



Issue 27 – March 2008

# BECHE-DE-MER

## information bulletin

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### Editorial

I would like to thank here, in this 27<sup>th</sup> issue of the *Beche-de-Mer Bulletin*, the many regular and new contributors who share their fieldwork and research findings with us in the pages of this bulletin. I would also like to thank the dedicated staff of SPC's Fisheries Information and Publication sections, who maintain this high quality publication.

Once again, I would like to draw your attention to the database of all articles and abstracts published in the bulletin to date. This was put together by SPC's Fisheries Information Section, and is available on SPC's website at: [http://www.spc.int/coastfish/news/search\\_bdm.asp](http://www.spc.int/coastfish/news/search_bdm.asp). The database includes around 600 article and abstract titles that can be searched by title, author name(s), scientific name, region or country. Each search result is presented with a hyperlink that allows downloading in PDF format.

This issue begins with information on the international workshop (organised by FAO and the Charles Darwin Institute) held in the Galapagos Islands last November, and some of the activities that followed (p. 2). Following this is an article that analyses the usefulness of underwater identification cards, and shows that they are useful to several user groups and can lead to improved fisheries management (p. 5).

There are several articles from the Indian Ocean region, including one on the sea cucumber fishery in Eritrea (p. 8), sea cucumber species and prices in Mozambique (p. 16), and sea cucumber distribution and abundance in the Maldives (p. 33). And from the Pacific Islands region, we have an article about the SPC Reef Fisheries Observatory's sea cucumber dataset (p. 38).

Other contributions cover the characteristics of specific sea cucumber species, such as the taxonomy of *Synaptula hydriformis* (p. 13), the distribution of *Thelenota rubralineata* (p. 29), the feeding activity of *Holothuria scabra* (p. 25), and the asexual reproduction of *Holothuria hilla* in Australia (p. 17) and Reunion Island (p. 24).

We received several observations on the natural spawning of four sea cucumber species from different regions. These observation notes (p. 40) are more detailed than in previous bulletins, and provide a clear picture of the seasonal reproductive cycle of different species not yet studied in detail.

As usual, this and all previous issues of the bulletin are available in PDF format on SPC's website at: <http://www.spc.int/coastfish>. Please note that the SPC Fisheries Digital Library is now available on SPC's website (<http://www.spc.int/mrd/fishlib.php>). The digital library gives access to electronic versions (in PDF format) of more than 5700 fisheries and aquaculture-related documents (in English and French), produced by, for, or in collaboration with SPC. This digital library is full text searchable.

Chantal Conand

## International Workshop on the Sustainable Use and Management of Sea Cucumber Fisheries, Puerto Ayora, Galapagos Islands, Ecuador, 19–23 November 2007

*report by V. Toral-Granda<sup>1</sup>, A. Lovatelli, M. Vasconcellos and the Scientific Committee composed of C. Conand, J.-F. Hamel, A. Mercier, S. Purcell and S. Uthicke*

### Background

Sea cucumbers fulfil an important role in marine ecosystems and are a significant source of income to coastal communities, therefore, their conservation and management are of paramount importance. The current worldwide population status of sea cucumbers has prompted international meetings<sup>2</sup> aimed at providing scientific information and tools to help in their conservation and sustainable exploitation. These workshops and other recent articles highlight the fact that, while great advances have been made in sea cucumber research, there are still some critical gaps in information available to fishery managers. Two areas of particular concern are taxonomy and management strategies.

The taxonomy of several groups of holothurians remains unclear, and some species have been redefined in the past decade. Commercial sea cucumber species globally comprise almost 50 species. The multi-species nature of sea cucumber fisheries affords them some demographic resilience, but often poses a difficult task for fisheries managers and customs officers in identifying sea cucumbers for export or estimating wild populations. The management of these resources will surely suffer in the absence of better support tools for identifying commercial species in their live and processed forms.

In tandem with taxonomic tools, resources managers also need to have prescriptive recommendations on what management regulations and activities are best for sea cucumber fisheries. Few guidebooks on managing sea cucumber fisheries are available, leaving the fishery manager with a subjective task of drawing on management principles based on other resources. In addition, sea cucumber fisheries differ greatly in their cultural setting, socioeconomic structure, methods and scale in which animals are exploited, and in the technical capacity of management bodies. Sea cucumber fishery managers are also more sensitised to the need to conserve species diversity and the role that CITES listing can play in that goal.

With these information needs in mind, the Food and Agricultural Organization of the United Nations (FAO) is implementing a global project on sea cucumbers. A central aim is to collate and disseminate information on the global status of commercially exploited sea cucumber stocks and to provide support tools to improve the conservation and sustainable exploitation of these benthic marine organisms. One major goal of the project is to develop technical guidelines to assist fisheries managers in deciding on regulations and processes for the better management, conservation, and sustainable exploitation of their sea cucumber fisheries. Further outputs will be a global identification guide on commercial species that should be user-friendly to fishery managers and customs officers, and a more complete record of genetic “barcodes” for commercial holothurian species.

The project has also commissioned five regional reviews on the current status of sea cucumber populations in Asia; Australia and Pacific Island nations; North America; Mexico, Central and South America; and Africa and Indian Ocean. In each region, one locality of topical interest was chosen as a “hotspot”, which was reviewed in greater detail. These regional reviews and hotspot analyses will provide case examples and a base for understanding the variation in context of sea cucumber fisheries. Drawing from the lessons learned in the above studies, the Technical Guidelines will consolidate the current knowledge and best practices for the sustainable use and management of sea cucumber fisheries.

Regional reviews and hotspots documents presented by the authors in the recent workshop held in the Galapagos (Ecuador) are listed below and will be available as an FAO document sometime during the first quarter of 2008.

- Regional review on the population status, fisheries and trade of commercially important sea cucumbers in Asia, by Poh Sze Choo.
- Hotspot: Philippines, by Poh Sze Choo.

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2. For example, the FAO technical workshop “Advances in sea cucumber aquaculture and management” and the CITES technical workshop “Conservation of sea cucumbers in the families Holothuridae and Stichopodidae”.

- Regional review of temperate sea cucumber fisheries in the Northern Hemisphere, by Jean-François Hamel and Annie Mercier.
- Hotspot: Precautionary management of *Cucumaria frondosa* in Newfoundland and Labrador, by Jean-François Hamel and Annie Mercier.
- Regional review on the population status, fisheries and trade of commercially important sea cucumbers in the Western Pacific region, by Jeff Kinch, Steve Purcell, Sven Uthicke and Kim Friedman.
- Hotspot: Papua New Guinea, by Jeff Kinch, Steve Purcell, Sven Uthicke and Kim Friedman.
- Regional review on the population status, fisheries and trade of commercially important sea cucumbers in Central and South America, by Veronica Toral-Granda.
- Hotspot: Galapagos, by Veronica Toral-Granda.
- Regional review on the population status, fisheries and trade of commercially important sea cucumbers in Africa and Indian Ocean Region, by Chantal Conand.
- Hotspot: Seychelles, by Riaz Aumeeruddy.

The workshop brought together sea cucumber experts in the fields of ecology, fisheries biology, socioeconomics and resource management (see photo). Their job was to review, discuss and agree upon generic and situation-specific management principles for sea cucumber fisheries. A major output from the workshop was to canvass the outline for the technical guidelines for the “Sustainable use and management of sea cucumber fisheries”.

### Technical guidelines

Developing countries require better decision support for developing fisheries management plans. They also need scientifically based, but easy to understand, information on basic parameters that could enhance the productivity of fisheries and the income they generate.

### Workshop participants (from left to right):

**3rd row:** Sven Uthicke, Kim Friedman, Jeff Kinch, Matthias Wolf, Annie Mercier, Steve Purcell, Marcelo Vasconcellos

**2nd row:** Ruth Gamboa, Poh Sze Choo, María Dinorah Herrero-Pérezrul, Chantal Conand, Priscilla Martínez

**1st row:** Jean-François Hamel, Alessandro Lovatelli, Verónica Toral-Granda, Akamine Jun, Eduardo Espinoza

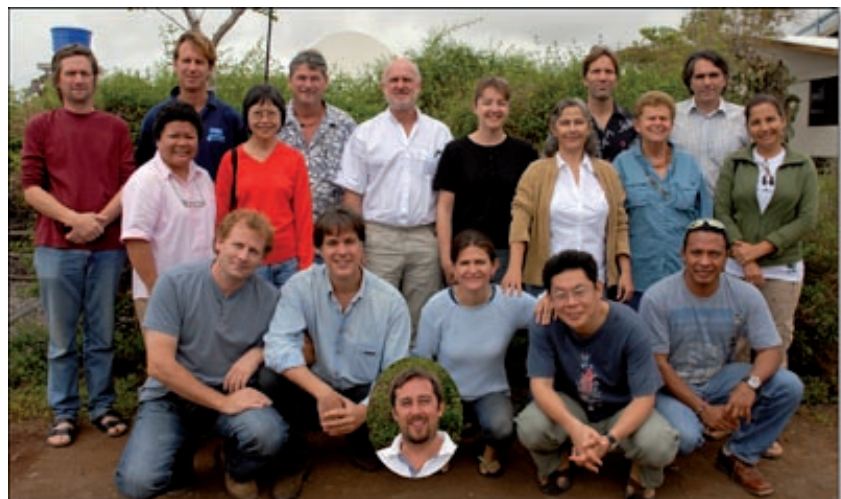
**Insert:** Alex Hearn

Recognizing a pervasive trend of overfishing, and mounting examples of local extinctions, guidelines for conserving biodiversity of sea cucumber populations should be a prominent feature of conservation and management. Recommendations for improving the species conservation status must, in concert, take into account the socioeconomic impacts of sea cucumber fisheries and their importance to rural coastal livelihoods.

The technical guidelines will strive to achieve a sensible balance between management regulations that maximize long-term benefits to fishers, and those that ensure the conservation of stock biodiversity. The guidelines aim to present a decision support model tailored for sea cucumber fisheries that will lead managers through a logical framework for deciding on the most appropriate management rules and activities, given the characteristics of their fishery. They will distinguish between generic and situation-specific management best practices and tools that could guide fishery managers in the development and implementation of local or national management plans for sea cucumber fisheries. Such advice has been broadly agreed on by expert biologists, sociologists and resource managers at the workshop, and will be supported in the technical guidelines by scientific findings and case examples.

Another aim of the technical guidelines is to identify key areas in which regulatory bodies can improve their scientific, patrolling and enforcing capacities. The guidelines should propose clear recommendations for customs agencies on trade regulations, and the collection and sharing of export data. They should also give guidance to how CITES listing can aid the management and conservation of threatened or depleted holothurian species.

The guidelines should ultimately assist countries in developing and implementing management plans that aim to maintain or restore the productive capacity of the stocks while addressing their role in the livelihoods of coastal communities.





## Observations of two *Holothuria* species (*H. theeli* and *H. portovallartensis*) from the Galapagos

Sven Uthicke<sup>1</sup>, Po-Sze Choo and Chantal Conand

Following the FAO workshop in the Galapagos Islands, we and some other participants observed several sea cucumbers with similar characteristics as *Holothuria leucospilota*. Following up on discussions within the PEET (Partnerships for Enhancing Expertise in Taxonomy) list, we hope that these observations will provide some interesting information on these little known species. Unfortunately, we were not allowed to take any samples or dissect specimens. We compared our observations with those of Hickman's (1998) on Galapagos echinoderms.

### *Holothuria theeli*

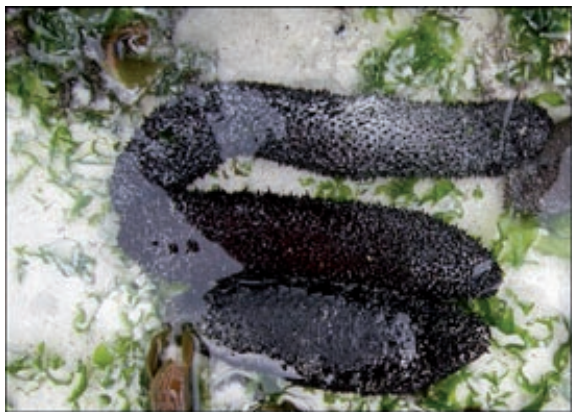
A species we first assumed was *H. leucospilota*, turned out to be *H. theeli* (Deichmann 1938). This species occurred in several locations: Santa Cruz, Bachas Bay (25 November 2007); Espagnola, Gardner Bay (27 November 2007); and Floreana, Punta Cormorant and Post Office Bay (28 November 2007).

Characteristics that differentiate *H. theeli* from *H. leucospilota* are:

- very tough body wall that appears thicker than that of *H. leucospilota*;
- no cuvierian tubules ejected, despite several trials;
- large triangular papillae on the bivium;
- white, very thin pedicellariae on the trivium among ordinary black papillae;
- bivium black and trivium often redish;
- buccal tentacles appearing as in *H. leucospilota*.

Other characteristics observed:

- mostly 17 cm in length, some rare 5–7 cm;
- found among blocks (often not fully exposed) at intertidal level and up to 5 m from the high-water mark;



*Holothuria theeli* (Photo: Sven Uthicke)

- very abundant in Gardner Bay (around 3 ind m<sup>-2</sup>);
- possible asexual reproduction in Bachas Bay.

### *Holothuria portovallartensis*

A second species was observed, which had characteristics of *H. portovallartensis* (Caso 1954). It was observed at low tide on Espagnola Gardner Bay (27 November 2007) and Floreana, Punta Cormorant and Post Office (28 November 2008).

Characteristics leading to differentiate *H. portovallartensis* from *H. theeli* and *H. leucospilota* were:

- soft body wall (similar to *H. leucospilota*), which appears to be thinner than that of *H. theeli*;
- no cuvierian tubules ejected, despite several trials;
- no large triangular papillae on the bivium;
- no white thin pedicellariae on the trivium, but many brown tube feet of equal size;
- bivium brown and trivium brownish-yellow;
- buccal tentacles appearing more digitated than those of *H. leucospilota*.

Other characteristics observed:

- mostly 18–22 cm in length;
- found among blocks with *H. theeli* (often not fully exposed) at intertidal level;
- possible asexual reproduction in Floreana Post Office (one specimen regenerating anterior end).

### Reference

Hickman Jr., C.P. 1998. A field guide to sea stars and other echinoderms of Galapagos. Lexington, VA: Sugar Spring Press. 83 p.



*Holothuria portovallartensis* (Photo: Sven Uthicke)

## Sea cucumber identification cards: An analysis of their utility in the Pacific

Aymeric Desurmont<sup>1</sup> and Steven Purcell<sup>2</sup>

### Abstract

Fisheries management personnel and other stakeholders need a means of ensuring consistency when identifying the various species exploited within a fishery. We conducted a questionnaire-based survey to evaluate the usefulness of SPC's "Pacific Island sea cucumber and beche-de-mer identification cards". Quality photographs of live animals were the most valuable information. The usefulness of other information depended on the user group, and whether users were from large, developed countries or small Pacific Island nations. A key finding is that the content and format in which the information is presented should largely be dictated by the intended user group. In this case, waterproof identification cards were considered by users as important tools in aiding in the identification of sea cucumber species, which can lead to improved data collection and fisheries management.

