yet fully recovered. NFA decided in early 2013 to keep the fishery closed for another three years, during which the status of stocks would be monitored. The current management plan is under review, and will probably include a modified total allowable annual catch and the allocation of species-specific quotas.

Solomon Islands opens its fishery for three months to allow export of stockpiled products

Solomon Islands closed its fishery in 2005. Two years later, the ban was lifted for the Western Province as economic relief for victims of the tsunami and earthquake that hit the area. It turned out to become a nationwide open season, as fishers from other provinces also went fishing for the valuable product. In 2009, the moratorium was re-enforced for the whole country, but incidents of fishing activities and stock piling have taken place during the last four years. In 2011, SPC assisted the Solomon Islands Ministry of Fisheries and Marine Resources with resource survey training in Marau and Ngella. The ministry then went ahead to complete assessment surveys in two sites in each of the seven provinces and it is now working on the data analysis and reporting. In 2012, SPC assisted the ministry with the drafting of a management plan, which needs to be discussed with the provinces and finalised. Stockpiling of products has resulted in pressure to lift the moratorium to allow exportation of the stockpiled products. The fishery was opened on 1 March 2013 for three months.

Cook Islands puts management measures in place before opening its fishery

In Cook Islands, commercial sea cucumber fishery was a very minor activity in the 1990s, and it did not last. Interest recently increased when investors expressed their will to exploit the resources. SPC is working with the Ministry of Marine Resources to train local officers in assessment of the resources and provide advice on harvestable quotas. One site has been assessed; training on the analysis of data will be completed in the first quarter of 2013, which will provide further advice on resources in other areas. SPC is also assisting with the formulation of sea cucumber fishery regulations that the government is working towards establishing prior to allowing exports of sea cucumber products.

Samoa puts management measures in place but is already experiencing illegal harvests

In Samoa, the fishery was closed in mid-1994 after commercial fishing threatened stocks of subsistence species important for food security (*Bohadschia argus*, *B. vitiensis*, *Holothuria atra*, *Stichopus herrmanni*, *S. horrens*). SPC assessments in 2005 recorded the density of two main species. Resources in the two main islands of Samoa were assessed during the second half of 2012 and results are being compiled, while, at the same time, a fishery management plan is being developed. Interest in opening the fishery is high; several illegal harvests have already been reported in the last two years, one of those involving a consignment intercepted at the airport. The situation also put pressure on the Fisheries Department to have in place a management plan and the necessary regulations to control the fishery. SPC is assisting the department to put in place formal management measures for the fishery.

Tonga experiences "boom and bust" production

Tonga's sea cucumber resources have been well studied, with SPC assistance. The first survey took place in 1990, followed by a recommendation to develop the fishery. Six years later, in 1996, a new survey showed a sharp decline of stocks, which, in 1997, led the local authorities to impose a ten-year closure. A further SPC-coordinated survey in 2004 revealed that most resources had recovered and the fishery was re-opened in 2008. Export production rose from 15 tonnes (t), to 370 t and 312 t in the following years. In 2011, a new assessment recommended another closure for three to five years, but instead the quota was reduced from 200 t to 100 t, following pressure to keep the fishery open. The final 2011 production (80 t) fell short of reaching the quota. The fishery management plan in place was not fully implemented and respected, allowing catches to reach the unsustainable levels of 2009 and 2010. Furthermore, despite a ban on the use of underwater breathing apparatus for this fishery, several sea cucumber fishers died from accidents related to scuba diving. The fishery is currently pending assessment, and at the end of 2013 a decision will be made on whether new management measures, including a possible new closure of the fishery, are needed.

Fiji experiences increasing interest to harvest and moves to regulate the use of UBA

Fiji has a significant fishery in the region, which has remained open ever since the boom period of the 1990s. The beche-de-mer exploitation guideline developed in 1998 is the only formal guideline on the management of the fishery, as emphasised by the Fiji Trade and Investment Board policy to promote private sector-led development of the fishery. There is currently no quota on the number of export licenses or the export quantity – by exporter or by area – so, as many other fisheries in the region are closed, there is an increasing number of interested exporters seeking a license to exploit the resource. In addition, the current size limit regulation of 7.6 cm is incorrect and cannot be implemented for all sea cucumbers, the lack of control measures making effective control difficult. Permitting underwater breathing apparatus (UBA) in the fishery has allowed access to stocks in deeper water and resulted in many UBA-dive related accidents. SPC re-engaged with the Fiji Department of Fisheries and NGOs in 2012 to address the situation; resource assessments have been conducted in Bua, one of Fiji's prime production areas, and the trained local teams have continued assessments in several other sites. They are now going through training on how to turn the information into fisheries management advice. Community management is strongly encouraged in Fiji; however, the declining trend of resources indicates the need to strengthen the upper level management systems to support local management at community level. SPC is assisting with the formulation of a national sea cucumber fishery management plan and with advice on resource assessments in other areas. At the same time, based on the assessment of the Bua Province stocks, which indicate the negative impact of UBA fishing on sea cucumber stocks, and based on similar findings from other areas in the Pacific region, SPC has collaborated with the Fiji Department of Fisheries to assist with a cabinet decision on UBA fishing in Fiji.

Marshall Islands implements new regulations

Two years ago, Marshall Islands did not have a sea cucumber fishery management policy, nor regulatory measures, and fishing and exporting of the product was taking place without any monitoring and control system in place. A total ban on export was enforced in early 2011, and work on the establishment of a management framework was initiated, with SPC collaboration. New sea cucumber fishery regulations were gazetted at the end of 2012. Preparation is now under way to open the fishery under these new regulations.

Palau has control measures in place but experienced unsustainable practice and wants to put in place more effective measures

Commercial fishing of sea cucumber ended in 1994 when the Palau Government banned the harvest of the six top commercial species of the 1990s boom fishery period. Sandfish (*Holothuria scabra*), white teatfish (*H. fuscogilva*), black teatfish (*H. whitmaei*), surf redfish (*Actinopyga mauritiana*), hairy blackfish (*A. miliaris*) and prickly redfish (*Thelenota ananas*) were banned from commercial harvest, but subsistence use of some of the banned species and non-regulated species were exempted from the ban. Sandfish, curryfish (*Stichopus herrmanni*) and hairy grayfish (*Actinopyga* sp., an unidentified species) are consumed locally so they are harvested for the local market sale and can be exported for home use to Palau nationals living abroad. These loopholes in the current regulation have resulted in illegal harvesting of protected species in recent years. In 2011, the fishery was opened for one species (hairy grayfish) only for the State of Ngardmau for 48 fishing days (two fishing days a week) over a six-month period. Monitoring of landings by the Bureau of Marine Resources allowed the collection of useful catch and price data from buyers. The data showed that the current practice of selling live cucumbers by 20 litre buckets was unprofitable for fishers, and that product valuation methods were needed. As in the Solomon Islands case, fishers from other states close to Ngardmau State also went fishing and incidents of harvesting non-prescribed species were a cause of concern that led to the decision to close the fishery again in 2012. A more comprehensive management arrangement must be in place before the fishery opens again in future. The Bureau of Marine Resources staff and SPC have developed a draft sea cucumber management plan for Palau; further consultations with stakeholders are required and resources in other States need to be assessed.

The Federated States of Micronesia are under pressure to open their fisheries

The fishery in Yap State has remained closed since 2007 but pressure from sea cucumber hatchery operators in the main island of Yap could influence decisions to lift the current closure. Assessment of the resources in 2009 by SPC led to the recommendation to keep the fishery closed to allow full recovery.

The fishery in Pohnpei State has been closed for nine years and the resources have not been assessed. Pohnpei is currently experiencing pressure from interested traders to open the fishery. SPC will be assisting Pohnpei State in 2013 to assess resources and formulate a fishery management plan for the fishery.

Tuvalu and Tokelau sea cucumber fisheries are closed

Both Tuvalu and Tokelau have small but important sea cucumber resources for the inhabitants. Traders entered Tuvalu in the 2009–2010 period and encouraged fishing for white teatfish and prickly redfish using UBA at depths reaching 50–70 metres. The use of UBA caused the loss of a few lives in Funafuti so access to areas outside Funafuti Atoll was denied by the Island Council to protect their resources and the lives of their people. The fishery in Tuvalu was closed at the end of 2010.