### Introduction

The ability to correctly identify the species being exploited is fundamental to fisheries management. In the case of sea cucumbers, identification can be more difficult after the animal is boiled and dried (beche-de-mer), because its original colour and form changes during processing. Aids used to help identify marine resources include guidebooks, posters and field identification cards. To determine which of these tools to invest in, it is important to know whether they assist in the identification of species, and what aspect of the information they contain is most useful.

In 2004, the Secretariat of the Pacific Community (SPC) produced a series of bound waterproof identification (ID) cards for common commercial species of sea cucumbers in the Pacific. These Pacific Island sea cucumber and beche-de-mer ID cards were produced in collaboration with the WorldFish Center, with financial support from the Australian Centre for International Agricultural Research (ACIAR). These cards were similar to ID cards produced in 2003 by SPC and the Papua New Guinea National Fisheries Authority, which were developed for identifying PNG's commercial sea cucumbers.

The ID cards illustrate 20 of the most common commercially valuable sea cucumber species in the Pacific (Fig. 1). One card is produced for each species, with each card showing a photo of the live animal in its natural habitat, photos of the processed (dried) specimens, a brief description of the key habitat and physical characteristics, and a description of the dried animals' appearance. The final cards in the series explain different processing methods applicable for each species, and give a narrative of basic sea cucumber biology and management. The intended users for these ID cards include fisheries officers from Pacific Island nations, customs officials that deal with product exports and reporting, processors, and fishers.

Almost 3000 ID card sets have been distributed, primarily in the Pacific. Recently, we contacted people to whom the cards were sent and asked them to complete a questionnaire about the usefulness of the cards. Below, we present a summary of the findings from the user survey, with a comparison of average ranked responses among user groups and regions. This survey contains useful lessons for the future design of identification aids for sea cucumbers and other marine resources.



Figure 1.

Cover page and example of a waterproof ID card, showing the live animal on the front and the dried product (beche-de-mer) on the back.

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## Methods

We prepared a questionnaire (see Table 1) with nine closed questions and asked for ranked responses of: very much (4), mostly (3), somewhat (2), not much (1), or not at all (0). In brief, questions asked whether the photographs and information were accurate and useful for identifying sea cucumbers, and whether respondents felt the cards had improved the processing and management of sea cucumbers in their fishery. Two open-ended questions asked about other species that could have been included, and the general usefulness of the ID cards. Respondents were categorised by location and agency type.

In total, 74 questionnaires were sent and 27 responses were received; 12 from Pacific Island countries, 10 from Australia, and 5 from outside the Pacific region. Of the 27 respondents, 10 were from research or extension agencies, 8 from fisheries departments, 5 from beche-de-mer trading companies, and 4 from non-governmental organisations (NGOs).

## Results and discussion

Respondents found the information on the cards to be mostly accurate (average rank 3.6). Photographs of the live animals were found to be the most useful tool for identification (mean rank 3.8), indicating that they are the key tool used to properly identify the different species. This is not surprising because identification is usually based on outer appearance. This finding indicates that priority should be given to obtaining the best and clearest photographs of live animals for use in identification materials.

Pictures of beche-de-mer (dried product) were on average viewed as “mostly useful”. As could be expected, researchers were the least interested by these pictures (mean rank 2.8). The relatively mild interest expressed by fisheries staff (mean rank 3.0) was less expected; one reason may be that some fisheries officers are not involved in monitoring the trade part of the fishery. Respondents from trade agencies and NGOs all gave the highest rank of “4”. The simple lesson from this result is that the importance placed on photographs depends on the intended user group(s).

Respondents from the Pacific region (Australia and Pacific Island countries) agreed that most local commercial species were shown on the cards (mean rank 3.7). As expected, respondents outside the Pacific did not find the majority of their local species in the card set (mean rank 2.6). Field identification tools thus need to be developed separately for each region, to ensure adequate representation of local species and to avoid redundancy from species present in other regions. In this context, larger reference tools (e.g. guidebooks) should include species distribution ranges.

Overall, the cards “mostly” helped respondents to improve their identification of sea cucumbers (mean 3.1). Excluding low rankings from sea cucumber “experts”, the result is even more positive (mean 3.6). There were no clear differences between respondent categories.

Overall, information on habitat and biology on each card “mostly” helped users in identifying species (mean rank 2.9). The most positive responses came from traders (mean rank 3.8) and respondents from

**Table 1.** Survey questions for sea cucumber ID cards

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Please place one number after each question, which best reflects your response, where:  
4 = very much; 3 = mostly; 2 = somewhat; 1 = not much; 0 = not at all.

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1. Did you find the information on the cards accurate?
2. Were the photos of live sea cucumbers the most useful information to you?
3. Were the photos and descriptions of dried beche-de-mer useful to you?
4. Did the cards show the majority of commercial species in your locality?
5. Have the ID cards improved your identification of sea cucumbers?
6. Were the habitat characteristics and biological information useful to you in your identifications of sea cucumbers?
7. To your knowledge, have the cards helped fishers to better identify sea cucumbers?
8. To your knowledge, were the descriptions of processing methods (towards the back of the cards) useful for improving the quality of beche-de-mer processed in your locality?
9. Did the information (last page of the cards) on biology and management improve your understanding of sea cucumbers?
10. What other commercially important species would you have wanted to see represented in the cards? (list species)
11. Do you have any other comments about the underwater ID cards?

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Pacific Island nations (mean rank 3.4). This finding indicates that such information is supplemental, and secondary, to quality photographs.

As to whether respondents felt the ID cards helped fishers to identify sea cucumber species correctly, the average rank response was only 3.0. Three respondents from Queensland, Australia noted that their fishery was exploited by a few knowledgeable fishers who were familiar with species identification; hence their low rank responses. A poignant comment from one trader was that the few ID card sets distributed by their fisheries department could not help the “thousands” of sea cucumber fishers in that country. Hence, the massive number of fishers in many small-scale fisheries must be taken into account in education strategies for fisheries management. Extension and training agencies must provide sufficient numbers of identification guides and devise means for disseminating them broadly if fishers are really the target user group.

Responses varied greatly about the utility of information on processing methods (at the end of the card sets). In Australia, where processing is mostly done by specialised companies, this information was viewed as less useful (mean rank 1.3). In Pacific Island nations, this information was considered to be “mostly” useful in improving the quality of sea cucumber processing (mean rank 3.2). A couple of respondents suggested developing a more comprehensive guide to processing methods, perhaps in the form of a specific booklet and/or video.

Regarding the biology and management information at the end of the card set, responses varied greatly according to regions and professional sectors. This information mostly helped respondents from the Pacific Islands (mean rank 3.2), but only “somewhat” improved the understanding of sea cucumbers from Australia (mean rank 1.9) or non-Pacific regions (mean rank 1.8). Likewise, researchers responded with low ranks (mean 1.4), while fisheries personnel and traders found the information important (mean ranks 3.1 and 3.4, respectively). The lesson here is that Pacific Islanders benefit more from additional information on biology and management, which they may not otherwise have.

Additional species that respondents suggested should be included in future guides or ID cards were *Actinopyga palauensis*, *A. spinea*, *Stichopus ocellatus*, *S. pseudohorrens*, *S. noctivagus* and *Thelenota rubralineata*. Also recommended was an updated card set to show new species names that have been taxonomically revised (e.g. *Holothuria nobilis*, now *Holothuria whitmaei*). Particular attention should be given to the taxonomy of the genera *Actinopyga*, *Bohadschia* and *Stichopus*. Some respondents also asked that new commercial species, sub-species and morphotypes should be shown.

One respondent noted that fishers are mostly illiterate in his locality. Educational programmes with actual demonstrations of improved processing methods and their advantages would be needed. One respondent stated it would be better to arrange the cards by scientific name, while another argued that cards would be better arranged by commercial value. In fact, the plastic pin binding in each card set can be removed, the cards reorganised as desired (since there is one card per species), and replaced with a split ring. For other cards or posters, we infer that the content and organisation of the cards depends on the key user group envisaged. One respondent suggested including recommended minimum size limits for each species; although this would vary among localities due to spatially variable life history traits of each species, we believe this does have merit. Some respondents wanted to see local names for species, but this would be cumbersome for cards intended for use in multiple countries. One fishery worker from Australia noted that the “cards have been the most useful technical publication we have ever used” and have “helped in training survey divers in the identification of species and helped our fishermen in accurate identification of species, which has in turn improved the accuracy of logbook information”. In this respect, species identification guides can play a powerful role in improving fisheries management.

## Conclusion

Identification cards and other information materials can help improve identification of species for fishery workers and fishers, thus improving fishery data used for management. Having multiple target user groups can diminish the utility of identification guides, since users from different sectors need different information. If fishers are the intended user group, thousands of copies may need to be produced and actively disseminated. ID cards or guides intended for remote communities or island nations should include additional information on management, biology, and processing. It was suggested that a poster, with biological information and photographs, would also be beneficial as it could be displayed at centres frequented by fishermen and/or producers. SPC, the WorldFish Center, ACIAR and FAO are preparing such a poster for commercial Pacific sea cucumbers, which should be available in 2008. The results of this study are helping us design the poster, and we thank respondents for their comments.

## Acknowledgements

We wish to thank Barney Smith of ACIAR for his encouragement to conduct this questionnaire-based study. Cathy Hair provided comments on this article and helped with requesting responses from users. This is WorldFish Center contribution No. 1860.

## Status and preliminary assessment of the sea cucumber fishery in Eritrea

*Tesfamichael Kalaeb<sup>1</sup>, Dawit Ghirmay, Yosief Semere and Filmon Yohannes*

### Abstract

In Eritrea, sea cucumbers — especially those from the families Holothuridae and Stichopodidae — form an important part of a multi-species invertebrate fishery. There is no domestic demand for sea cucumber products and so they are exported. In Eritrea, there are no rules or regulations governing sea cucumber fishing activities, and no reasonable stock status estimates are available. As a result, the sea cucumber fishery faces managerial and technical capacity limitations.

The UN Food and Agriculture Organization (FAO) — through the United Nations Development Programme (UNDP) — provided funds to the Ministry of Fisheries, State of Eritrea for a preliminary survey of the status of sea cucumber stocks, and a study of the socioeconomic and environmental impacts of sea cucumber fishing. This report outlines the ecological and biological aspects of Eritrea's sea cucumber fishery.

Eritrea's northern fishing ground is relatively abundant with diverse species of commercial sea cucumbers. The sea cucumber fishery in Eritrea is relatively better condition than the sea cucumber fisheries in other parts of the Red Sea (e.g. Egypt). The density of animals in offshore and deeper areas is higher than in shallow and nearshore areas. This study shows the habitat preference and depth distribution of commercial sea cucumber species. Length-frequency data for each commercial sea cucumber species, and baseline information for the important sea cucumber fishing grounds, was recorded for comparison with future studies. Finally, monitoring sites were chosen in all of the important fishing grounds, and, permanent monitoring sites will be placed at Green and Dissie islands, which have been proposed as marine protected areas.

Based on this study of the sea cucumber fishery, the following recommendations have been made to the Ministry of Fisheries, State of Eritrea:

- conduct in-depth research on sea cucumber biology (i.e. growth, reproductive rate, etc.);
- develop management strategies specific to the sea cucumber fishery (using a precautionary approach that includes the formulation of a national fishing advisory committee);
- develop post-harvest handling and mariculture techniques for stock replenishment; and
- formulate regulations to protect wild sea cucumber stocks.

### Introduction

The current high demand for dried sea cucumber product is likely to continue and increase in many Southeast Asian countries (FAO 2003). The commonly exported product is the dried body wall known as beche-de-mer or trepang. Global stocks of sea cucumbers have declined over the years, mostly due to overharvesting in many countries. Sea cucumber fisheries have undergone cycles in which the total catch decreased despite an increase in the fishing effort. This has led to the overexploitation of the resource and low economic returns to coastal communities (Ibarra and Soberon 2002). Due to the high value placed on sea cucumbers, the ease with which they can be harvested, and their particular biology, population dynamics and habitat preferences, they are vulnerable to overexploitation

(Bruckner et al. 2003). Hence, the fishery is characterized by boom and bust cycles with biological overexploitation often occurring before economic overexploitation (Preston 1993; Conand 1997).

In Eritrea, sea cucumber harvesting has been occurring for less than 50 years, and was initially confined to shallow waters. Since 2000, however, there has been intensive exploitation and sea cucumber catches and export rates have dramatically increased. Eritrea has now become a supplier of dried sea cucumber products (beche-de-mer) to outside markets (Tewelde and Woldia 2007).

In 2000, about 11 tonnes (t) of gutted and dried sea cucumbers were produced. Since then, the amount has steadily increased (Table 1). In 2007, the fishery was closed by an administrative deci-

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sion to stop illegal fishing and export (Tewelde and Woldia 2007).

**Table 1.** Eritrea's beche-de-mer production (2000–2006).

Year	Beche-de-mer production (t)
2000	11
2001	80
2002	242
2003	452
2004	283
2005	380
2006	278

The principal objective of the present survey was to assess the stock status, establish baseline information on ecological and biological parameters, and introduce some preliminary recommendations for more sustainable exploitation of sea cucumbers.

### Study area

Eritrea is on the northeast coast of Africa (between 12–18°N and 36–43°E) and stretches along the Red Sea between Sudan and Djibouti. Eritrea's mainland

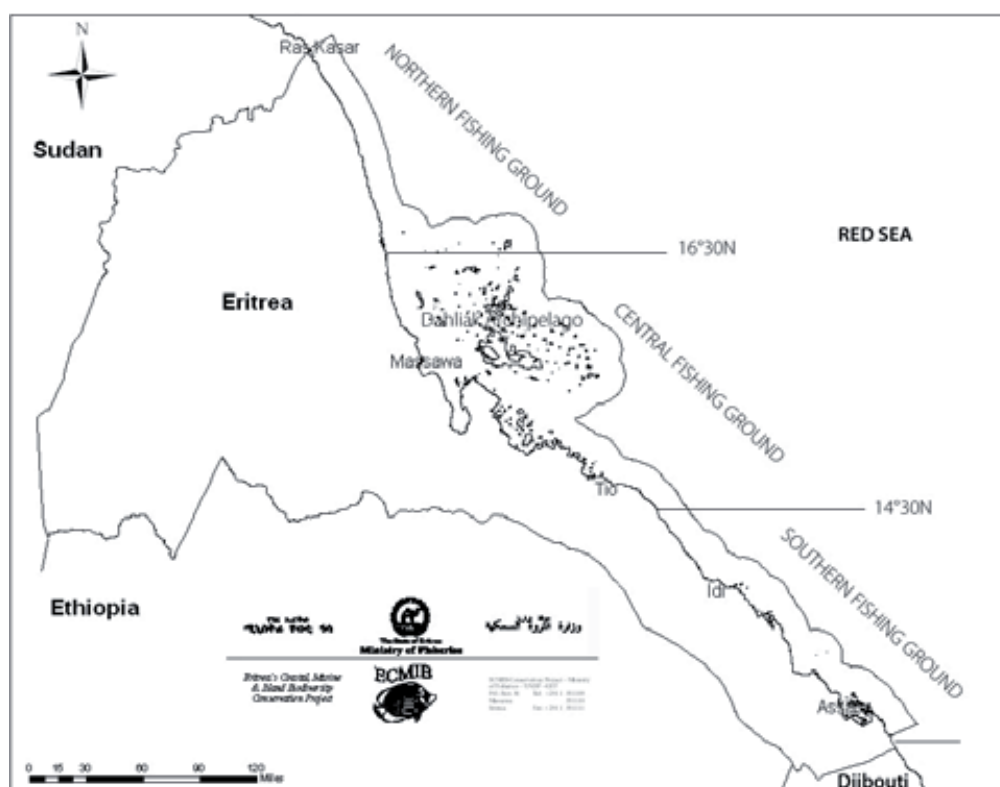
coastline is approximately 1350 km long, extending from Ras Quesar (northern border with the Sudan) to Ras Dumera (southern border with Djibouti). The coastline of the numerous offshore islands is about 1900 km long.