Sea cucumber fishing began in Tokelau in December 2011 through a joint venture arrangement with a local Tokelauan. Concern by the Island Council resulted in the suspension of the fishery until resource assessment and management measures were in place. The resource assessment was done by SPC in April 2012 and a management plan was drafted and delivered to the Island Council, which allowed Asian traders to process and export a limited amount of resources from Nukunonu Atoll.

Nauru has received interest from traders to harvest surf redfish resources

The Ministry of Fisheries has requested SPC assistance to assess and advise on the state of the surf redfish resource before deciding if the fishery can be opened.

French Polynesia closed its fishery while putting in place a management system and the assessment of its sea cucumber resources

As in Cook Islands, sea cucumbers of French Polynesia have not been fished commercially in the last 20 to 30 years (some fishing may have occurred in the early 1990s, but reliable data are lacking). Only recently did commercial fishing for export start, and it steadily increased from three tonnes in 2008 to 125 tonnes in 2011. As the status of the sea cucumber stocks was unknown and no specific management measures were in place, this rapid increase in production, which could have a great impact on natural resources, led to the closure of the fishery in 2013. The assessment of sea cucumber resources in fished and un-fished areas, as well as the drafting of a management plan and regulations, is being undertaken.

Wallis and Futuna sea cucumber fishery stays open

Fishing and export of sea cucumber in Wallis has been in an on and off trend, coinciding with the state of resource recoveries. Exporting took place in the 1990s for a few years, ceased for some years, resumed in 2001, ceased again and resumed once again in 2010. Fishing and export is undertaken by a local business interest in a joint venture with a Fiji-based company; divers from Fiji were brought into Wallis to collect sea cucumbers. In Wallis and Futuna, the Department of Environment issues the fishing license under the Environment Act, while the Department of Fisheries monitors the resources. In 2012, around seven tonnes were exported. The fishery is currently open and it is not known if it will need to be closed to allow recovery of stocks at the current level of exploitation.

Natural spawning observations on Rodrigues Island, Indian Ocean

Alexandre Bédier[1], Chloé Bourmaud[1] and Chantal Conand[1]

The holothurian fauna from Rodrigues Island was described by Rowe and Richmond in 2004 and presents 29 species. Here we present the first observations of natural spawning of *Holothuria fuscocinerea*, a species that has not been recorded there previously, and also the presence of several holothurian species exhibiting spawning behaviours.

Species: *Holothuria* (*Stauropora*) *fuscocinerea*, Jaeger, 1833.

Location: North / East of Paté Reynieux, Mourouk cove, on the eastern coast of Rodrigues Island, Mauritius.

Date and time: 12 January 2013, daytime (16:00–16:30, local time). The climate is subtropical and it was summer time at the time of observation. Cloudy weather and relatively windy.

Figure 1. Male spawning specimen of *Holothuria fuscocinerea* releasing gametes in the water column (Image: Chloé Bourmaud).

Environmental parameters

Moon phase: New moon + 1 day.

Depth and tide: Specimens lying at a depth of approximately 2 m, 20 m from shore, on a dense seagrass bed. High tide (276 cm high) going down to 121 cm high with moderate water current that wobbled the erect specimens.

Bottom substrate: Soft substrate composed of fine grain sand of coral and volcanic origin covered with seagrass. The seagrass was colonised by epiphytes and an algal tuff. *Caulerpa* spp. macroalgae and whitish ascidians were relatively abundant in the seagrass bed. Two colonies of *Porites* spp. Corals were seen on the seagrass bed where the observation took place.

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Note: Only one specimen (*H. fuscocinerea*) was seen to release gametes in the water column at the time of observation. A few specimens of this species were erect and reasonably close to each other (three specimens in a 15 m radius).

Other holothurian species with spawning posture

The multispecies holothurian density on the spawning site was relatively important with several species (*Holothuria leucospilota*, *H. atra*, *Bohadschia vitiensis*) (Fig. 2 and 3) and synaptids (Fig. 3) present on the seagrass bed. Particularly, several specimens of *H. leucospilota* and *H. atra* were observed in the upright posture at the time *H. fuscocinerea* specimens were spawning, which is a typical mass-spawning behaviour. However, there was no evidence of gametes release by these species. No other echinoderm was seen to be spawning at the time of observation.

Several observations of spawning in the Indian Ocean have been published in previous issues of *SPC Beche-de-mer Information Bulletin* and are compiled here (Table 1). This contribution is the first from Rodrigues Island and involves several holothurians in a dense seagrass bed, showing simultaneous spawning behaviour. Synchronised spawning was described by Pearse et al. (1988) in British Columbia, involving specimens from several echinoderm classes, but this is not the case here, where only holothurians were showing the characteristic posture. These observations are of importance for broadcast spawners and the success of fertilisation.

Figure 2. *Holothuria leucospilota* (left) and *H. atra* (right) in the upright posture on a seagrass bed in Rodrigues Island.

Figure 3. Synaptids (left) and *Bohadschia vitiensis* (right) in the vicinity of the spawning holothurians.

Table 1. Natural spawning observations from the Indian Ocean recorded in the *SPC Beche-de-mer Information Bulletin* from issues 1 to 32 and present observations.

Species	Site	References	Year of observation	BDM issue	Observation	Note
Holothuria nobilis	Maldives	Reichenbach (1995)	1994	BDM 7	Three males spawned in holding tanks after being collected from the wild. Specimens were collected in June and October 1994.	
Thelenota ananas	Maldives	Reichenbach (1995)	1994	BDM 7	Two males and one female spawned in a holding tank after being collected from the wild. Males spawned first, and then the female released their gametes.	
Bohadschia vitiensis	La Saline Reunion Isl.	Durville (1996)	1995	BDM 8	Two specimens spawned in the late afternoon, at low tide, full moon.	
Undetermined	Seychelles	Durville (1998)	1997	BDM 10	Isolated male specimen spawning in the late afternoon. Undetermined.	Probably *H. fuscocinerea*.
Holothuria atra	India	Mohan (1999)	1998	BDM 11	Six observations of spawning in holding tanks, mostly males, from March to October 1998.	
Bohadschia marmorata	Petit trou d'eau Reunion Isl.	Rard (2004)	2004	BDM 20	Two males spawning in the late afternoon in 1 m depth.	The species is probably *B. vitiensis*.
Pearsonothuria graeffei	Vabbinfaru Isl. North Male Atoll Maldives	Muthiga (2005)	2005	BDM 27	A few specimens, close to each other, spawned in the late afternoon	
Bohadschia vitiensis	Trou d'eau Reunion Isl.	Gaudron (2006)	2006	BDM 24	Two specimens among 20 released gametes in the late afternoon, after a tropical storm and an increase in freshwater runoff into the fringing reef.	
Stichopus chloronotus	Étang Salé Reunion Isl.	Barrere and Bottin (2007)	2007	BDM 25	Several specimens spawned simultaneously over a period of two days, always in the late afternoon, two days after the full moon. The spawning period lasted for two days.	
Pearsonothuria graeffei	Aride Isl. Seychelles	Engelhardt (2007)	2007	BDM 27	Two erect specimens spawned in the mid-afternoon.	
Stichopus monotuberculatus	Saint Leu Reunion Isl.	Bollard (2008)	2008	BDM 30	The species was supposed to be nocturnal and spawned in the middle of the day (12:30).	
Synapta maculata	La Varanague Saint Leu Reunion Isl.	Ribes (2009)	2009	BDM 30	Several specimens spawned simultaneously.	
Bohadschia vitiensis	N'Gouja Mayotte	Bigot (2009)	2009	BDM 30	Specimen erected on a sandy bottom with sparse seagrass patches.	
Holothuria fuscocinerea	Rodrigues Isl. Mauritius	Bédier et al.	2013	This issue	Isolated male specimen spawning in the late afternoon.	Specimens from other species (*H. atra*, *H. leucospilota*) exhibited spawning behaviour but were not observed to release gametes.

Observation of juvenile *Holothuria fuscogilva* on the fringing reefs of New Ireland Province, Papua New Guinea

Jeff Kinch[1], Yolarnie Amepou and John Aini*

Species: *Holothuria fuscogilva*

Note: Juveniles *Holothuria fuscogilva* were observed inhabiting seagrass beds on a fringing reef flat on the southwest coast of New Ireland Province, Papua New Guinea. These seagrass beds have been artificially created due to the presence of an old logpond causeway extending at right angles from the coastline and across the fringing reef to its edge. This causeway has stopped the natural flow of water along the coastline, creating some protection from coastal processes and forming a small bay with increased sediments. Juveniles *H. fuscogilva* were found in the intertidal area, heavily covered in algae. Densities of juveniles *H. fuscogilva* at Belifu were reported from a recent survey this year to be 19 animals ha^{-1}. *H. fuscogilva* appear to recruit to shallow marine grass beds, before migrating to deeper waters as they approach sexual maturity.

Date observed: 14 September 2012 (~ noon).

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Map: Courtesy of Paul Anderson. / Photographs: Courtesy of Cathy Hair.

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Observation of juvenile *Holothuria pardalis* at Sikka Coast, Gulf of Kachchh, India

H.K. Kardani[1] and M.K. Gadhavi[1]*

Species: *Holothuria pardalis*

Note: We visited the intertidal area of the Sikka coast near the GSFC jetty (220 27′ 39.23″ N and 690 48′ 16.64″ E), at low tide as part of our research for a pearl oyster project. Juveniles *H. pardalis* were observed underneath dead coral skeleton. The substratum was sandy and rocky, covered mainly by two algae (*Sargassum* spp. and *Colurappa* spp).

Date: 1 January 2013.

Time: 12:30.

Juvenile *Holothuria pardalis*.

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Communications...

from: *C. Conand, H. Eriksson, A. Lovatelli, N.Muthiga and S.W. Purcell*

Workshop on sea cucumber fisheries: An ecosystem approach to management in the Indian Ocean, Zanzibar, Tanzania, 12–16 November 2012

The workshop was organised by the West Indian Ocean Marine Science Association (WIOMSA) and the Food and Agriculture Organization under the FAO/EU SmartFish project of the Indian Ocean Commission with additional financial contributions from the Australian Centre for International Agricultural Research (ACIAR) and the Sultanate of Oman. The final report will be published by FAO, in 2013. Please contact Alessandro Lovatelli for a hard copy (alessandro.lovatelli@fao.org).

Sea cucumber fisheries from the Indian Ocean are showing signs of significant decline from unsustainable exploitation rates (Conand 2008). This situation is worrying because sea cucumbers provide substantial income to people and countries in the region. This decline can, at least partly, be attributed to insufficient management (Eriksson et al. 2012a). To assist sea cucumber fisheries managers worldwide in decision-making, the Food and Agriculture Organization (FAO) has supported the development of improved management systems through several programmes (Lovatelli et al. 2004; Toral-Granda et al. 2008; FAO 2010; Purcell 2010). One of these programmes is a regional sea cucumber project to gain a comprehensive understanding on a range of aspects relating to this resource. It is supported by WIOMSA, through the Marine Science for Management (MASMA) programme (Conand and Muthiga 2007).

In addition, ACIAR (Friedman et al. 2008) and FAO (2010) recently developed pragmatic manuals for the management of this fishery. The ACIAR manual provides a "managers' toolbox" by outlining indicators that assist in identifying the status of a fishery and the FAO manual provides a "roadmap" to decision-making about management measures. These manuals have been widely distributed throughout the tropical world. Because this fishery is so little understood, a need was identified – to develop practical hands-on training approaches using these manuals so that managers could develop practical skills to guide their management decisions. This need was met through the development of a workshop series called *Sea cucumber fisheries: an ecosystem approach to management (SCEAM)* (Purcell and Lovatelli 2012a). The first workshop focussed on Pacific sea cucumber fisheries and was held in Fiji in 2011 (Purcell and Lovatelli 2012b).

Figure 1. The participants at the SCEAM Indian Ocean workshop (Image: Saad M.).

This article announces the completion of the SCEAM Indian Ocean workshop, held in Zanzibar in November 2012 (see also Eriksson et al. 2012b). Workshop participants were identified and selected on the principle that they had to be managers, or senior officers, with an intimate knowledge of the fishery in their country (Fig. 1). Other criteria were that they could actively contribute to the workshop and could influence management changes to improve their fisheries after the workshop. Fifteen participants from 14 countries participated in the workshop. Prior to the workshop, all participants submitted a data form that summarised key aspects of their fishery. The information from these forms revealed, among other things, the diversity of fishery operations targeting sea cucumbers in the region and how there are different management needs and capacities in the countries of the Indian Ocean.

The workshop aimed to: (1) provide a forum for group sharing of experiences and lessons learned of sea cucumber fisheries management; (2) facilitate learning to support the development of new management plans (or revisions to existing plans) for sea cucumber fishery; and (3) collate and analyse current information from the Indian Ocean sea cucumber fisheries on management practices and constraints. The workshop was a week-long exercise and the programme was built around eight sessions that encompassed theoretical presentations by facilitators, plenary discussions, practical workgroup sessions and a field day.

During the workshop, the facilitators (C. Conand, H. Eriksson, A. Lovatelli, N. Muthiga and S.W. Purcell) held introductory seminars on up-to-date research and the ecosystem approach to management in sea cucumber fisheries, based on recent publications (Conand 2008; Conand and Muthiga 2007; Friedman et al. 2008; Purcell 2010; Eriksson et al. 2012a; Purcell et al. 2013; Toral-Granda et al. 2008). The workshop then built on interactive sessions to facilitate group discussions and exercises. After being guided through the ACIAR "toolbox", the participants worked in groups to review the six indicators in the manual to assign a status to their fishery. Based on this assigned status, the participants were led through the FAO "roadmap" and, in workgroups, decided what regulatory measures and management actions are appropriate for their fishery. In these exercises, emphasis was placed on the importance of interpreting the manuals in the context of the fishery operations and institutional system in the country. The manuals do not give definitive answers to the problems/challenges, but help guide the manager through decision-making. In an exercise to define management objectives, the highest ranked objective by the participants was to "maintain/restore abundances of sea cucumbers for future generations".

In the middle of the week, a day for field activities was organised to provide practical skills on sea cucumbers and trade products in Zanzibar. The first activity was a presentation by Conand C. on the commercial species of the Indian Ocean region, including an original laminated sheet of the 36 most commercially important species. The second activity was a walk in an intertidal zone, identifying species along the walk on the southwest corner of Zanzibar. The habitat was a mixture of seagrass beds and sand-muddy patches where the species recorded were sandfish *Holothuria scabra*, lollyfish *H. atra* and white threadsfish *H. leucospilota*. The third activity was a snorkel trip to Kwale Island. The group searched for holothurians among patches of live corals, sandy floor and seagrass areas. Surprisingly few sea cucumber individuals were found, indicating severe overfishing. The following species were found at this site in decreasing order of abundance: *Pearsonothuria graeffei*, *Thelenota ananas*, *Actinopyga echinites*, *H. atra*, *Bohadschia subrubra*, *Stichopus herrmanni* and *H. edulis*.

Finally, a visit to a processing facility north of Stone Town showed classical processing procedures. The participants observed live catch, salted and boiled products, smoking racks, drying in an oven and sun-drying on bare concrete. Species ready for the first boiling were: *Stichopus herrmanni*, *Holothuria spinifera* and *H. lessoni*. There was a large variety of species drying in the sun, sorted and graded by species; most were from medium to low value. The high-valued teatfish (black teatfish *H. nobilis*, white teatfish *H. fuscogilva* and *H.* sp. "pentard") and *Thelenota ananas* represented only a small percentage of the large quantities drying and many specimens were rather small, suggesting a decline in the high-value species (Fig. 2). A large batch of *Thelenota anax* of large size and many individuals of *Bohadschia* spp. (some *B. atra*, *B. vitiensis* and other species) were also drying on the concrete. A fair amount of the drying product were Stichopodids, especially *S. hermanni* and another characteristic species with large papillae, which, when processed, present a spiny appearance and could be *S. naso* or a species not yet described. *Actinopyga*

Figure 2. Mixed species of medium-low quality drying in the sun (Image: Lovatelli A.).

spp. were also fairly abundant, especially *A. echinites* and *A. mauritiana*. Finally, several small-bodied species, including *H. atra*, were mixed together in batches. Participants also observed several bags containing the dry product, sorted by species, and ready for shipping in a large drying room.

Plenary sessions and discussions were an important component of the workshop agenda. Here, barriers or management challenges identified by participants were discussed. During the final plenary session, key priority research areas to aid management, and training needs to facilitate monitoring and enforcement of regulations, were identified. The regional/sub-regional movements of fishers and trade were frequently mentioned as a problem that undermines national management, and governance structures that can facilitate regional cooperative management were suggested as a means to tackle this challenge. The training needs that were identified included manuals for the identification of live animals (targeting management agencies and researchers; see Purcell et al. 2012, published a few weeks after the workshop) and dried products (mostly for customs monitoring and enforcement). A major benefit of the workshop was that managers from the region met and shared discussions on common challenges in managing fisheries in general and sea cucumber fisheries in particular. In the post-workshop satisfaction forms, all of the participants responded that the activity had been useful for them – emphasising that the workshop helped managers develop relevant practical skills using the manuals and existing publications and connecting science with policy.