### Survey area

For the purpose of this study, Eritrea's coast was divided into three sea cucumber fishing grounds: northern, central and southern (Fig. 1). The selection of survey sites was based on the presence of important sea cucumber habitat (e.g. coral reef, sand substrate, muddy beaches, mangrove beds, seagrass beds and macroalgae), areas of fished and non-fished grounds, and areas nearshore and offshore from an island or the mainland. In total, 150 sites were selected: 60 sites in the central fishing grounds, 45 sites in the southern fishing grounds, and 45 sites in the northern fishing grounds.

### Survey methodology

Two teams of divers surveyed a 100-m-long transect, recording information that was 1 m on either side of the transect (i.e. 2 m total width). When the visibility was poor, the total width of the observation was reduced to 1 m. The transect was placed perpendicular to or, sometimes parallel to, the beach depending on the local topography. The study was carried out from the reef flat to a depth of 30 m.



**Figure 1.** Eritrea's coastal area and numerous offshore islands.

Data recorded included length measurements of all sea cucumber species observed, substrate type (described in terms of percent cover of coral, seagrass, micro-algae beds, sand, mud or mangrove stands).

## Results

### Sites and species

To date, 91 sites (out of the total 150 sites selected) have been surveyed: 16 sites in the northern fishing ground, 60 sites in the central fishing ground, and 15 sites in the southern fishing ground. The remaining 59 sites will be surveyed next year. Thus far, 16 sea cucumber species have been identified and two have been recorded as unidentified (Table 2).

### Abundance and species diversity among the different fishing grounds

Sea cucumber abundance and species diversity varies among the three fishing grounds. The highest diversity was recorded in the northern fishing ground with the presence of eight of the nine main commercial sea cucumber species found in Eritrea (Fig. 2).

### Comparison between fished and non-fished areas

To determine the impact of sea cucumber fishing activities on stocks, the abundance of sea cucumbers in non-fished (or very little fished) areas was compared with the abundance in heavily fished areas. The average abundance values were 21.6 individuals per transect for non-fished areas, and 11.8 indi-

viduals per transect for heavily fished areas. Figure 3 shows a clear pattern of increasing fishing impact on the overall abundance of sea cucumber populations.

### Comparison of sea cucumber densities from other studies

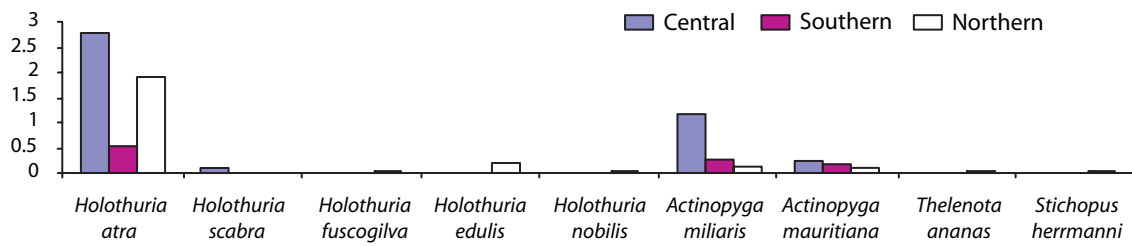
To determine the status of sea cucumbers in Eritrea, the density of animals per hectare was compared with the density recorded in Egypt (Lawrence et al. 2004) (Table 3).

**Table 3.** Density of some commercial sea cucumber species in Eritrea and Egypt.

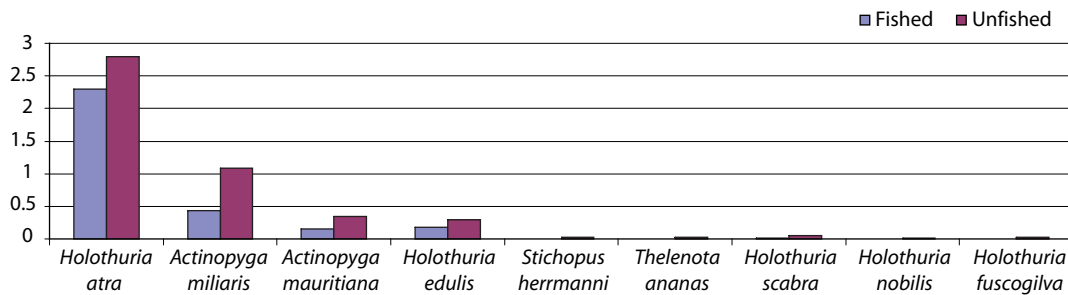
Species	Density (ind ha <sup>-1</sup> ) in Eritrea	Density (ind ha <sup>-1</sup> ) in Egypt
<i>Holothuria scabra</i>	7.5	0.0
<i>H. atra</i>	295.0	155.48
<i>H. edulis</i>	48.5	-
<i>H. fuscogilva</i>	3.0	1.2
<i>H. nobilis</i>	1.0	0.66
<i>Stichopus horrens</i>	10.0	0.654
<i>S. herrmanni</i>	3.0	-
<i>Actinopyga mauritiana</i>	35.0	11.45
<i>A. miliaris</i>	157.5	-
<i>Thelenota ananas</i>	3.5	-

**Table 2.** Sea cucumber species encountered during field surveys along the Eritrean coast.

No.	Species name	Common English name	Local name	Value/grade	Commercial value
1	<i>Actinopyga mauritiana</i>	Surf redfish	Abu Sanduk Hager	2 <sup>nd</sup> grade	Yes
2	<i>A. miliaris</i>	Blackfish	Abu Shelalik	3 <sup>rd</sup> grade	Yes
3	<i>Holothuria atra</i>	Lollyfish	Lega	3 <sup>rd</sup> grade	Yes
4	<i>H. edulis</i>	Pinkfish	Abu Sanduk Tina	2 <sup>nd</sup> grade	Yes
5	<i>H. fuscogilva</i>	White teatfish	Abu Habhab Abyed	1 <sup>st</sup> grade	Yes
6	<i>H. hilla</i>	-	-	No grade	No
7	<i>H. impatiens</i>	-	-	No grade	No
8	<i>H. nobilis</i>	Black teatfish	Abu Habhab Aswed	1 <sup>st</sup> grade	Yes
9	<i>H. scabra</i>	Sandfish	Hedra Beyda	1 <sup>st</sup> grade	Yes
10	<i>H. spinifera</i>	-	-	No grade	No
11	<i>Pearsonothuria graeffei</i>	Flowerfish	-	No grade	No
12	<i>Stichopus chloronotus</i>	Greenfish	Abu Jezma	no grade	No
13	<i>S. herrmanni</i>	Curryfish	Hamra	2 <sup>nd</sup> grade	Yes
14	<i>S. horrens</i>	Dragonfish	Abu Jezma	No grade	No
15	<i>Synaptula media</i>	-	-	No grade	No
16	<i>Thelenota ananas</i>	Prickly redfish	Abu Mud	1 <sup>st</sup> grade	Yes
17	unidentified (1)	Unknown	Unknown	Unknown	Unknown
18	unidentified (2)	Unknown	Unknown	Unknown	Unknown



**Figure 2.** A comparison of the abundance of nine sea cucumber species in the northern, central and southern fishing grounds in Eritrean waters. Values are expressed as the mean number of individuals per transect



**Figure 3.** Comparison of abundance between fished and unfished areas in the Eritrean Red Sea. Values are expressed as mean number of individuals per transect.

Table 4 is a preliminary listing of sites where smaller individuals of commercially important sea cucumber species (i.e.  $\leq 10$  cm) were found.

**Table 4.** Sites with juveniles of commercially important sea cucumber species.

Site	Species	Length (cm)
Barasole (island)	<i>A. mauritiana</i>	6.0
Umm Namus	<i>A. miliaris</i>	10.0
Green Island	<i>H. atra</i>	10.0
	<i>S. chloronotus</i>	8.0
Arabi Seil	<i>H. atra</i>	6.5
Martaban	<i>H. atra</i>	9.0
Barasole (mainland)	<i>H. atra</i>	10.0
Museri	<i>H. edulis</i>	10.0
Yermalkau	<i>H. edulis</i>	9.0

**Depth and habitat distribution of commercial sea cucumber species**

The depth distribution of the commercial sea cucumber species shows that sea cucumbers were found from the outer reef flat to depths of 30 m, although most were found in depths ranging between 6 m and 15 m. The commercial species (*H. atra*, *H. edulis*, *A. miliaris* and *A. mauritiana*)

were found mainly on coral and sand substrates. *H. scabra* was primarily found in muddy areas and seagrass beds.

**Environmental impact of the sea cucumber fishery**

Commercial harvesting of sea cucumbers leads to environmental impacts on land near sea cucumber processing camps. Terrestrial environmental impact surveys were conducted specifically on the central and south-central islands where sea cucumber fishermen have established processing camps. During the survey, mangrove destruction, halophyte clearing, and littering and solid waste disposal were recorded. Evidence of turtle consumption (carapaces found) and bird nest disturbance were observed. The survey did not record underwater damage caused by trawling for sea cucumbers.

**Discussion**

The abundance and species diversity comparison among the three different fishing grounds shows that the northern fishing ground is more diverse with commercial sea cucumber species. Eight out of the nine commercial species (*H. atra*, *H. nobilis*, *H. fuscogilva*, *T. ananas*, *H. edulis*, *S. herrmanni*, *A. miliaris* and *A. mauritiana*) were found in the northern area. The reasons for this high diversity include greater depth, remoteness, and exposure of



the area to strong winds and rough sea conditions, all of which make it more difficult for fishermen to harvest sea cucumbers.

Small-sized individuals ( $\leq 10$  cm) were recorded in several sites (in particular Museri, Yermalkau, Arabi Seil, Martaban, Umm Namus, Barasole, Salima and Dorrum). These areas may possibly be nursery grounds for commercial species and may need some conservation status, such as the establishment of no-take marine reserves.

With the exception of *H. scabra*, which was predominantly found in muddy and seagrass substratum, other commercial sea cucumber species were found mainly on coral reefs and sandy substrates.

Although Eritrea's commercial sea cucumber are found in depths ranging between 6 m and 15 m, *H. fuscogilva* and *H. nobilis* are typically found in deeper water, although in this study, they were found in shallow areas, in depths of 6–10 m.

Sea cucumbers must be thoroughly processed before the final product is ready for export. This processing has detrimental impacts on the terrestrial environment, including the fauna and flora of the area. Mangroves are cut to provide firewood for boiling the sea cucumbers, plastic and other garbage is disposed off at the sites or in the sea, bird nests are destroyed and turtles are caught and eaten by the fishermen.

A comparison of sea cucumber abundance between fished and non-fished areas shows clear patterns of increasing fishing intensity (but not yet overfished) for all commercial species. Therefore, fishing intensity has a pronounced impact on the overall abundance of sea cucumber species. In the absence of catch per unit of effort data for the sea cucumber fishery, it is difficult to give evidence of overexploitation. At present, most fishing effort has been concentrated on the central fishing ground, and the decrease in sea cucumber production is related to this area.

In Eritrea, there are many problems with the current status, regulation and management of sea cucumber fishery resources. In fact, there is no legislation specific to the sea cucumber fishery. A seasonal closure (October–February) applies to all types of fisheries. The total allowable catch of 500 t and the minimum legal size (5 cm wet length), are terms of agreement between the National Fisheries Corporation and fishermen engaged in the sea cucumber fishery. There is a lack of information on the population dynamics of exploited species. Illegal fishing and exporting activities are occurring. In conclusion, there is little concern about this resource, despite its ecological role and economic importance to small coastal communities.

The establishment of adequate management and regulation measures, bans and closures (both in season and fishing ground), size and catch limits are needed. Also needed are regular monitoring and surveying programmes and the development of mariculture for sea cucumbers. These actions could allow Eritrea to develop a sustainable sea cucumber fishery.

### Acknowledgements

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## Description of calcareous structures of the apoda holothurian *Synaptula hydriformis* (Lesueur 1824)

Cynthia Grazielle Martins Delboni<sup>1</sup>

Echinoderms usually have a rigid body wall with an elaborate magnesium-rich calcite endoskeleton (Raup 1966). In the Holothuroidea class, the integumental skeleton consists of microscopic ossicles formed within multinucleated syncytial sclerocytes present in the dermal layer of the body wall (Stricker 1986). These ossicles may show a great variety of forms from the simplest, such as small rods, to the most elaborate ones such as forms that vary from perforate and ornamented plates. The calcareous ring, a structure formed by calcified plates that surround the pharynx, is also part of the endoskeleton of these animals (Conand 1990). These calcareous structures have great importance for the systematic character of species identification of holothurians (Pawson and Fell 1965). In this work, the ossicles and other calcareous structures of the apoda holothurian, *Synaptula hydriformis* (Lesueur, 1824), were studied in confocal and scanning electron microscopy.

Adult specimens of *S. hydriformis*, collected in the Canal de São Sebastião in São Paulo, Brazil, were reared in a laboratory at the Centro de Biologia Marinha (Universidade de São Paulo) in the same city. Specimens were relaxed in 7.5% MgCl<sub>2</sub> solution in seawater (1:1) and preserved in 70% alcohol. For scanning by electron microscopy (SEM), the ossicles were isolated by digesting the body wall fragments using a solution of NaOH, and transferred to double-face tape in stubs and coated with gold. The mate-

rial was observed in a TSM 940 Zeiss microscope. To study the development of the ossicles using confocal microscopy, living adults were immersed in a container filled with a solution of seawater and tetracycline-HCl (fluorescence marker), with food, for five days (modified from Stricker 1985). The sea cucumbers were returned to the rearing containers for the same period of time. Then, all of the animals were relaxed and preserved for analysis in a LSM Zeiss microscope. Specimens of *Synaptula hydriformis* were deposited in Museu de Zoologia (Universidade de São Paulo) - MZUSP 153 (Echinodermata).

The main ossicles of this species are composed of two parts: a plate and an anchor, distributed all over the skin (Hendler et al. 1995). The various stages in the formation of anchors and plates observed in *Synaptula hydriformis* essentially coincide with the developmental patterns reported for others species of synaptid holothurians (e.g. Clark 1907; Woodland 1907). As in *Leptosynapta clarki* (Stricker 1985), *S. hydriformis* has several isolated anchors, but fully developed plates without anchors are rarely found. In this species, each anchor is usually attached to a plate and measures about 120 µm long, reaching up to 170 µm in some specimens. First, the anchor is formed as a small baton. After the baton has grown longer, the flukes and the stock of the anchor are formed (Fig. 1). The plates are first formed after the anchors are well developed but, in a few cases, plate



**Figure 1.**  
Scanning electron microscopy:  
Sequence of anchor formation  
in *Synaptula hydriformis*.

formation begins before the flukes and stocks appear. The plate is first formed as a small bar that lies near and somewhat perpendicular to, the middle of the anchor's longest axis. Further bifurcation of this structure combined with the fusion of calcium carbonate curved deposits form a whole plate, which measures 95–130  $\mu\text{m}$  (Figs. 2 and 5a,b,c). Others calcareous structures are the batons of the tentacles (the miliary granules) and the oral ring plates. The batons are observed in every margin of the tentacles, and measure 63  $\mu\text{m}$  on average (Fig. 3). The miliary granules, which are usually grouped, measure from 4.82–15.35  $\mu\text{m}$ , and can be found in the corporal wall (Figs. 4a and 5d). Oral ring plates can be of two types: radial and interradiial. The first plates are about 339.4  $\mu\text{m}$  wide, and the interradiial ones, 208.9  $\mu\text{m}$  (Figs. 4b and 4c). It was observed that, in this species, the ossicle formation and the development of the calcareous structures occur throughout the whole life (including adult stage).

Holothurian species are classified by analyses of tentacles together with the format of the calcareous ring and, mainly, by the form and size of the ossicles. Therefore, this study is an important taxonomic tool, as knowing the sequence of ossicle development makes it possible to identify holothurians that present ossicles in different degrees of formation for this species.

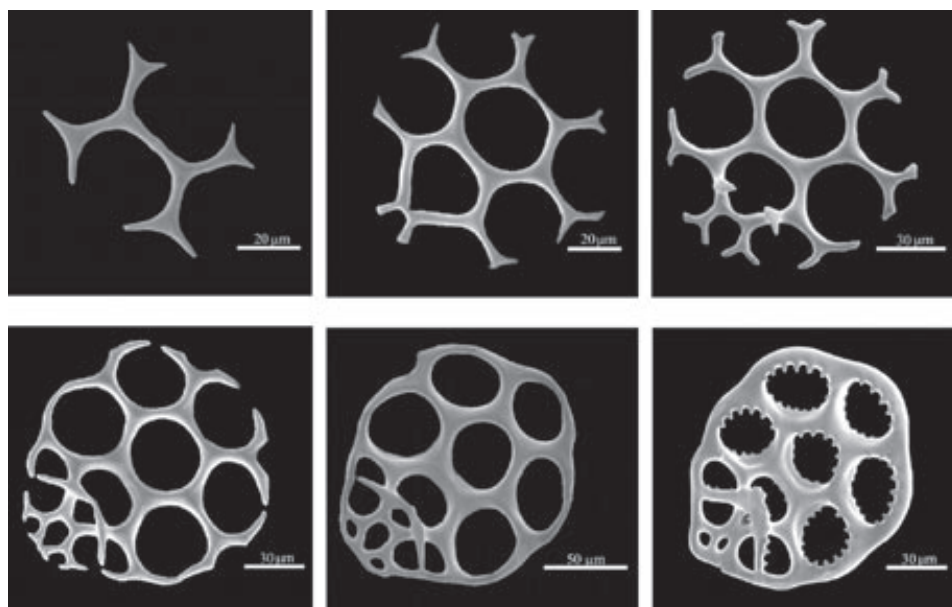
### Acknowledgements

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logistical support. The author thanks Dr Alberto Augusto de Freitas Ribeiro, Enio Mattos, Eduardo Mattos and Waldir Caldeira for their invaluable help with electronic scanning microscopy and confocal microscopy analyses. The author also gives special thanks to the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq or National Counsel of Technological and Scientific Development) and the Programa de Apoio à Pós-Graduação-Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (PROAP-Capes) for the grant that supported her master's degree studies.

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**Figure 2.** Scanning electron microscopy: Sequence of plate formation in *Synaptula hydriformis*.

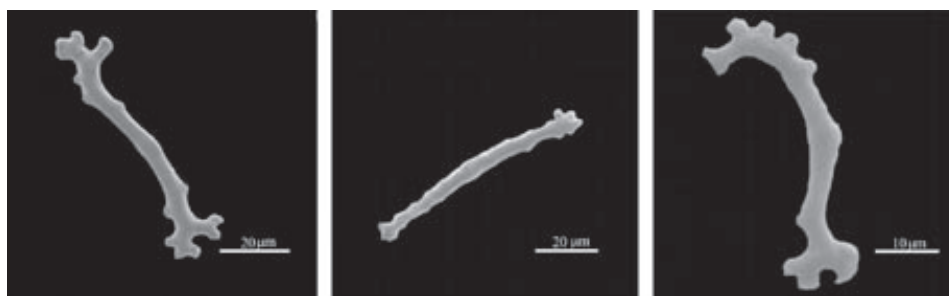


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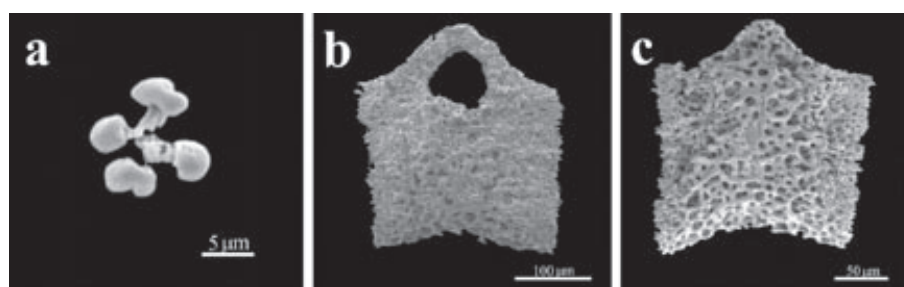
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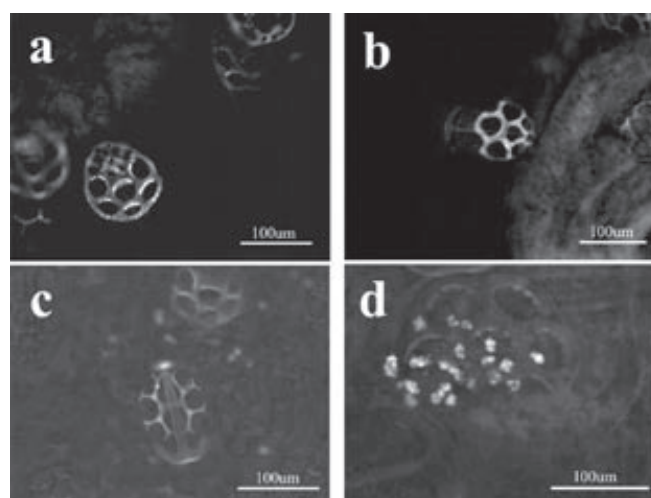
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**Figure 3.** Scanning electron microscopy: Baton of the tentacles.



**Figure 4.** Scanning electron microscopy: a. miliary granule; b. piece radial of oral ring; c. piece interradial of oral ring.



**Figure 5.** Confocal microscopy: a., b. and c. plate formation; d. miliary granule.

## Information on the sea cucumber fishery in the Querimbas Archipelago, Mozambique

Nick Hill<sup>1</sup>

All sea cucumbers on Vamizi Island, in the northern Querimbas Archipelago in northern Mozambique, are generically referred to as *macajojo*. The sea cucumber fishery there has existed since 2000 and possibly earlier. Some fishermen specifically target sea cucumbers (using just a mask or a mask and snorkel), while others collect them incidentally while they are spearfishing for finfish.

The sea cucumber fishery is particularly popular with transient or immigrant fishers, with 10 or 20 people setting out on a collecting trip in a single *machua* (traditional wooden sailing boat). A small number of resident fishermen also collect sea cucumbers. Apparently, sea cucumber fishing used to be very productive, but fishermen complain of declining catches and now say that very few are left.

Sea cucumbers are not eaten locally, but are instead kept in buckets of water and sold to traders; their ultimate destination is unknown.

Prices for sea cucumbers vary greatly according to species, but ranged in 2005 from MZN 500– 100,000 per animal.

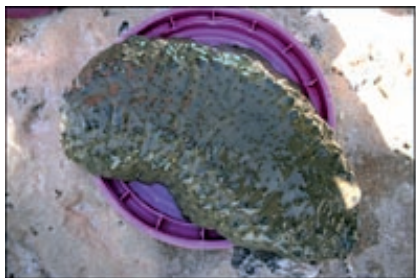
**Table 1.** Prices for three sea cucumber species

Local name	Scientific name	Price per animal
Subinho	<i>Thelenota ananas</i>	50,000 MZN
Trogida	<i>Stichopus herrmanni</i>	50,000 MZN
Namonha	<i>Bohadschia</i> sp.	1000 MZN

Another species, probably *Holothuria fucogilva* (Fig. 4) (C. Conand pers. comm.), was collected as secondary information opportunistically, so I am uncertain as to how many species/types of sea cucumber the fishermen can recognise.



**Figure 1.** Subinho (*Thelenota ananas*)



**Figure 2.** Trogida (*Stichopus herrmanni*)



**Figure 3.** Namonha (*Bohadschia* sp.)



**Figure 4.** *Holothuria fucogilva*?

## Asexual reproduction by fission of a population of *Holothuria hilla* (Lesson 1830) at One Tree Island, Great Barrier Reef, Australia

Jessica Lee,<sup>1</sup> Maria Byrne<sup>1</sup> and Sven Uthicke

### Introduction

Asexual reproduction through fission is a feature of many of the most abundant aspidochirote holothuroids in the Indo-Pacific region (Uthicke 1997, 2001). Fissiparous species split in half and the two halves regenerate to make complete individuals. Thus far, six *Holothuria* and two *Stichopus* species are known to be fissiparous and asexual reproduction appears to be a major form of reproduction used in maintaining populations (Ebert 1978; Harriott 1982; Conand and de Ridder 1990; Chao et al. 1994; Conand et al. 1997; Uthicke 2001). All aspidochirotids for which asexual reproduction has been described also reproduce sexually and have dispersive larvae. Spawning of aspidochirotids occurs at variable times of the year for different species, with spawning usually in summer (e.g. Conand 1993; Guzman et al. 2003; Ramofafia et al. 2000) however exceptions such as the winter spawning of *H. whitmaei* have been observed (Conand 1981; Shiell and Uthicke 2006). Asexual and sexual reproduction are both important in the maintenance and genetic structure of populations of tropical aspidochirotids (Conand et al. 2002).

In this study we investigated the asexual and sexual reproduction in a population of *Holothuria hilla*. *H. hilla* is a soft-bodied holothuroid that is widespread in the Indo-Pacific region (Kerr 1994; Rowe and Gates 1995). It has a distinctive light-brown body wall with light-yellow to white papillae. *H. hilla* tends to be nocturnal and is found under coral rubble or on reef flats region emerging at dusk to feed (Lawrence 1979; Kerr 1994). On midshelf reefs of the Great Barrier Reef, densities of 82–220 ind ha<sup>-1</sup> have been observed, with lower numbers on outer shelf reefs (Hammond et al. 1985).

### Materials and methods

One Tree Island (OTI; located at 23°30'S, 152°05'E) is in the Capricorn Bunker Group of the Great Barrier Reef. Asexual reproduction in *Holothuria hilla* was monitored in samples collected at 6 to 7 week

intervals from March 2005 to November 2006. No samples were collected from December to February. *H. hilla* were collected at low tide from under coral rubble from the inlet on the east side of OTI. The length of each *H. hilla* was measured with a ruler and weighed using a 1-kg Super Samson spring balance to the nearest 5 g. Each specimen was examined externally for signs of fission. They were categorised into five stages of fission and regeneration according to Conand (1996): (1) W = whole or undivided specimen, (2) A = an anterior specimen with an existing mouth at one end and a closed wound at the other, and (3) P = a posterior specimen with an anus at one end and a closed wound at the other. All specimens were returned to the collection site. The proportion of anterior and posterior fission products were compared by a paired t-test. The location of *H. hilla* at night was investigated in night snorkels in July 2004 and November 2005 from approximately three hours after sunset.

In November 2006 we examined five individuals for the presence of gonads. Histology was used to document gamete development and to define the stage of gonad maturation. The gonads were fixed in formalin and stored in 70% ethanol. For histology, gonad sections (7 µm) were stained with Mayer's haematoxylin and eosin (H/E), and the slides were examined by light microscopy. Stages of gametogenesis were classified into one of the following five categories: (1) Indeterminate — unable to define whether the specimens are male or female as no gametes is evident; (2) Growing — developing eggs and sperm in the gonad; (3) Mature — fully developed eggs or sperm were present in the tubules. This was seen by a great volume of eggs or sperm packed tightly inside the tubules; (4) Partly spawned — eggs or sperm seen in the tubules and maybe loosely arrayed due to recent release of its gametes. Some gonad gametes were still growing to maturity; and (5) Spent — tubules were found to be empty. Residual oocytes or sperm may be present. Brown bodies usually seen in association with spent tubules.

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## Results

*H. hilla* was locally abundant in the inlet adjacent to One Tree Reef. During the day it was found under coral rubble, emerging at night to feed. The maximum length of whole individuals was 15–20 cm and maximum weight was 75–80 g. For fission products, the maximum length and weight was 10–15 cm and 45–50 g, respectively.

### Incidence of asexual reproduction and growth

At the beginning of the study, in March 2005, fission products of *H. hilla* were evident in the population. The body of *H. hilla* is light brown distinct with white or yellow papillae. *H. hilla* that have undergone fission are easily distinguished because the regenerating region of the body is lighter in colour and smaller in diameter than the original body (Fig. 1). The various stages of fission and regeneration were found within all sampling times. However, we did not encounter individuals in the process of fission. Although fission occurs year round, it appears to be more prevalent in cooler months (May–August). Over the 20-month study (Fig. 2a), fission was most prevalent in June 2005 and July 2006 when fission products were 59% of the specimens collected. The incidence of fission was lowest in November 2005 (0%) and 2006 (14%). The presence of anterior and posterior fission products in the population varied over time (Fig. 2b), but the proportion of these individuals did not differ ( $df = 9, t = 0.246, p > 0.05$ ).

Figure 3 shows the frequency distribution of weight for *H. hilla*. The weight range of whole *H. hilla* was 10–210 g while fission products were 10–110 g. Large non-regenerating *H. hilla* were 5–35 cm in length and fission products were 5–25 cm in length (Fig. 4). The minimum mean weight was found in March 2005 at 42.3 g (SE = 8.38 g,  $n = 24$ ). The heaviest specimens were found in November 2006 (mean = 113.5 g, SE = 12.2,  $n = 26$ ). This also corresponds with the highest proportion of whole non-regenerating individuals. In 2005, the mean weight and length of *H. hilla* in the populations increased from a low of 42.2 g and 14 cm respectively in March, to 80 g and 22 cm respectively in November. Similarly, in 2006 mean weight and length was 49.8 g and 14 cm in April and 113.5 g and 20 cm in November. This represents a gain in weight of ca. 56% in 2005 and 89% in 2006 over 6–7 months, equivalent to a weight gain of 3.14 and 5.3 g per month respectively. If individuals only split once during this period, the *H. hilla* approximately doubled in weight post fission.