We thank WIOMSA and FAO for the organisation, the support of ACIAR and the Sultanate of Oman, and the participants for their active engagement during the workshop.

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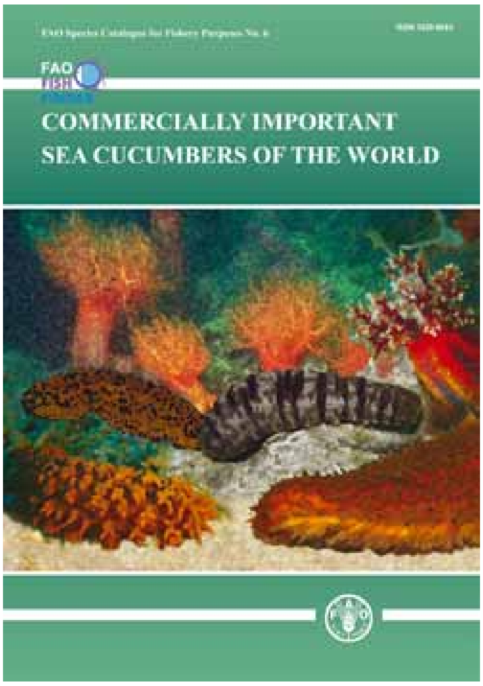
from: *C. Conand and A. Lovatelli*

Global sea cucumber identification book published by FAO

Sea cucumbers are presently 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. The processed animals are exported mostly to Asian markets and need to be distinguished to species level by customs and trade officers. This presented a need for a global species identification book that also summarises the biology and exploitation of these species.

The citation for the book is: 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: FAO. 150 p. + 30 colour plates.

Available at: http://www.fao.org/docrep/017/i1918e/i1918e.pdf



For each of the 58 species, including 37 Holothuriidae, 18 Stichopodidae and 3 Cucumariidae, the following information is given.

- Species name and common names at different localities
- General appearance and descriptive characteristics
- Diagnostic features: description with drawing, ossicles, processed appearance, body weight and lengths
- Habitat and reproductive periods
- Exploitation: fisheries, regulations, and human consumption
- Market destinations, landing prices and Asian market prices
- Known geographical distribution, including a map

The book is intended as an identification tool for fishery managers, scientists, trade officers and industry workers to distinguish the more commonly exploited and traded species worldwide. It provides identification information on 58 species, including 37 Holothuriidae, 18 Stichopodidae and three Cucumariidae. There are presently many other species that are exploited, either in a small number of localities or in relatively small quantities, that are not presented in this edition.

The introduction summarises the general morphology and anatomy of sea cucumbers, their ossicles (and the method of their preparation), and post-harvest processing techniques. Two-page identification sheets provide information to allow readers to distinguish each species from other similar species, both in the live and processed (dried) forms. The following information for each species has been included: nomenclature together with known common names; general appearance and distinguishing features; scientific illustrations of the body and ossicles; descriptions of ossicles present in different body parts; colour photographs of live and dried specimens; basic information on size, habitat, biology, fisheries, human consumption, market value and trade; and a geographic distribution map. The bibliography, the index and a series of 30 colour plates of live and processed (when available) specimens are given at the end.

Users are encouraged to base their identifications on a combination of morphological features, samples of ossicles from different body parts and information on which habitat and locality the species was found.

To request a hard copy of the book, please contact Mr Alessandro Lovatelli (Alessandro.Lovatelli@fao.org). Please provide your full name, position (in your organisation), name of your institute, full mailing address and contact details (including your email address).

from: *A.-R. Dabbagh, M. Keshavarz, H. Atashzaban and M.R. Sedaghat*

Problems related to *Holothuria scabra* culture in Iran

The present paper concerns problems in the breeding and culture of the sea cucumber *Holothuria scabra* in Iran. Earlier breeding attempts in Hormozgan and Sistan-Baloochestan provinces did not bear fruit. The current breeding and culture efforts started in 2010 in the Persian Gulf Mollusc Research Station, which is located in Bandar-e Lengeh, Hormozgan Province in south Iran.

In that year, prior to the main activity, a survey was carried out by the author on the identification and diversity of Iranian holothurians. Stocks of commercial species were identified, in particular of the highly valued sandfish sea cucumber, known from Qeshm Island (Dabbagh et al. 2012a). At that time, due to an absence of knowledge on breeding and culture of sea cucumbers, it was decided to start with breeding an abundant and highly accessible species, *Holothuria leucospilota*, which is found in some coastal areas around Bandar-e Lengeh, for example at Bandar-e Bostaneh. After learning the necessary techniques the commercially important species *Holothuria scabra* would be collected and studied.

First, in the early summer of 2010, 20 *Holothuria leucospilota* broodstock were transferred to the Persian Gulf Mollusc Research Station. On the day after this transfer, the broodstock was exposed to a thermal shock. Although a number of them spawned, due to inexperience, the eggs were not successfully collected. But the next time, with more knowledge, the eggs were stocked in 300 litre tanks and reared according to methods described in the breeding manual by Agudo (2006). After observation of doliolaria larvae, a fibreglass sheet was put in the tanks as a settlement substrate. However, due perhaps to the use of excessive amounts of *Sargassum* (brown algae) extract, intended to induce larvae to settle, as well as failure to sterilise this extract, many unwanted organisms were found in the larval tanks. Juveniles of 1 mm length were observed but nothing more (Dabbagh et al. 2011a).

In the following year (2011) more studies were carried out, this time with sandfish. We tried to benefit from the experiences of several scientists, including Drs Mary Byrne, Beni Giraspy, Anne Mercier, Rayner Pitt and Steven Purcell. In early summer, 20 broodstock sandfish (*Holothuria scabra*) were transferred to the Persian Gulf Mollusc Research Station from Qeshm Island. A few days later, however, after attempting to stimulate spawning, no eggs were obtained. Various methods such as thermal shock, pressure shock and drying were used without success.

The next attempt to induce new broodstock to spawn also failed. The broodstock was maintained in a tank beside blacklip pearl oysters for a month and fed with extract of phytoplankton cultured on the station. The final attempt to induce the broodstock took place in late summer, and we succeeded in getting eggs from *H. scabra* for the first time in Iran.

The general methods for rearing larvae and early juveniles followed methods described in recent papers: Pitt and Duy (2004), James (2004), Ivy and Giraspy (2006). Early juveniles were fed only commercial supplements such as Algamac 3050, Algamac Protein plus and Spirulina powder (Dabbagh et al. 2011b). One problem here is that no mud-flat area could be found around Bandar-e Lengeh for culture of juveniles. Hence, just commercial supplements were used. Algamac 3050 led to less growth and higher juvenile mortalities. Also, because environmental conditions were not perfect we had to use artificial light. Where we were able to use natural light and food such as extract of *Sargassum*, this resulted in better juvenile growth.

It seems the most fundamental problems leading to the low growth of juveniles in Bandar-e Lengeh were the salinity of the Persian Gulf (40‰ and sometimes even more), and the intense sunshine. Temperatures are over 30°C for most of the year, with only three months a year in when temperatures are below 25°C.

Surviving juveniles were cultured under these conditions for a year, after which time they reached 20 g in weight (Dabbagh et al. 2012b) (Fig. 1). We looked at the environmental conditions in other parts of the world with similar latitudes. For example, in Madagascar temperatures are like those in the Persian Gulf but the salinity (35‰) is less. This is because the Persian Gulf is semi-enclosed and salinity may increase towards the end of the gulf. The growth rate in Madagascar was 300 g in 10–12 months (Eeckhaut et al. 2008). Since the project of breeding and culture of sandfish was not an approved project and not awarded sufficient funding we had difficulties in overcoming such problems, in lowering the salinity and transferring mud (from the natural habitat of sandfish) from Qeshm Island.

Figure 1. A nursery in the Persian Gulf Mollusc Research Station.

Figure 2. A 10 m^3 concrete pond in Bandar-e Moallem Center.