### Sexual reproduction

The gonad of *H. hilla* is a single tuft with numerous branching tubules attached to the gonad basis on the anterior body wall. The sex of the gonads for the majority of the specimens was difficult to determine macroscopically but histological examination showed all five specimens had gonads: one was female, one was male and the remaining were of spent (with no remaining gametes) or indeter-



**Figure 1.** Fission products of *Holothuria hilla*. Posterior fission product (top) and anterior fission product (bottom). Arrows show the regenerating regions. Scale = 1:2

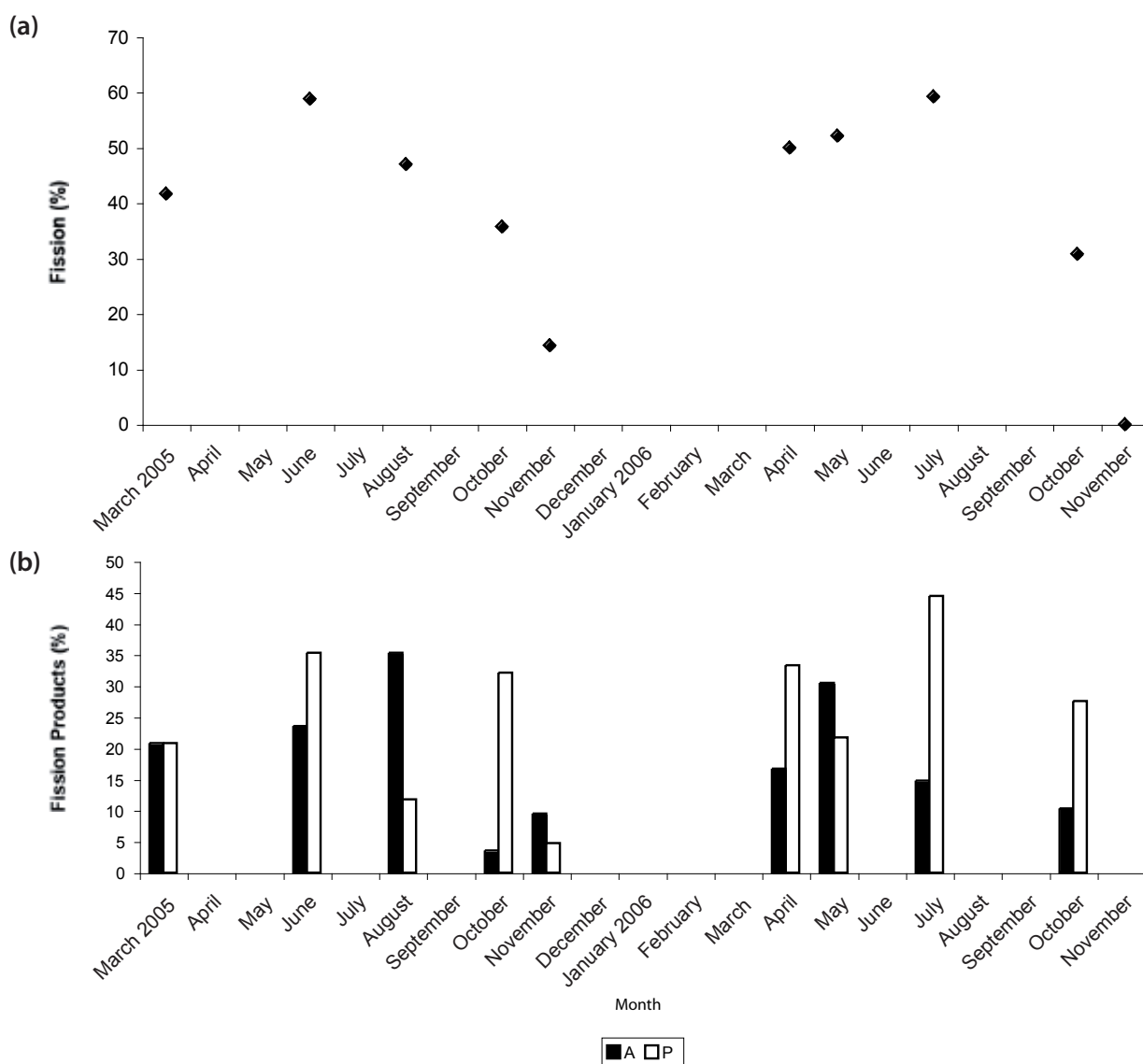
minate stages (Figs 5A–F). The sex of the specimen could not be determined in the indeterminate specimens. Females were distinguishable as spent ovary tubules contained a few remaining oocytes (Figs 5A and B). The oocytes were on average 88.19  $\mu\text{m}$  in diameter ( $n = 30$ ,  $SD = 11.52$ ). Indeterminate and spent specimens had an empty lumen and highly reduced tubules with a wrinkled appearance (Figs 5C–F). No gametes were present in the indeterminate and spent specimens.

## Discussion

This is the first documented study of asexual reproduction in *Holothuria hilla*. As for other fissiparous holothuroids, *H. atra* and *Stichopus chloronotus* on the Great Barrier Reef and elsewhere (Conand 1996; Conand et al. 1997; Uthicke 1997; Conand et

al. 2002), asexual reproduction in *H. hilla* predominates in the cooler months. Populations of *H. hilla* in Hawaii also undergo fission (Discipline of Anatomy and Histology, Bosch Institute, University of Sydney, pers. comm.). This is a popular species in hobby aquaria and is also known to undergo fission in aquaria (Robert Toonen, Hawaii Institute of Marine Biology, University of Hawaii Toonen, University of Hawaii, pers. comm.).

Fission in *H. hilla* was prevalent for eight months of the year over the cooler months sampled (March–October) from autumn to spring. The highest incidence of fission in *H. hilla* in June and July coincided with mid-winter, similar to that documented for populations of *H. atra* and *S. chloronotus* on OTI and elsewhere (Harriott 1982; Conand 1996; Uthicke 1997, 2001; Lee 2005). Fission is considered to play



**Figure 2.** The incidence of asexual reproduction of *Holothuria hilla*:  
(a) Percentage of fission in each sample.  
(b) Percentage of anterior (black) and posterior (white) fission products in each sample.

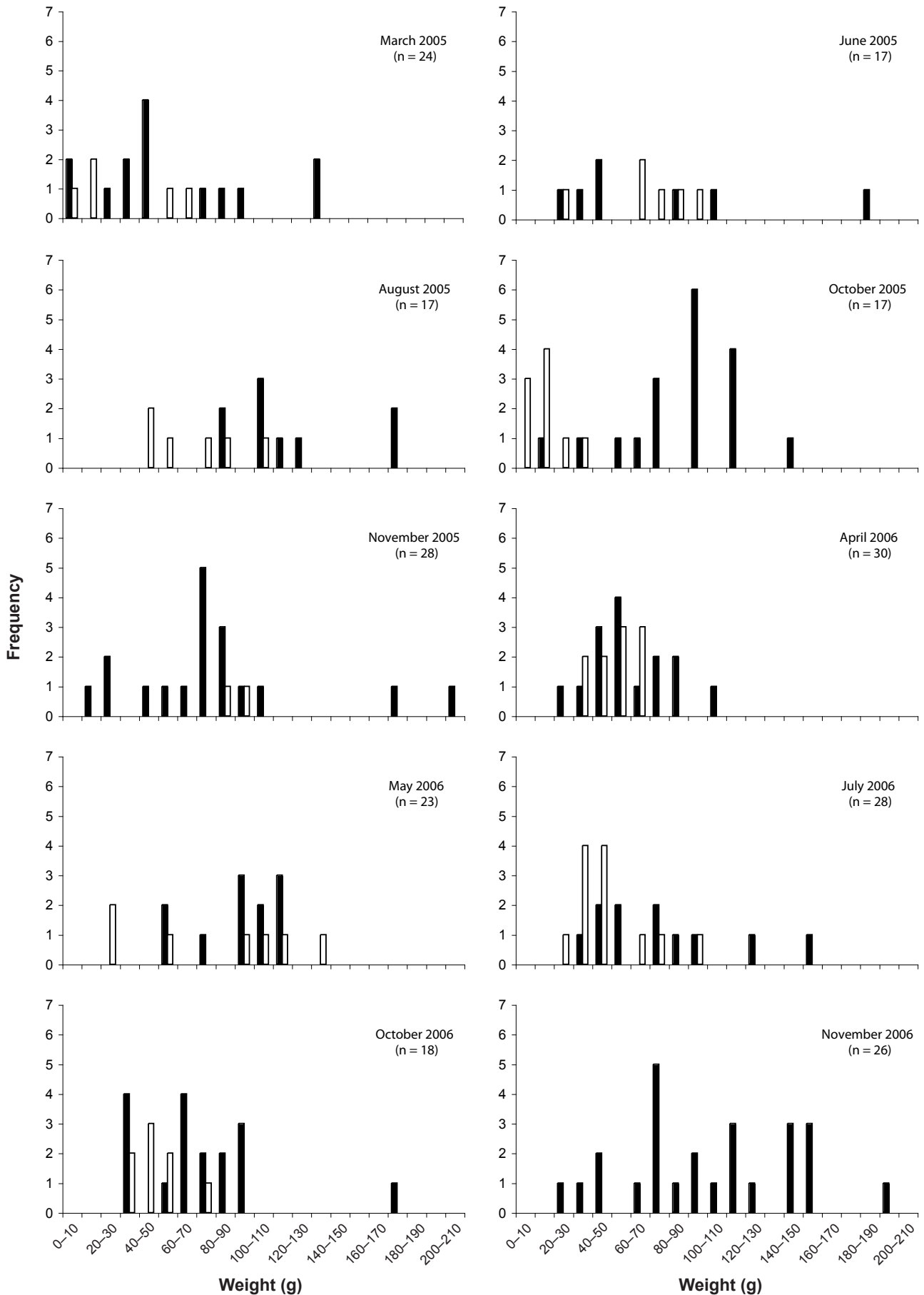


Figure 3. Weight frequency distribution of *Holothuria hilla* over 20 months. Whole individuals (black) and fission products (white). Upper size limit for each category given.

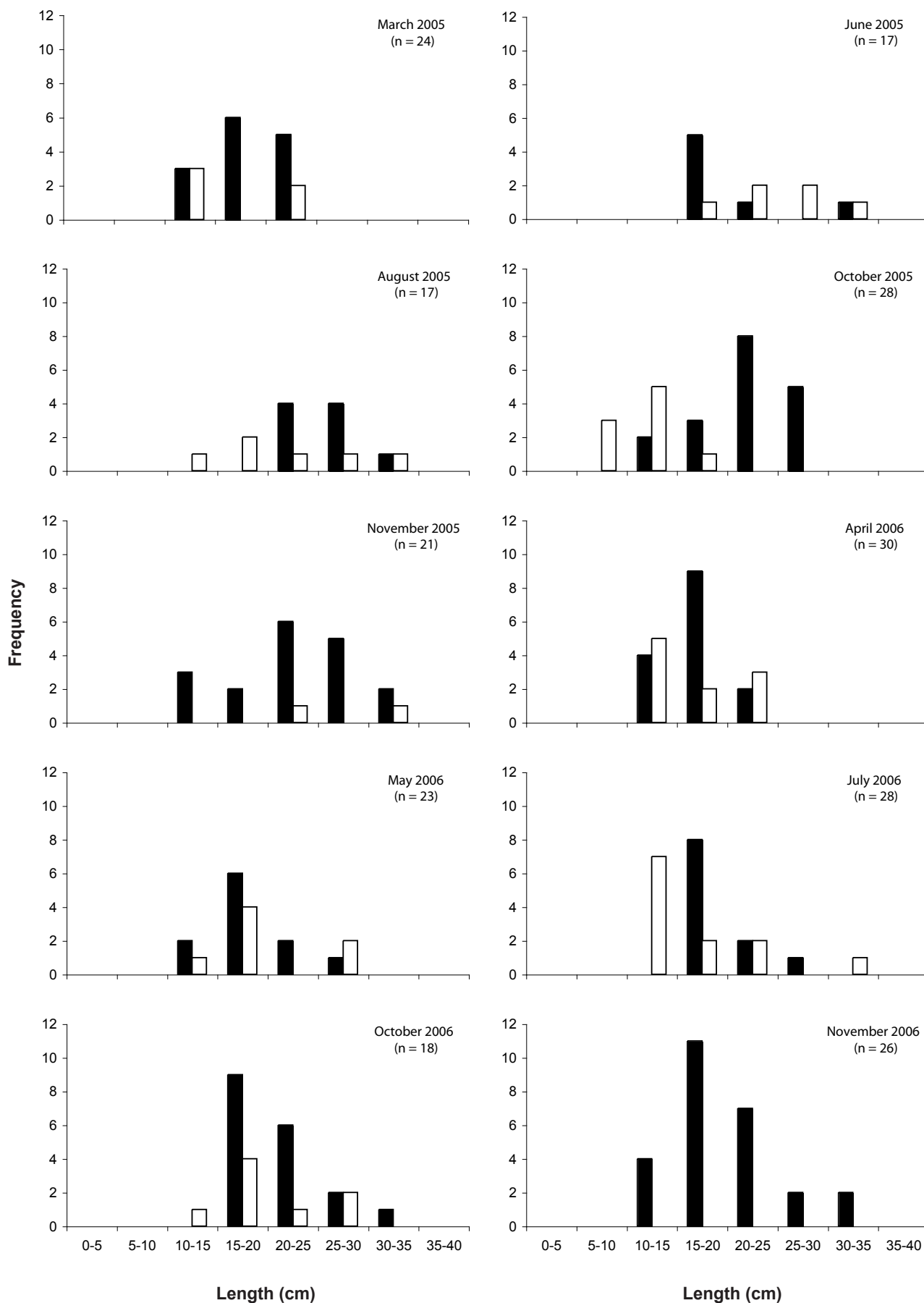


Figure 4. Length frequency distribution of *H. hillia* over 20 months. Whole individuals (black) and fission products (white). Upper size limit for each category given.



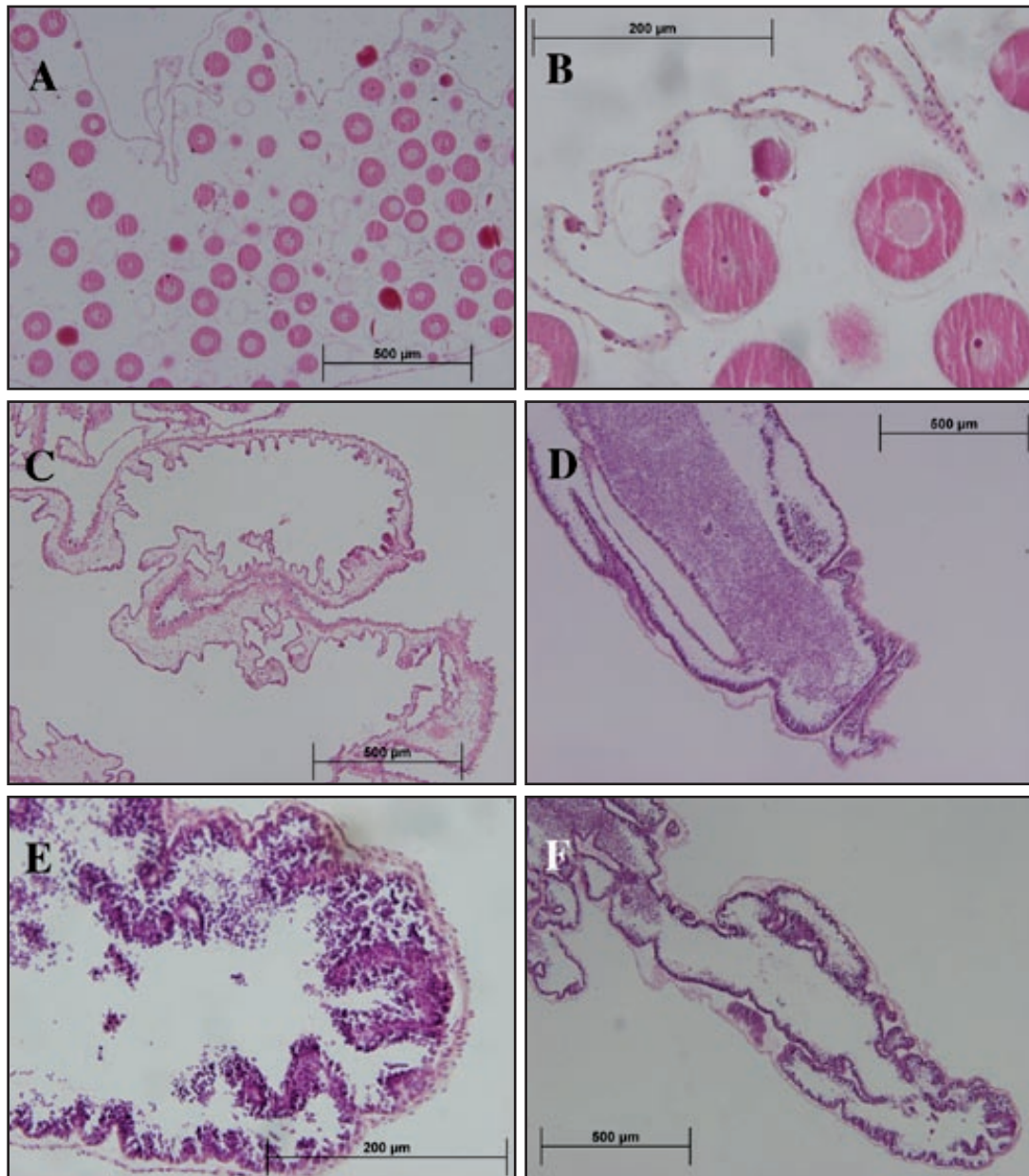


Figure 5. *Holothuria hilla*.

A, B: Spent ovaries; shrinkage of tubules occurring and few oocytes (O) present.  
C–F: Spent and indeterminate specimens.

a role in maintaining populations of several Indo-Pacific holothuroids by compensating for mortality and migration (Ebert 1978; Harriott 1982; Chao et al. 1994; Uthicke 2001). This may also be the case for the *H. hilla* population at OTI, but data on population density over time are required to address this.

The mean weight of the population of *H. hilla* increased from March to November in both years. Because fission in *H. hilla* occurs over a long period of time (up to eight months) it is not clear if this weight increase was due to regeneration post one fission event in individuals. As suggested for other fissiparous holothuroids (Uthicke 2001), *H. hilla* may grow to a minimum length and weight size

before fission occurs. The approximate doubling in size as the *H. hilla* regenerate and grow post fission is similar to that seen for *H. difficilis* and *H. atra* at OTI and elsewhere (Lee et al. in review).

Fission appears to be suppressed in *H. atra* and *S. chloronotus* in the warmer months, perhaps in association with gonad development and a shift towards sexual reproduction. This may also be the case for *H. hilla*. However, in this study, the stage of maturation of the gametes of *H. hilla* could not be determined as one sample contained gametes remaining from spawning, or gametes on their way to becoming mature, and remaining samples were indeterminate or spent. A cursory look for gonads of *H. hilla* dur-

ing the fission season indicated that they were not present (Maria Byrne, Discipline of Anatomy and Histology, Bosch Institute, University of Sydney, pers. obs.). Fission products of *H. atra* have been known to contain gonads of all stages of development and have been proposed to regenerate two months after fission (Doty 1977; Uthicke 1997, 1998). Further studies would be required in order to understand the complete reproductive cycle of *H. hilla*.

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## First record of asexual reproduction of *Holothuria (Mertensiothuria) hilla* in a fringing reef at Reunion Island, western Indian Ocean

Thierry Hoareau<sup>1</sup>, Émilie Boissin, Chantal Conand<sup>2</sup>

*Holothuria hilla* — a relatively rare species on Reunion Island — has been observed under blocks of rubble on the reefs at Saint Leu and Etang Sale during the day (Conand and Mangion 2002; Conand et al. 2003). This species, formerly from the subgenus *Thymiosycia*, has been changed to *Mertensiothuria* (Samyn and Massin 2003).

Around 10 species of holothurians are known to be naturally fissiparous, and several belong to the genus *Holothuria* (*H. atra*, *H. leucospilota*, *H. edulis* and *H. parvula*). This note reports on the observation of asexual reproduction in *Holothuria hilla* at Reunion. Evidence of natural fissiparity had been previously observed in this species in June 2001, with an anterior specimen regenerating the posterior end (weight 22 g) and a posterior one regenerating with an anterior end (weight 32 g). Only one specimen of the species was observed at this date.

We report here the observations made in January 2008 at Etang-Sale, Reunion Island (21°16'10"S,

55°20'00"E). Despite the sampling effort (on a 100 m-transect on coral debris with coarse sand), only 12 specimens were found, and these were located in the first 30 minutes. The survey revealed only two specimens showing recent fission out of the 12 "normal" specimens found. These two specimens were found together under the same rock. One showed regeneration of the posterior part and the other of the anterior part (Figs 1B and C).

Because this species is usually rare, it is likely that the species has proliferated on this site by asexual reproduction from a few specimens. The size-frequency distribution shows the absence of juveniles and a unimodal shape (Fig. 2). Further genetic studies should help us to identify the possible founder effect (settlement of a new population) and the functioning of this low density population.

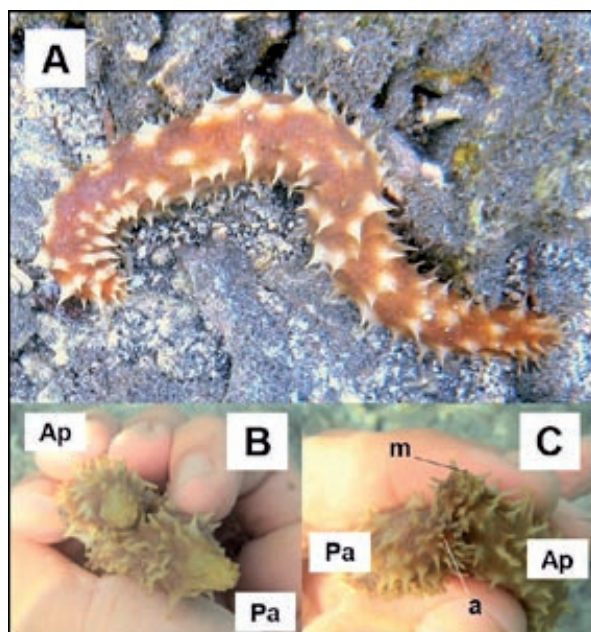


Figure 1

- 1A. *H. hilla* observed on the fringing reef of Etang-Sale (Reunion Island);  
 1B. Regenerating parts of the two specimens after fission;  
 1C. Conserved parts of the two individuals after fission. (Ap: Anterior individuals displaying regeneration of the posterior part; Pa: Posterior individuals displaying regeneration of the anterior part; m: mouth; a: anus).

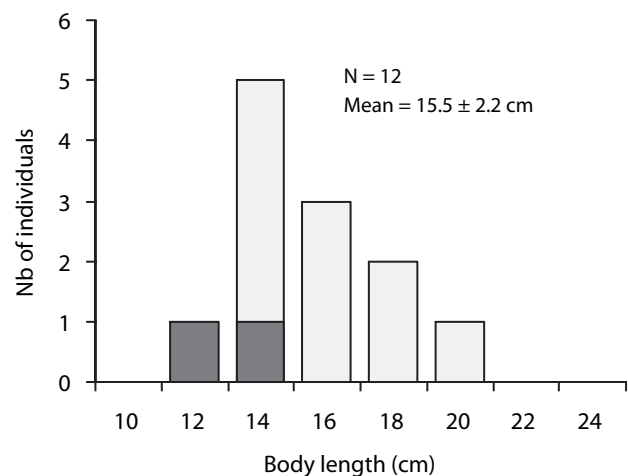


Figure 2. Length-frequency distribution of *H. hilla* on the fringing reef of Etang-Sale (Reunion Island); the dark part of the bars indicates the two regenerating individuals.

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## Burying and feeding activity of adult *Holothuria scabra* (Echinodermata: Holothuroidea) in a controlled environment

Svea Mara Wolkenhauer<sup>1</sup>

### Abstract

This study investigated the relationship between temperature and burying and feeding behaviour of adult *Holothuria scabra* (sandfish) within a diel cycle. Animals were kept in aquaria in a constant light regime (14 h light/10 h darkness) and temperature was reduced 1°C each day from 24°C to 17°C. A scoring system was used to categorise the animals' burial state and behaviour (e.g. burying, feeding, resting) at two-hourly intervals. Sandfish showed a distinct diel burying and feeding cycle, with most animals exposed and feeding between 13:00 h and 20:00 h, and most buried and inactive between 1:00 h and 9:00 h. Periods of being buried increased with decreasing temperature from 6.7 h per day at 24°C, to 14.5 h per day at 17°C. Feeding activity decreased from 9.8 h a day at 24°C, to 0.8 h per day at 17°C. Temperature was significantly positively correlated with both feeding and burying behaviour. Based on the results of this study, the most suitable time to conduct population surveys of *H. scabra* in the southern hemisphere would be during summer (December to February) from midday to late afternoon.

### Introduction

*H. scabra* show various cyclical patterns of burying, depending on their age (Battaglione 1999; Mercier et al. 1999; Mercier et al. 2000; Uthicke 2001; Yamanouchi 1939; Yamanouchi 1956). Juveniles, probably due to their higher risk of predation, are synchronised by day/night regimes, burying at sunrise and re-emerging at sunset (Mercier et al. 1999). *H. scabra*'s feeding activity can be somewhat independent of its burying cycle, in that exposed animals are not necessarily feeding, and burying animals may still ingest sediment (Mercier et al. 1999; Wiedemeyer 1992; Yamanouchi 1939; Yamanouchi 1956).

An understanding of burying activity is crucial to minimising errors in population and distribution surveys. Additionally, seasonal variation in burying and feeding activity may affect ecosystem function and bioturbation rates attributed to holothurians within their habitat. The aim of this study was to investigate a possible relationship between burying and feeding activity, and temperature of adult sandfish, while excluding other possible factors that may influence the animal's burying and feeding pattern such as tides, current and light.

### Methods

Six 100-L aquaria, each with 10 cm depth of substrate, were set up. Based on results from previous studies and personal observations (Wiedemeyer 1992; Wolkenhauer unpubl. data), this was an adequate sediment depth for allowing normal burying behaviour of adult *H. scabra*, since their anus is usually in constant contact with the water column to facilitate respiration.

Artificial lamps were placed over the aquaria to simulate natural summer light regimes (14 h light and 10 h darkness). Each of the six aquaria was stocked with one adult sandfish (~17 cm length, ~300 g wet weight) collected from Moreton Bay, southeastern Queensland, Australia.

Initial temperature was set to 24°C and subsequently, temperature was decreased one degree every day for a week until reaching 17°C at the end of the experiment.

The aquaria were monitored every two hours for seven days, and the activity of the animals was classified on each occasion as various combinations of burial state and behaviour (Table 1).

**Table 1.** Activity of *H. scabra* in aquaria classed as combinations of burial state and behaviour.

behaviour	burial state		
	fully buried	half buried	fully exposed
resting	1	2	3
burying		4	
emerging		5	
feeding levelled (on substrate)			6
feeding upright (on walls)			7
searching			8

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In order to prepare the data for statistical analysis, I converted scores of different activities of interest into binomial form (true/false) and analysed the responses using a generalized linear model (GLM) with binomial error structure. Each state (e.g. feeding/not feeding or buried/not buried) was therefore treated as a binary response and the probability of this behaviour occurring was estimated as a probability between 0 and 1. Furthermore, harmonic transformation of the time-of-day, using sine and cosine functions representing the daily feeding and burying cycles, were used as supplementary explanatory variables.

## Results

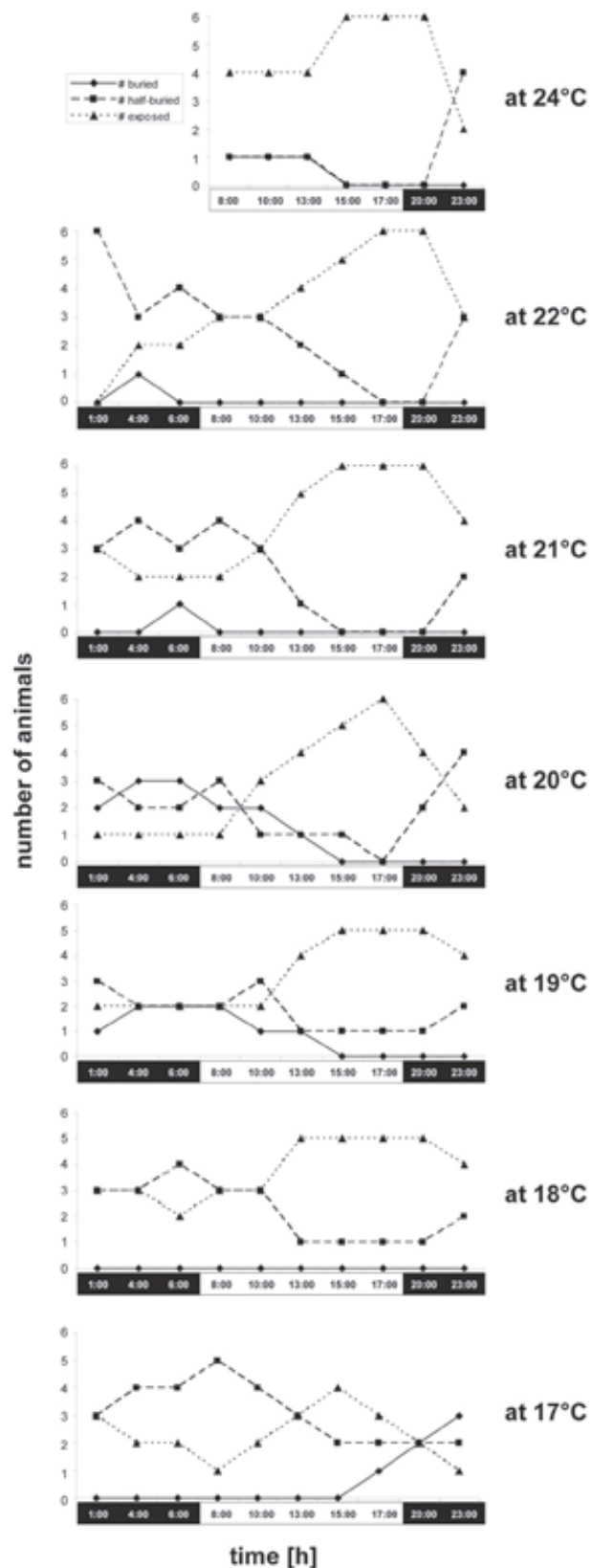
*Holothuria scabra* showed a distinct diel burying cycle (Fig. 1), with most of the animals exposed and active between the hours of 13:00 and 22:00 and most buried and inactive between 01:00 and 09:00. As experimental temperatures decreased, fewer animals were exposed and active, while more remained buried or half buried, showing a significant ( $p = 0.002$ ) correlation with temperature. However, the trend of burying during the day did not change, but rather the burial duration lengthened. This effect was particularly obvious in the morning (08:00–10:00), with only one animal out of six being buried at 24°C, compared to four out of six animals being buried when the temperature reached 17°C (Fig. 1).