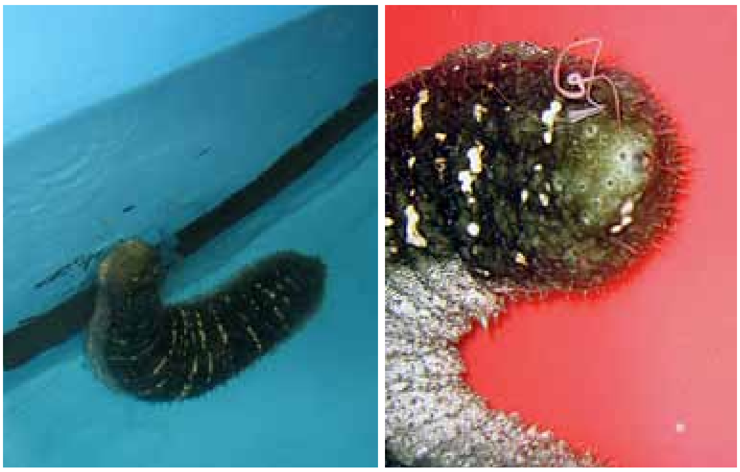


Figure 3. Male spawning spontaneously after the water change.

In 2012 a new attempt to breed and culture sandfish was launched in Bandar-e Moallem Center, a hatchery next to Bandar-e Lengeh. This centre was originally set up to breed shrimp and high-value marine fish such as silver bream and groupers. We decided to breed sandfish there, and part of the centre was allocated to us for that purpose. The remaining sandfish broodstock were stocked in 10 m^3 concrete ponds under shade, with a layer of fine sand, and extract of *Sargassum* was used for feeding. In early summer the first batch of broodstock sandfish was transferred there from Qeshm Island (Fig. 2). At that time temperature and salinity were 28ºC and 40‰, respectively. Water was changed daily.

Two weeks after stocking (at two individuals per square metre) the first male spawned spontaneously after the water change (Fig. 3). After that, males spawned again several times and were removed so they would not stimulate females to spawn. However, when this did in fact happen, the facilities and unicellular algae were not ready. When these essentials had been prepared, unfortunately no more sandfish, not even a new broodstock batch, could be induced to spawn. A further batch was transferred in early fall but never spawned.

A problem that we have encountered in Bandar-e Moalem was that most broodstock eviscerated. This occurred throughout the period of our trials, which we consider may be due to environmental factors, with temperatures rising to more than 30ºC as well as salinity of 40‰. The water was not treated by UV sterilisation. We were told by an expert that evisceration is common under these conditions.

Being unable to reduce the salinity we decided to the maintain broodstock in seawater near the hatchery into which fresh water flows from a cave, and which has a salinity of 30‰. Again the result was not a success as the animals were not fed and their movement decreased. After the failure of this project, it was decided to leave the broodstock in the sedimentation tank of the hatchery centre for a long time. After six months we observed a reduction in their weight.

In conclusion, sandfish culture and breeding need to be carried out under controlled conditions of water temperature and salinity. Hence we would suggest the use of Qeshm Island as a hatchery centre because of ease of access to broodstock. Also we propose that mariculture of juveniles may be done in pens, which could be set up, for example, in the mangrove forest of Bandar-e Khamir, where the salinity is lower than in other places.

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from: *M. González-Wangüemert, C. Conand, S. Uthicke, G. Borrero-Pérez, M. Aydin, K. Erzini and E. Serrao*

Sea cucumbers: The new resource for a hungry fishery (CUMFISH). Project PTDC/MAR/119363/2010

Sea cucumber stocks have been overfished in many countries around the Indian and Pacific oceans as a result of ever-increasing market demand, uncontrolled exploitation and/or inadequate fisheries management. The life-history traits of holothurians make them especially vulnerable to overfishing because they have low or infrequent recruitment, high longevity and density-dependent reproductive success.

This situation has resulted in catches of new target species from the Mediterranean Sea and northeastern Atlantic Ocean, whose fisheries are in the process of development. Among the new economically important species to stress are *Holothuria mammata* (Grube, 1840), *H. tubulosa* (Gmelin, 1970) and *H. polii* (Delle-Chaije, 1823) (Fig. 1). The main problem of these fisheries is the existence of several sea cucumber species living in the same region with similar external morphology, very difficult identification and scarce information about life strategies, population dynamics and evolution history. Another target species from the Mediterranean Sea, Atlantic Ocean, Antilles and Gulf of Mexico is *Parastichopus regalis* (Cuvier, 1817), which is commercialised mainly for human consumption in the NW Mediterranean (Catalonia) (Fig. 1). *H. arguinensis* (Koehler and Vaney, 1906), could become a very important target species. The last considered species is *Isostichopus badionotus* (Selenka, 1867) which is found throughout the Caribbean and is very common in Bermuda (Fig. 1).

Therefore, the main goals of this proposal are to study the incipient sea cucumber fisheries of several sites from Mediterranean Sea and Atlantic Ocean (Fig. 2) and to assess the genetic structure of these species, including the selection effects of fisheries. More precisely, the aims are: (1) to clarify the taxonomic status of holothurian target species; (2) to quantify the captures from these incipient fisheries; (3) to increase the knowledge of biological features of these species; (4) to assess the genetic diversity and gene flow between populations of these new target species; (5) to identify the possible stocks; (6) to assess the effects of human selection (fishery) on sea cucumber genetic structure; and (7) to suggest management measures for the sustainability of their fisheries.

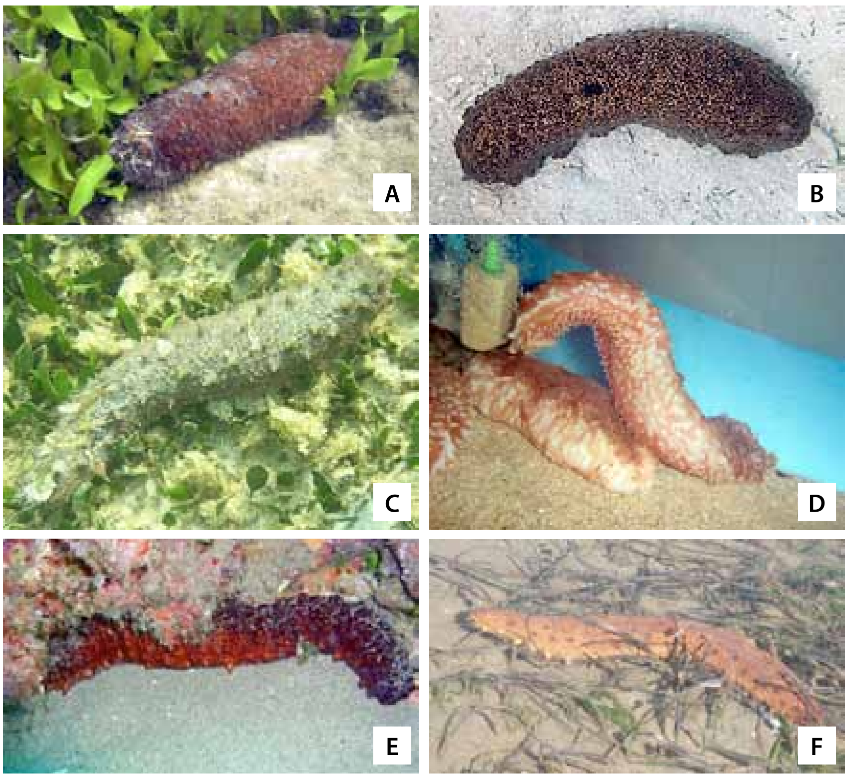
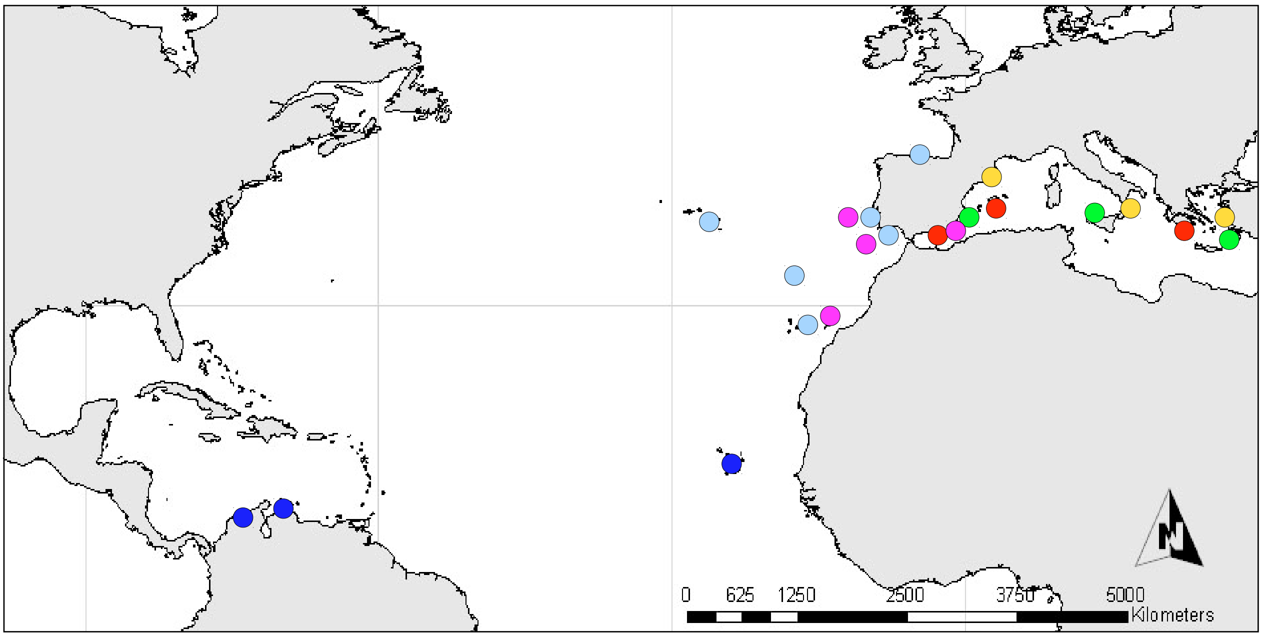


Figure 1. Sea cucumber target species.
A: *Holothuria polii*; B: *Isostichopus badionotus*; C: *Holothuria tubulosa*;
D: *Parastichopus regalis* (Image: Nuno Vasco); E: *Holothuria mammata*; F: *Holothuria arguinensis*.

To implement this project and to accomplish the aims we rely on other highly qualified researchers working on different subjects such as sea cucumber systematic, population genetics, phylogeography and fisheries: Dr Gonçalves from Coastal Fisheries Research team, Centro do Ciências do Mar, CCMAR (Portugal); Dr Aydin from Ordu University (Turkey); Nuno Vasco from Escola Superior de Turismo e Tecnologia do Mar de Peniche; Dr Lleonart from Consejo Superior de Investigaciones Científicas, CSIC (Spain); and Dr Ramón from the Instituto Español de Oceanografía, IEO (Spain).

This project started last year (1 February 2012) with three years to run and it has been funded by FCT (Fundação para a Ciência e a Tecnologia, Ministério da Ciência, Tecnologia e Ensino Superior, Portugal). Two grants are associated with this project and several MSc students are collaborating with us. More information about this project is available on our website (http://www.ccmar.ualg.pt/cumfish/) and the CUMFISH Facebook group (http://www.facebook.cm/groups/408508309208037/). So if you are interested, you can contact us. People wishing to collaborate with us will be welcome.



● *H. tubulosa*, *H. mammata*, *H. polii*, *P. regalis*
● *H. tubulosa*, *H. mammata*, *P. regalis*; low fishery
● *I. badionatus* ● *H. mammata*, *P. regalis*
● *H. tubulosa*, *H. mammata*, *P. regalis*; high fishery
● *H. arguinensis*

Figure 2. Sampling sites
(Tasks 1, 2, 3, 4 and 5: red, magenta and blue circles; Task 6: green circles, areas with low fishery pressure, and orange circles, areas with high fishery pressure).

Abstracts and new publications...

Sea cucumber fisheries: Global analysis of stocks, management measures and drivers of overfishing

S.W. Purcell, A. Mercier, C. Conand, J.-F. Hamel, A. Lovatelli, V. Toral-Granda and S. Uthicke

Fish and Fisheries 14:34–59 (2013)

Worldwide, most sea cucumber fisheries are ineffectively managed, leading to declining stocks and potentially eroding the resilience of fisheries. We analyse trends in catches, fishery status, fishing participation and regulatory measures among 77 sea cucumber fisheries through data from recent fishery reports and fishery managers. Critical gaps in fisheries biology knowledge of even commonly targeted species undermine the expected success of management strategies. Most tropical fisheries are small-scale, older and typified by numerous (> 8) species, whereas temperate fisheries are often emerging, mono-specific and industrialised. Fisher participation data indicated about 3 million sea cucumber fishers worldwide. Fisher participation rates were significantly related to the average annual yield. PERMANOVA analysis showed that over-exploited and depleted fisheries employed different sets of measures than fisheries with healthier stocks, and a non-metric multidimensional scaling ordination illustrated that a broad set of regulatory measures typified sustainable fisheries. SIMPER and regression tree analyses identified that the dissimilarity was most related to enforcement capacity, number of species harvested, fleet (vessel) controls, limited entry controls and rotational closures. The national Human Development Index was significantly lower in countries with over-exploited and depleted fisheries. Where possible, managers should limit the number of fishers and vessel size and establish short lists of permissible commercial species in multispecies fisheries. Our findings emphasise an imperative to support the enforcement capacity in low-income countries, in which risk of biodiversity loss is exceptionally high. Solutions for greater resilience of sea cucumber stocks must be embedded within those for poverty reduction and alternative livelihood options.

Commercially important sea cucumbers of the world

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

FAO Species Catalogue for Fishery Purposes No. 6. Rome: Food and Agriculture Organization. 150 p. (2012)
http://www.fao.org/docrep/017/i1918e/i1918e00.htm

Sea cucumbers are exploited and traded in more than 70 countries worldwide. This book provides identification information on 58 species of sea cucumbers that are commonly exploited in artisanal and industrial fisheries around the world. Not all exploited species are included. It is intended for fishery managers, scientists, trade officers and industry workers. This book gives key information to enable species to be distinguished from each other, both in the live and processed (dried) forms. Where available for each species, the following information 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.
Persons with a genuine need for the hard copy may request one from Mr Alessandro Lovatelli (Alessandro.Lovatelli@fao.org). Please ensure to provide your full name, position (in your organisation), name of your institute, full mailing address and contact details (including your email address) and intended use of the book (e.g. identification for research or trade).

Sea cucumber culture, farming and sea ranching in the tropics: progress, problems and opportunities

S.W. Purcell, C. Hair and D. Mills

Aquaculture 368:68–81 (2012)

Tropical sea cucumber mariculture has potential to become a profitable industry and contribute towards natural population replenishment. Here, we synthesise the fields of progress, current impediments and research opportunities in tropical sea cucumber aquaculture arising from recent studies and an Indo-Pacific symposium. We present novel comparisons of data from hatcheries, earthen ponds and sea pens from published and unpublished studies in various countries. Of the few tropical species to have been cultured, only the sandfish *Holothuria scabra* has been bred extensively. While risks from hatchery-produced sea cucumbers are recognised, more genetic research is needed in farming and sea-ranching programmes. Advances have been made in the culture and nursery rearing of tropical sea cucumber juveniles but few have been published. Sandfish larvae have now been grown successfully on just one microalga species, but experimental studies to optimise culture conditions are needed urgently. Disease of tropical sea cucumbers in culture is infrequent but the treatment of disease and parasites is understudied. Earthen ponds are currently most effective for nursery rearing of juvenile sandfish to a size for stocking. Growth rates and survival of sandfish in ponds to market size are also favourable, and should improve via studies on stocking density, feeding regimes and pond management. Sea pens confer ownership of released stock and can provide a means of limiting predation in natural habitats but the costs of materials, maintenance and surveillance against poaching can diminish profitability. Sea ranching has minimal material costs but needs a large leased area and may require juveniles to be marked prior to release. Retail prices of sandfish in Hong Kong increased exponentially with body size. A cost-benefit analysis illustrated that labour and utility costs in pond farming will preclude profitability of monoculture in some cases, forcing proponents to look towards co-culture or gamble with uncertain survival in sea ranching. Better governance and consultation regarding the stocking of sea cucumbers have been advocated. We conclude that well-designed experiments and meta-analyses are needed to fill critical knowledge gaps if sea cucumber mariculture is to expand in the tropics as it has in temperate Asia. Co-culture remains a burgeoning frontier despite poor success of initial studies. Sea cucumbers have superb potential to diversify mariculture industries in the tropics and potentially ameliorate the detrimental effects of mariculture on coastal ecosystems.