There was a significant ( $p < 0.001$ ) correlation between feeding activity and temperature. Daily periods of feeding decreased by 9 h from 9.8 h at 24°C to about 0.8 h at 17°C.

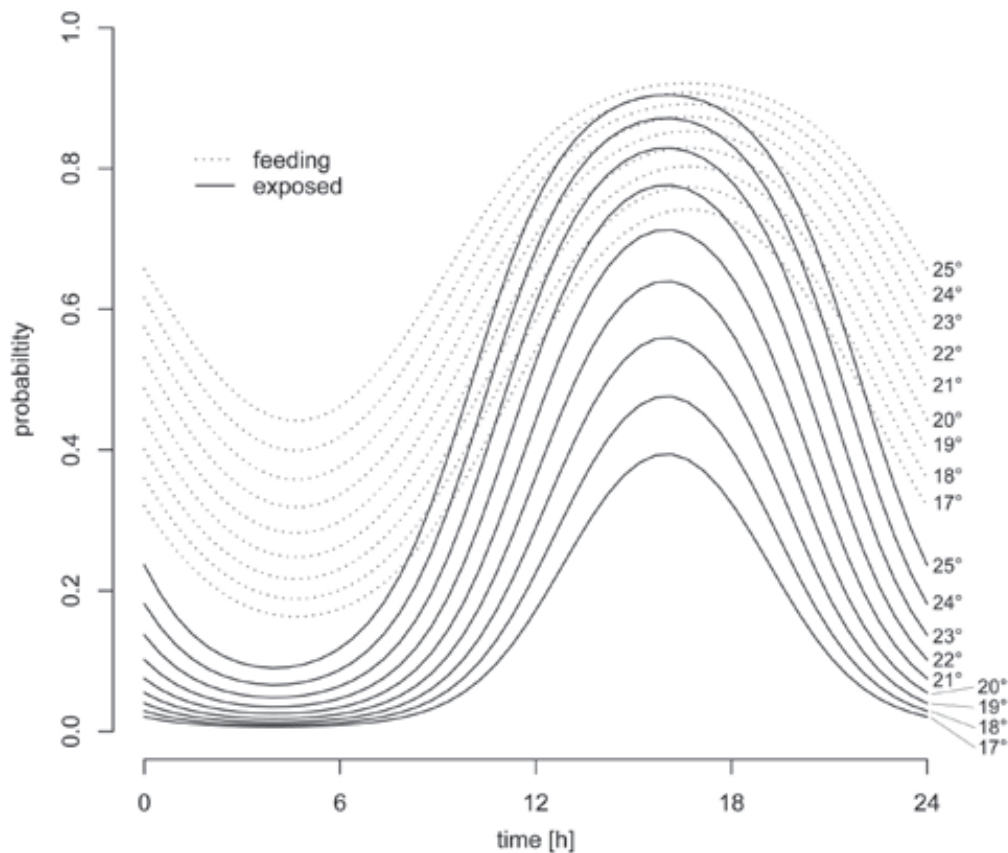
Modelling the daily feeding and burying cycle showed that the probability of feeding increased directly with increasing temperature, irrespective of time of day (Fig. 2). However, the probability of exposure increased only slightly with increasing temperature during the early hours of the morning, whereas during daylight, the amplitude as well as duration increased rapidly with increasing temperature (Fig. 2).

## Discussion

This study shows that adult *Holothuria scabra* have a diel burying cycle as described for juveniles (Battaglione et al. 1999; Mercier et al. 1999). Furthermore, the length of time spent buried shows a significant relationship to temperature. Purcell and Kirby (2005) also found more adult sandfish buried for longer periods during the day with decreasing water temperature. However, they did not specify any temperature range and did not investigate actual timeframes of the animals being buried based on a 24-hour cycle since the observations took place



**Figure 1.** Diel burying cycle of *H. scabra* with decreasing temperature. Open and solid bars on X-axis represent light and darkness.



**Figure 2.** Generalized Linear Model prediction of probability of feeding and burying behaviour (cos-sin function). Dotted line = probability of animals feeding, solid line = probability of animals being exposed. Numbers on the right represent the temperature in degrees Celsius for each line.

only during daylight hours. Mercier et al. (2000) found that most adult *H. scabra* on the surface did not follow their usual burying cycle when the water temperature was increased to more than 30°C.

Other factors that are known to cause sandfish to bury for prolonged periods of time include stress (Purcell et al. 2006), spring tides and strong currents (Skewes et al. 2000), predation (Dance et al. 2003), and desiccation or changes in salinity (Mercier et al. 2000). These factors might counteract or prolong the effect temperature has on their burying cycle in the wild. However, this study aimed specifically to exclude those variable factors to find a potential underlying pattern in response to temperature alone.

Further study is needed to determine how light and temperature interact, and if adult *H. scabra* have a potential tendency to reverse their burying cycle in accordance with reversed light regimes, overruling the temperature effect, as has been shown for smaller juveniles (Mercier et al. 1999).

Temperature also shows a significant decrease on the animal's time spent feeding. Studies on feeding behaviour of other echinoderms show similar effects with temperature (Hollertz and Duchêne 2001; Schinner 1993; Thompson and Riddle 2005). For example, Thompson and Riddle (2005) showed that sea urchins *Abatus ingens* increased their displacement activity with only one degree increase in temperature.

## Conclusion

My data indicate that observed differences in burying and feeding behaviour of adult *H. scabra* are strongly related to changes in water temperature. Hence, the ecosystem function of holothurians alters depending on seasons, and should be taken into account when establishing the ecological role of those animals within their habitat. These findings have implications for population surveys for this species when relying on visually counting animals. Surveys should be conducted at consistent diel and seasonal timing if results are to be compared with

previous data. Based on burying data presented here, I suggest the most suitable time to conduct population surveys on *H. scabra* would be during the summer from midday to late afternoon.

### Acknowledgements

This study was conducted as part of the 13<sup>th</sup> International Biology Workshop held on Stradbroke Island, Moreton Bay, Australia in February 2005. I would like to thank the Moreton Bay Research Station (University of Queensland) for the opportunity to use their facilities, and am grateful for their staff's extraordinary support. Furthermore, I would like to thank Dr Matthew Browne for his valuable assistance with the statistical analysis. This study is part of my PhD thesis entitled, "Impact of removal – A case study on the ecological role of the commercially important sea cucumber *Holothuria scabra*", and is funded through the Daimler-Benz Foundation and CSIRO Marine and Atmospheric Research. The study will be published in full as part of a special edition of the journal "Memoirs of the Queensland Museum" in mid-2008.

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## Distribution and abundance records updated for *Thelenota rubralineata* in the western Pacific, with notes on the “vacant niche” hypothesis

David J.W. Lane<sup>1</sup>

### Introduction

*Thelenota rubralineata* at the time of its formal description in 1991 (Massin and Lane 1991) has generally been considered to be rare over its distribution range. More recent reports indicate that this species occurs in significant numbers at some localities such as the Bunaken–Manado Tua Marine Reserve in north Sulawesi (Lane 1999a), Solomon Islands (Kinch 2005), Zaragosa Island, Cebu, Philippines (Alexander Kerr, pers. comm.), and that in the Solomon Islands at least, it is exploited — to an as yet unquantified extent — as a beche-de-mer resource (Kinch 2005). Rarity and vulnerability have prompted concerns over the conservation status of this spectacular member of the echinofauna (Lane 1999b; Kinch 2005), but moves to list this, or indeed most other threatened beche-de-mer species, under CITES (Anon 2002) are as yet unsuccessful, largely because the global status of these species is currently considered data deficient, and species and product identification issues remain (Sant 2006).

This short note updates the known distribution records for *T. rubralineata* and documents sightings — by the author, through personal communications to the author, in the published literature, and from underwater photograph archives on the Internet (Fig. 1 and Table 1). I also address, but do not presume to fully answer, the following questions:

- (a) Is *T. rubralineata* a rare species?
- (b) Is the increased number of sightings a consequence of: 1) diving forays further afield and/or to deeper depths by diving scientists and underwater photographers, 2) an increase in population recruitment, 3) a migration to shallower depths on reef slopes, or 4) a combination of any or all of these factors?
- (c) If population numbers are indeed increasing on shallow reef slopes, could this be in response to the existence of a “vacant niche” resulting from overexploitation (Conand 1998; Uthicke and Benzie 2000; Uthicke et al. 2004) of other members of the beche-de-mer macro-

fauna, and their delayed or persistent lack of population recovery?

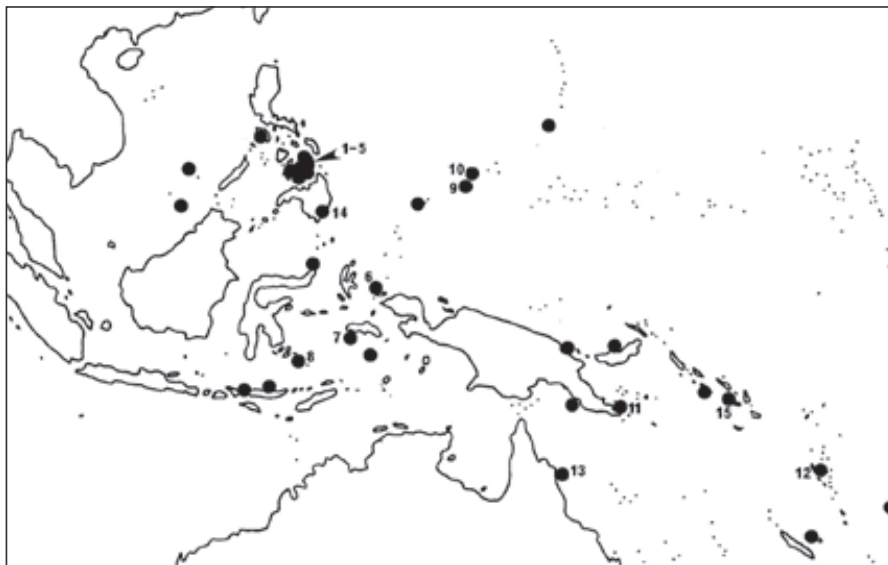
### Results and discussion

Updated distribution data (Fig. 1 and Table 1) indicate many more sites, since the late 1990s (Lane 1999a), where *T. rubralineata* has been reported. These sites however, are all within the known distribution range, which, as noted by Kinch (2005), covers much of the “coral triangle” of maximum marine biodiversity, as well as the adjacent region of the tropical western Pacific Ocean. Delineation of the zone maximum marine biodiversity is currently the focus of much debate and research (Hoeksema 2007) but it is interesting to note that extension of the range for *T. rubralineata* to the southeast through Melanesia (Fig. 1.) concurs with the suggestion (Hoeksema pers. comm.) that for corals there may be need to extend the peak marine biodiversity zone to the southeast. Unlike its congeners, *T. ananas* and *T. anax*, which extend their range to the western Indian Ocean, *T. rubralineata* has not been reported from the Indian Ocean. A recent origin for this species within the maximum marine biodiversity triangle is a distinct possibility but this is currently speculative as molecular clock data on the phylogeny of the genus are not yet reported and details of the reproductive biology, particularly the duration of planktonic larval life and dispersal capability, are unknown.

In addition to the above-mentioned reports of *T. rubralineata* occurring in significant numbers and densities, there are also a number of other locations where multiple sightings have been recorded (Table 1). Three individuals were reported close together on 13 December 2007 at a depth of 20–25 m at Yeffam Island, northwest Pulau Keruo, Rajah Ampat, West Papua, and another on 2 December 2007 at a similar depth at southwest Kri Island nearby (Bert Hoeksema pers. comm. and photographs). Multiple sightings of *T. rubralineata* have been made by the author at Espiritu Santo, Vanuatu, with records from three sites (south Aore

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**Figure 1.** Distribution of *Thelenota rubralineata* (presence indicated by solid circles). Un-numbered sites are from Lane (1999 a,b). Numbered sites represent new records by the author, records from personal communications to the author, data from recent publications, and photographic records in Internet archives. The site numbers cross reference to Table 1, which provides details of records and sources.

**Table 1.** Data records for recent sightings (mainly after 1997) of *Thelenota rubralineata*.

Site No.	Location	Number recorded	Date	Depth (m)	Source
1	Tulang Is, Camotes Islands, Philippines	1	2003, 2005	27	<a href="http://www.poppe-images.com/images/search_results.php?category=sea%20cucumber&amp;species=Thelenota%20rubralineata">http://www.poppe-images.com/images/search_results.php?category=sea%20cucumber&amp;species=Thelenota%20rubralineata</a>
2	Panglao, Philippines	1	2006	34	
3	Mactan Is., Philippines	1	2006	37	
4	Cuatro Islas, Leyte, Philippines	1	?	20+	Schoppe 2000
5	Zaragosa Is., Cebu, Philippines	Abundant	2006	6-30+	Alexander Kerr, pers. comm; Kerr et al., 2006
6	Rajah Ampat, West Papua	4	2–13 Dec 2007	20-35	Bert Hoeksema, pers.comm.
7	Ambon, Indonesia	2	1996	20-30	
8	Wakatobi Is, Tukangbesi Islands, SE Sulawesi	1	2006	?	<a href="http://paulsim.myphotos.cc/Photo%20Pages/Indonesia/Sulawesi/Wakatobi/House%20Reef/thele.htm">http://paulsim.myphotos.cc/Photo%20Pages/Indonesia/Sulawesi/Wakatobi/House%20Reef/thele.htm</a>
9	Yap, Caroline Islands Micronesia	1	2007?	60+	Brian Greene, cited in Kerr et al. 2007
10	Ulithi Atoll, Caroline Islands, Micronesia	1	?	ca 25	Alexander Kerr, pers. comm. (data from Vanessa Fread)
11	Milne Bay Province	4	2002	0-20	Skewes et al. 2002
12	Aore Is., Áesé Is. & Palikaulo Bay, Espiritu Santo, Vanuatu	8	14–30 Sept 2006	30-35	Records of the author and Willem Renema
13	Ribbon Reef, northern Great Barrier Reef, Australia	1	?	?	<a href="http://www.reef.crc.org.au/publications/annualreport/annrep98_99.pdf">http://www.reef.crc.org.au/publications/annualreport/annrep98_99.pdf</a>
14	N. Samal Is., Mindanao, Philippines	2	Nov 2006	?	Steve Purcell, pers. comm.
15	Bonegi, Guadalcanal, Solomon Islands	3	2006	18-30	Ramohia 2006

Island, 35 m depth, 14 September 2006; Palikaulo Bay, 30 m<sup>+</sup>, 23 and 30 September 2006; northwest Áesé Island, 30 m depth, 29 September 2006), and up to four individuals were seen during a single dive (northwest Áesé Island). Two individuals were reported and photographed in November 2006 from north Samal Island, near Davao, Mindanao, Philippines (Steve Purcell, WorldFish Center, pers. comm.). At Bonegi, Guadalcanal in the Solomon Islands, three individuals were found in a single “deep” transect (18–30 m) during marine fishery resource assessments (Ramohia 2006). However, none were noted off-transect or in any of the other 62 deeper transect sites. Other reports similarly indicate infrequent sightings of *T. rubralineata* during intensive sea cucumber stock assessments. For example, large-scale surveys (1126 dives covering an area of 256,000 km<sup>2</sup>) throughout Milne Bay Province (Skewes et al. 2002) recorded just four individuals for this species and at Yap a stock assessment and biodiversity inventory records a single individual at 60 m<sup>+</sup> depth (Brian Greene, cited in Kerr et al. 2007).