Principles and science of stocking marine areas with sea cucumbers

S.W. Purcell

p. 92–103. In: Hair C.A., Pickering T.D. and Mills D.J. (eds). Asia-Pacific tropical sea cucumber aquaculture. ACIAR Proceedings No. 136. Canberra: ACIAR. (2012)
http://aciar.gov.au/publication/PR136

Clearly stating the goals of stocking builds an essential platform for success. The scales, methodologies, management and time frames of the interventions can then be matched to the original goals. Stock enhancement, restocking and sea ranching will involve different stocking strategies. The genetic risks to wild stocks must be minimised by preventing translocation of juvenile sea cucumbers to different locations than those where broodstock were collected, unless studies show wider genetic homogeneity of the stock. Cultured juveniles are easily marked by immersion in a fluorochrome solution (e.g. tetracycline or calcein), which provides a long-term, unequivocal means of distinguishing hatchery-produced animals from wild conspecifics. Use of open sea pens is an experimental tool that provides better estimates of early stocking success. Juvenile density can be assessed by searching through sand and mud in quadrats by hand, whereas sub-adults and adults can be surveyed visually in transects with a stratified arrangement. Proponents of sea cucumber stocking in the wild should be conservative and realistic about the expected returns; 1 in 5–10 (10–20%) of released juvenile sea cucumbers surviving to market size is a benchmark. Clear goals, use of existing technology, and realistic expectations in sea ranching and restocking of sea cucumbers will provide the foundation for success.

Sea cucumbers collected by the Kermadec Biodiscovery Expedition 2011 (Echinodermata: Holothuroidea: *Apodida* and *Dendrochirotida*)

P.M. O'Loughlin and D. Vandenspiegel

Zootaxa 3515:60–66 (2012)

Three shallow holothuroid species are recorded for the rocky shoreline of the Kermadec Islands. The new apodid species *Chiridota kermadeca* sp. nov. is described. Two dendrochirotid species are reported, both previously found in New Zea- land: *Plesiocolochirus ignavus* (Ludwig, 1875) and *Pseudocnus sentus* (O'Loughlin and Alcock, 2000).

The caudinid sea cucumbers of New Zealand (Echinodermata: Holothuroidea: Molpadida: Caudinidae)

N. Davey and P.M. O'Loughlin

Zootaxa 3613(4):357–368 (2013)

Five species of Caudinidae occur in New Zealand waters. Two new species are described: *Paracaudina alta* sp. nov. and *Paracaudina reductia* sp. nov. Two species reported previously are discussed: *Paracaudina chilensis* (Müller) and *Paracaudina coriacea* (Hutton). A lectotype has been established for *P. coriacea* (Hutton). *Hedingia albicans* var. *glabra* (Théel) is raised out of synonymy with *Hedingia albicans* (Théel), and the variety elevated to species status as *Hedingia glabra* (Théel). A key is provided for the New Zealand species of Caudinidae.

PhD Dissertation

Analysis of certain nutritional components that are essential for *Holothuria scabra* (Echinodermata, Holothuroidea): Influence of sediment quality on sea cucumber development during aquaculture and the importance of bacteria

PhD Student: Thomas Plotieau

Phd Thesis. Belgium: University of Mons (2012)

It has become clear that natural sea cucumber populations are decreasing drastically around the world due to the heavy demand of the Asian market. The disappearance of sea cucumbers not only leads to ecological problems, as they are one of the main sediment bioturbators in marine ecosystems, but also to an enormous social problem since the beche-de-mer trade is a source of income for thousands of people living in developing countries. One of the best responses to this global problem has been the development of sea cucumber farming, involving villagers in coastal zones who raise end-of-cycle specimens. At the current time, *Holothuria scabra*, a tropical Indo-Pacific species, is farmed in a semi-industrial manner in Madagascar. This species is one of the best for aquaculture in tropical settings, given its broad distribution, high market value and ability to grow in sea pens managed by coastal communities. *H. scabra* feeds by ingesting the top few millimetres of the sediment layer, which is composed of a mineral portion and an organic portion. The latter is itself composed of detritus and a large number of associated micro-organisms. Although *H. scabra* is of great interest ecologically, economically and socially, very little information is available about its nutrition. This paper concentrates on just that – more specifically, on the influence that sediment quality has on *H. scabra* development and the importance of the bacterial portion.

H. scabra's growth was recorded over a four month period in two villages involved in juvenile growout in south-west Madagascar. The growth rate for sea cucumbers at the two sites did, in fact, differ greatly: at the first site, specimens had a growth rate of 1.4 g day^{-1}, whereas at the second site, the rate was only 0.4 g day^{-1}. The sediments were described so as to identify differences in organic matter and mineral matter composition that might explain this enormous difference in growth rates. The site where the highest growth rate was recorded had sediment with finer grain sizes and more abundant organic matter. In addition, the latter contained a higher percentage of autotrophic microorganisms. The protein concentrations and the number of bacteria in the sediment at the two sites did not differ significantly, but the mineral composition was very different: at the first, i.e. the one that allowed more rapid growth, the mineral composition was more diverse with a high percentage of quartz. The sediment at the other site, i.e. the one with the lower growth rate, contained more than 80% carbonates, mainly bioclastic. So, *H. scabra* growth rates were better when specimens lived on sediment with high levels of organic matter rich in autotrophic microorganisms, lower percentages of particles greater than 1 mm and a high percentage of particles under 250 μm. Terrigenous deposits in the sediment caused by runoff were not a problem for *H. scabra* growth rates.

While sediment has an impact on *H. scabra* growth, intensive farming of this sea cucumber species has an impact on the sediment. Various elements in the sediment's surface layer, which serves as feed for *H. scabra*, were tested inside and outside the farm pens of two other aquaculture sites in south-west Madagascar. These tests showed that (i) the percentage of the finest grain size (less than 250 μm) decreased by 5% to 14%, (ii) the percentage of carbonates decreased by 5%, (iii) aragonite was the type of carbonate most affected by sea cucumbers, then calcite and magnesian calcite, (iv) organic matter levels were not affected by sea cucumbers, (v) the number of bacteria decreased by up to 50% and (vi) the concentration of autotrophic microorganisms decreased by up to 22%.

Farming trials for *H. scabra* juveniles with 15N-marked organic matter components demonstrated that juveniles assimilate gram- bacteria from the genus *Vibrio* and gram+ bacteria from the genus *Clostridium*. Adding 15N-marked ammonium sulphate, one of the preferred sources of nitrogen for autotrophic microorganisms, and antibiotics showed that *H. scabra* juveniles assimilate autotrophic microorganisms. Also, 15N-marked alanine, dissolved in the water, is assimilated by sea cucumbers, and bacteria may also be an indirect way for them to assimilate this compound. *H. scabra* assimilates plant debris, such as spermatophyte debris, although it probably serves more as a medium for the development of live micro-organisms. In addition, the growth rate of juveniles raised in areas with spermatophyte debris was no greater than that of control juveniles. Juvenile growth was significantly higher than that of control juveniles when 15N-alanine, with or without antibiotics, 15N-marked ammonium sulphate or 15N-alanine-marked bacteria from the genus *Vibrio* were added on a weekly basis. Of the various compounds tested, only bacteria from the genus *Clostridium* proved harmful for juvenile development.

Some 116 bacterial phylotypes belonging to the following groups: g-proteobacteria (62%), a-proteobacteria (23%), bacteroidetes (6%), actinobacteria (2.75%), fusobacteria (1.75%), firmicutes (1.75%), cyanobacteria (1.75%) and d-proteobacteria (1%), were found in *H. scabra*'s digestive tract. The number of bacteria was significantly higher (1.5 x) in the anterior end of *H. scabra*'s digestive tract as compared to the sediment it feeds on. Then, this number decreased significantly in the digestive segment and remained stable straight through to the faeces. Some g-proteobacteria species, including bacteria from the genus *Vibrio*, are less sensitive to digestion than other groups. In addition, the first segment of the digestive tract could serve as a reservoir when certain species of bacteria such as the genus *Vibrio* may proliferate. The season has an influence on bacterial diversity in the digestive tract of *H. scabra*: in fact, during the dry season, the g-proteobacteria group was more abundant whereas, during the rainy season, it was the a-proteobacteria group. The genus *Vibrio* was the most widespread with certain well-known opportunistic pathogens such as *V. harveyi*, *V. alginolyticus* and *V. proteolyticus*, which are very common in *H. scabra*'s intestine.

In their natural setting, spermatophyte grass beds, *H. scabra* select sediment zone based on the grain size and organic matter level. Once in that zone, they assimilate compounds that come from spermatophyte, bacteria, autotrophic microorganisms such as diatoms and elements dissolved in the water. When the sediment passes through the digestive tract, the carbonate part, mainly aragonite, is dissolved. In that way, *H. scabra* frees up bioclastic and non bioclastic carbonates for other organisms in the reef ecosystem. During aquaculture, this loss in elements caused by sea cucumbers should be offset by adding feed that contains the various compounds assimilated by *H. scabra*, as shown by our work.

Titles of the presentation of the 14th International Echinoderm Conference (Brussels, August 2012)

Oral Communications

Reexamination of the genus *Lissothuria* (Verrill, 1867) (Echinodermata: Holothuroidea)
Arriaga-Ochoa J.A., Solís-Marín F.A. and Laguarda-Figueras A.

Feeding preferences of the Arlequin crab, *Lissocarcinus orbicularis* (Dana, 1852), an obligate symbiont of holothurians
Caulier G., Van Nedervelde F., Lepoint G. and Eeckhaut I.

Echinoderm diversity, biogeography and abundance along the shores of the Sultanate of Oman
Claereboudt M.R. and Al-Rashdi K.M.

The Echinoderm fauna of Europa Island (French Eparses Islands) in the Mozambique channel (South Western Indian Ocean)
Conand C., Stöhr S., Eléaume M., Magalon H. and Chabanet P.

Characterisation of the adhesive proteins from the Cuvierian tubules of *Holothuria forskali*
Demeuldre M., Wattiez R., Hennebert E., Becker P. and Flammang P.

Growth rate in *Parastichopus californicus* contained off Vancouver Island, Canada: An important wild and potential aquaculture species
Duprey N.M.T., Hannah L., Hand C.M. and Pearce C.M.

Reproductive biology and nocturnal behaviour of *Holothuria sanctori* (Delle Chiaje, 1823) in Canary Islands (eastern Atlantic Ocean)
Navarro P.G., García-Sanz S. and Tuya F.

Genetic structure and demographic history of Atlanto-Mediterraean sea cucumbers: Congruent and contrasting patterns in some *Holothuria* species
Borrero-Pérez G.H. and González-Wangüemert M.

Molecular systematics of the Holothuriidae (Echinodermata: Holothuroidea)
Michoneau F. and Paulay G.

Organ regeneration by the uptake of dissolved organic material in the holothurian *Parastichopus californicus*
Nestler J., Brothers C.J. and Lee R.

Some quantitative data for the holothuroids of the antarctic benthos (Echinodermata, Holothuroidea)
Mark O'Loughlin, Niki Davey, Ty Hibberd, Susanne Lockhart and Melanie Mackenzie

Utilization of maternal reserves during embryonic and early larval development of the New Zealand sea cucumber *Australostichopus mollis*
Peters-Didier J. and Sewell M.A.

Giant Mesozoic Holothurian Larvae?
Reich M. and Stegemann T.R.

Nutritional profile and antioxidant properties of the sea cucumber *Holothuria arguinensis*
Roggatz C.C., Custódio L., González-Wangüemert M., Barreira L., Pereira H. and Varela J.

Sea cucumber in recirculating systems and integrated multi-trophic aquaculture (IMTA) in Tanzania, South Africa and the United Kingdom
Slater M.J., Beltran-Gutierrez M., Robinson G., MacDonald C.L., Ferse S.C.A., Kunzmann A., Jones C.L.W, Eeckhaut I. and Stead S.M.

Biodiversity and biogeography of the southern African holothuroid echinoderms
Thandar A.S.

Comparison of methods for estimating abundance of a depleted population of sea cucumber (*Isostichopus fuscus*)
Ulate K., Huato-Soberanis L. and Sanchez-Ortiz C.A.

Advances in the understanding of the feeding biology of the Australasian sea cucumber, *Australostichopus mollis* (Echinodermata: Holothuroidea), and its aquaculture implications
Zamora L., Jeffs A. and Slater M.

Posters

Has the cucumber changed its spots? Cryptic *Bohadschia* species in the Malaysian Beche-de-mer fishery
Byrne M., Conand C., Choo P.S., Rowe F.W.E. and Uthicke S.

Preservation of bioactive saponins through the preparation of *trepang*
Caulier G., Flammang P., Gerbaux P. and Eeckhaut I.

Biodiversity of echinoderms on the underwater lava flows with different ages from the volcano Piton de La Fournaise (Reunion Island, Indian Ocean)
Bollard S., Quod J.P., Boissin E., Eleaume M. and Conand C.

Antarctic holothuroids from the Ross Sea and adjacent Islands and seamounts, with descriptions of new species based on morphological and molecular phylogeny
Davey N., O'Loughlin M. and Van den Spiegel D.

Protecting a wild fishery while introducing aquaculture: Adding aquaculture activities into British Columbia's healthy sea cucumber population
Duprey N.M.T., Hand C.M. and Pearce C.M.

Development of a promising polyculture farming involving the sea cucumber *Holothuria scabra* and the red algae *Kappaphycus alvarezii* in the South West of Madagascar
Tsiresy G., Eeckhaut I., Lavitra T., Razanakoto I., Dubois P., Lepoint G. and Pascal B.

Sea cucumbers: The new resource for a hungry fishery (CUMFISH project)
González-Wangüemert M., Conand C., Uthicke S., Borrero-Pérez G., Erzini1 K., Aydin M. and Serrao E.

Holothuroids collected by Kakichi Mitsukuri and Hiroshi Ohshima deposited in the University Museum, the University of Tokyo
Inoue J., Ueshima R. and Fujita T.

Asexual reproduction of the holothurian *Cladolabes schmeltzii* (Holothuroidea, Echinodermata)
Kamenev Ya.O. and Dolmatov I.Yu.

The littoral sea cucumber (Echinodermata: Holothuroidea) fauna of Guam re-assessed – A diversity curve that still does not asymptote
Borrero-Perez G.H., Honey M., Kamarudin K.R., Kerr A. M., Kim S., Menez A., Michonneau F., Miller A., Ochoa J.A., Olavides R.D., Paulay G., Samyn Y., Setyastuti A., Solis-Marin F., Starmer J. and VandenSpiegel D.

Biodiversity of Antarctic holothuroids (South Shetland Islands, BOUVET Island and WEDDELL Sea)
Moles J., Ballesteros M. and Avila C.

Development of gonad-stimulating substance-like peptide system during larval development in the sea cucumber, *Apostichopus japonicus*
Ahmed H.O., Katow T. and Katow H.

The enigmatic sea cucumber *Holothuria* (*Stichothuria*) *coronopertusa* Cherbonnier, 1980 (Echinodermata: Holothuroidea) re-examined
Samyn Y., Michonneau F., Starmer J., Uyeno D., Naruse T., Kerr A. and Paulay G.

Analysis of the impact of *Holothuria scabra* intensive farming on sediment
Plotieau T., Baele J.-M., Eeckhaut I.

Nutritional value and fatty acid profile of five sea cucumber species from the Mediterranean Sea and North-east Atlantic Ocean
Roggatz C.C., Custódio L., González-Wangüemert M., Barreira L., Pereira H. and Varela J.

The whereabouts of Carl Semper's sea cucumber (Echinodermata: Holothuroidea) types
Samyn Y., Massin Cl. and Smirnov A.

Total evidence phylogeny of the subgenus *Selenkothuria* supports Deichmann's theory of evolution of ossicles
Honey-Escandón M., Solís-Marín F.A. and Laguarda-Figueras A.

Echinoderm Research and Diversity in Latin America
Alvarado J.J. and Solis-Marin F.A.

Population density of the black sea cucumber following an exceptional rainfall event in the inner Gulf of Thailand
Sutthacheep M., Klingthong W., Samsuvan W., Panthawee W. and Yeemin T.

Parasitic protozoan oocysts in the ovaries of sea cucumber *Apostichopus japonicas*
Unuma T., Yamano K., Tsuda N., Sawaguchi S., Kamaishi T. and Sakai Y.

Sublittoral and Bathyal sea cucumbers (Echinodermata: Holothuroidea) from the Northern Mozambique Channel with description of five new species
Samyn Y. and VandenSpiegel D.

A pilot study on optimal anaesthetic agents for studying the external morphological features of sea cucumber
Yamana Y., Hamano T. and Yamamoto K.

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