Thus, it appears that *T. rubralineata*, an unmistakable and not easily overlooked member of the macrofauna that is non-cryptic in its behaviour (as an adult at least), occurs widely over its range but is patchy in distribution and rare at many localities. Perhaps the highest densities recorded thus far are at Bunaken Island, northern Sulawesi (Lane 1999a,b), with a density of 17 individuals per 3750 m<sup>2</sup>, equating to 45 individuals per ha. It is possible that localised aggregation of this species at the Bunaken site is the consequence of eddy current entrainment of larval recruits behind the promontory of this boomerang-shaped island. However, since aggregations occur elsewhere, an alternative explanation is possible. Large aspidochirote sea cucumbers are generally overfished and severely depleted throughout much of the tropical western Pacific (Conand 1998; Uthike and Benzie 2000; Uthicke et al. 2004) and it is possible that new juvenile recruits of *T. rubralineata* or migrants from deeper water are colonizing a vacant niche on shallow reef slopes. At the Bunaken–Manado Tua Marine Reserve, populations of high and medium value commercial beche-de-mer species remain low, apparently a legacy of earlier exploitation (Lane 1999a). During a week-long scuba search by the author at the Bunaken Reserve in December 2007, not a single specimen of *Thelenota ananas* or *Holothuria whitmaei* was seen; only two *Holothuria fuscogilva* were found and other beche-de-mer species were infrequently encountered. Thus, although hard quantitative data are lacking, recovery of commercial beche-de-mer stocks at this now protected marine reserve near Manado is imperceptible. The food resource for benthic-feeding aspidochirote sea

cucumbers on reef slopes thus appears to be underutilized at this location and probably also on fished-out reef slopes elsewhere.

The December 2007 visit to Bunaken Island revealed the continued presence of significant numbers of *T. rubralineata* at the site surveyed 10 years previously in 1997 (Lane 1999a,b). Six individuals were sighted during a single dive on 20 December 2007 over a depth range of 15–30 m. None were measured but all were adult and of similar size to those measured in 1997. Since juveniles or intermediate sizes (less than 1 kg) were not observed either in 1997 or 2007, and since the population appears to be localized, the question of individual longevity arises. Photographs of numerous individuals were taken in 1997 and a repeat of this exercise, in collaboration with Faculty of Fisheries and Marine Science, Sam Ratulangi University, Manado, is anticipated for early 2008 in the hope of matching individuals, on the basis of the not unreasonable assumption that the complex fingerprint-like patterns of crimson lines are stable over time.

### Acknowledgements

I thank the many colleagues who kindly sent me unpublished distribution data or alerted me to recent sea cucumber stock assessment reports.

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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.

## Field observations of sea cucumbers at North Male Atoll in the Maldives

Nyawira Muthiga<sup>1</sup>

### Introduction

The commercial exploitation of sea cucumbers began recently in the Republic of the Maldives, starting in the mid-1980s and dramatically increasing to 745 t in 1990 (Conand and Bryne 1993). Management measures — including a ban on using scuba — were introduced in 1993 because of dramatic declines in sea cucumber catches (Ahmed et al. 1996). Very little information is available on sea cucumber resources in the Maldives. Joseph (1992), in a review of the sea cucumber fishery for the Bay of Bengal Programme, reported that eight species had been identified from Baa, Haa Alifu and Haa Dhaalu atolls during investigations carried out in 1988 under a UNDP/ESCAP-sponsored Maldives/China pilot study in the Male atolls. Joseph (1992) provides the relative abundance of species that are collected for commercial purposes. The relative abundance is based on information provided by fishers during a study of the ecology and reproductive biology of *Holothuria fuscogilva* (Reichenbach 1999).

The present study describes the findings of a sea cucumber survey that was conducted on the coral reefs of the islands of North Male Atoll. The study was part of a larger survey (McClanahan 2005) that assessed the coral reef recovery after the 1998 bleaching event, which caused widespread mortality of corals (McClanahan 2000).

### Materials and methods

The survey of the abundance and distribution of sea cucumbers was carried out at eight islands around the center of North Male Atoll (Table 1). At each location, 40-minute searches were made along a visual transect parallel to the reef crest, using scuba, snorkel or walking, depending on depth. Surveys were carried out by examining the benthos and searching under crevices and rocks in the lagoon, reef crest and reef edge, and identifying and recording all sea cucumbers that were encountered.

In addition, the abundance of sea cucumbers was estimated in 50 m × 2 m belt transects, laid paral-

lel to the shoreline in the reef lagoon, reef crest and reef edge at Vabbinfaru, a site adjacent to the Banyan Tree Resort and Spa. Although the reefs of Vabbinfaru were not officially designated as protected, conservation activities by the Banyan Tree Resort and Spa resulted in no fishing occurring on these reefs; hence, the area effectively functioned as a protected area. The characteristics of the reef, including the benthic cover of the main ecological components of the substrate, were derived from data collected using line transects during the larger coral reef surveys (Table 1).

### Results

Turf algae dominated the benthic cover, followed by hard coral and coralline algae (Table 1). There was a very low percentage (> 6%) of sand, soft coral, sponge and fleshy algae in the substratum (McClanahan 2005). The average hard coral cover at all sites was 20% of the substratum. The sites at Angsana and Vabbinfaru had the highest hard coral cover, and the Furana site had the lowest hard coral cover. This is significantly higher than the 8% reported by McClanahan in 2000, indicating that there has been some recovery since the 1998 bleaching.

Fourteen species of sea cucumber were encountered during the survey (Table 2). Of these, two (*Holothuria nobilis* and *Thelenota ananas*) were of high and medium commercial value (respectively), while the rest were of low commercial value. Six species were recorded at Lohi Fushi, Vabbinfaru and Angsana, five at Thulgaari, and one each at Furana and Kalhuga. No sea cucumbers were encountered during searches at Rasfari and Magaari. The number of additional species that were encountered during each 40-minute search (Fig. 1) showed an increasing trend and did not approach a plateau.

The total number of individual sea cucumbers encountered at all the sites was 233 within a search period of 8.7 hours. The overall density was  $17.93 \pm 16.09$  ind per 40-min search. The density of sea cucumbers was highest at the Vabbinfaru where 92% of all individuals counted occurred.

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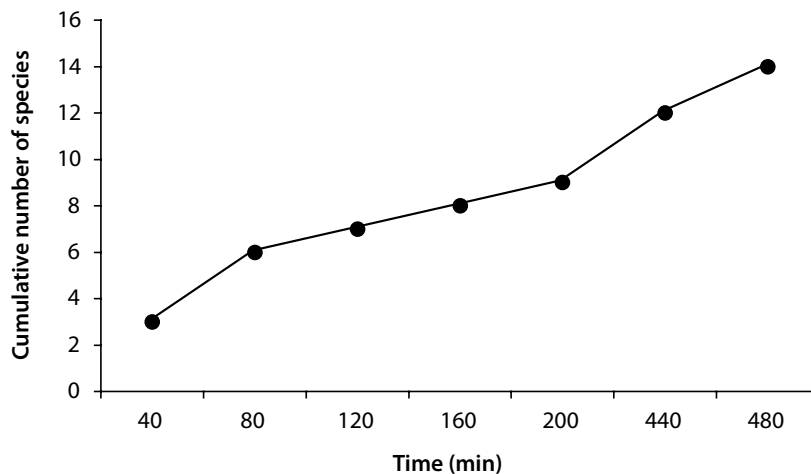
**Table 1.** Survey site locations and habitat characteristics. The benthic substrate of the main ecologically important benthic components are reported as the average per cent cover (SEM) of three 10 m line transects measured at each site (modified from McClanahan 2005).

Location	Hard coral (%)	Turf algae (%)	Fleshy algae (%)	Coralline algae (%)	Sand (%)
Lohi Fushi	10 (2.4)	80.7 (1.3)	0	7.0 (1.1)	1.5 (0.7)
Vabbinfaru (E)	14.5 (2.9)	67 (3.4)	0	17.6 (0.6)	0
Vabbinfaru (W)	39.6 (4.1)	41.5 (2.2)	0.1 (0.1)	18.4 (3.9)	0
Rasfari	20.7 (8.3)	64.3 (10.6)	0	5.3 (1.8)	6.8 (3.5)
Furana	4.9 (1.7)	70.1 (6.6)	0	23.8 (5.1)	0.4 (0.4)
Angsana (E)	29.2 (7.7)	64.8 (11)	0	5 (3.6)	0.8 (0.8)
Angsana (W)	43.2 (2.0)	35.3 (2.7)	0	20.8 (3.8)	0.5 (0.5)
Thulgaari	12.2 (3.4)	56.7 (4.8)	0	29.0 (1.6)	0
Kalhuga	20.7 (3.7)	46.4 (6.4)	0	23.0 (4.9)	4.1 (4.1)
All sites	20 (2.4)	60.5 (2.8)	0	15.7 (1.6)	2.5 (0.9)

**Table 2.** Sea cucumber species recorded during the survey of North Male and species reported by Joseph (1992) and Reichenbach (1999).

Species	Location						
	Lohi Fushi	Vabbinfaru	Furana	Angsana	Thulgaari	Kalhuga	James (1992) Reichenbach (1999)
<i>Actinopyga echinites</i> (Jaeger 1833)							•
<i>Actinopyga lecanora</i> (Jaeger 1833)					•		.*
<i>Actinopyga mauritiana</i> (Quoy & Gaimard 1833)	•		•		•		.*
<i>Actinopyga miliaris</i> (Quoy & Gaimard 1833)				•			•
<i>Actinopyga</i> sp.							•
<i>Bohadschia argus</i> Jaeger 1833							•
<i>Bohadschia atra</i> Massin et al. 1999		•		•			
<i>Bohadschia graeffei</i> (Semper 1868)		•					•
<i>Bohadschia marmorata</i> (Jaeger 1833)							.*
<i>Bohadschia vitiensis</i> (Semper 1868)		•					
<i>Holothuria atra</i> Jaeger 1833	•	•		•			.*
<i>Holothuria edulis</i> Lesson 1830					•		•
<i>Holothuria hilla</i> Lesson 1830		•					
<i>Holothuria leucospilota</i> Brandt 1835	•	•					.*
<i>Holothuria fuscogilva</i> Selenka 1867							•
<i>Holothuria (Microthele) fuscopunctata</i> Jaeger 1833							•
<i>Holothuria nobilis</i> (Selenka 1867)	•						.*
<i>Pearsonothuria graeffei</i> (Semper 1868)	•	•		•	•		•
<i>Stichopus chloronotus</i> Brandt 1835	•	•		•			.*
<i>Stichopus hermanni</i> Semper 1868							•
<i>Thelenota ananas</i> (Jaeger 1833)				•			•
<i>Thelenotaanax</i> H.L. Clark 1921					•	•	•
<i>Synapta maculata</i>							.*

\* indicates species recorded in 1988 during a UNDP project



**Figure 1.** Species cumulative curve for sea cucumbers recorded at all sites during 40-minute searches.

**Table 3.** Sea cucumber abundance in the survey. Relative abundance is reported as the per cent occurrence of each species relative to the total number of individuals encountered at all sites.

Species	Location						Relative abundance (%)
	Lohi fushi	Vabbinfaru	Furana	Angsana	Thulgaari	Kalhuga	
<i>Actinopyga lecanora</i>	1				1		0.43
<i>A. mauritiana</i>			1		1		1.29
<i>A. miliaris</i>				1			0.43
<i>Bohadschia atra</i>		1		1			0.86
<i>B. vitiensis</i>		1					0.43
<i>Holothuria atra</i>	1	100		1			43.78
<i>H. edulis</i>					1		0.43
<i>H. hilla</i>		1					0.43
<i>H. leucospilota</i>	1	1					0.86
<i>H. nobilis</i>	1						0.43
<i>Pearsonothuria graeffei</i>	1	10		1	1		5.58
<i>Stichopus chloronotus</i>	1	100		1			43.78
<i>Thelenota. ananas</i>				1			0.43
<i>T. anax</i>					1	1	0.86

The abundance of individual species was very variable (Table 3), ranging from 0–100 ind per 40-min search. *Holothuria atra* and *Stichopus chloronotus* were the most abundant species, with a relative abundance of 43.78% each, followed by *Pearsonothuria graeffei* (5.58%) and *Actinopyga mauritiana* (1.29%). *H. atra* and *S. chloronotus* were also among the most frequently observed

species along with *P. graeffei* and *A. mauritiana* (Table 3). There was no clear relationship between any of the benthic substrate components and the number of species or, the density of sea cucumbers. High numbers of species were found in sites of both high hard coral cover (Vabbinfaru and Angsana) and low hard coral cover (Lohi Fushi and Thulgaari).

At Vabbinfaru, 10 belt transects were laid in the reef lagoon, reef crest and reef edge. Four species of sea cucumbers were counted in these transects (Table 4). Of the four species encountered, there were significantly more *H. atra* ( $8.4 \pm 3.6$  ind  $100 \text{ m}^{-2}$ ) than the other three species observed. There were also more individual sea cucumbers counted in the reef lagoon ( $7.38 \pm 4.51$  ind  $100 \text{ m}^{-2}$ ) than on the reef crest and reef edge, although this difference was not significant between reef habitats (Table 4). Approximately 70% of the *H. atra* recorded were observed in the lagoon, while all *P. graeffei* encountered were on the reef edge.

## Discussion

The sea cucumber resources of the Maldives are poorly studied and the available information consists of publications and reports mainly concentrating on the sea cucumber fishery and a study on the ecology and reproduction of *H. fuscogilva* (Joseph 1992; Conand and Bryne 1993; Ahmed et al. 1996; Reichenbach 1999). The present study adds to data on sea cucumber diversity and distribution in the Maldives. The survey recorded eight species that were reported in Joseph (1992) and four species that have not previously been recorded in the Maldives: *Actinopyga miliaris*, *Bohadschia atra*, *B. vitiensis* and *Holothuria hilla*. Two species previously reported by Joseph (1992), *Bohadschia marmorata* and *Stichopus maculata*, were not encountered in the current survey; the former is probably *B. atra* but it is difficult to verify this identification because no samples were collected. The diversity of sea cucumbers in the present study is lower than the 75 species reported by James (1989) in the shallow waters of the seas around India. The cumulative species curve of the individuals encountered is an upward trajec-

tory, which indicates that additional surveys need to be carried out to get a more complete species list for the Maldives. In general, most of the species encountered on the reefs of North Male Atoll during the present survey are also common elsewhere throughout their range (Clark and Rowe 1971).

Joseph (1992) reported that the most abundant species were *Holothuria atra*, *H. leucospilota* and *Actinopyga Lecanora*, while *H. atra* and *Stichopus chloronotus* were the most common and most abundant sea cucumbers in the current survey. These species are also the most common sea cucumber species in the western Indian Ocean (Conand and Muthiga 2007). Reichenbach (1999) reported that *H. fuscogilva* was the dominant species on the lagoon floor between islands, with a relative density ranging between 70% and 94.9%. *H. fuscogilva* was not encountered in this study, possibly due to the focus on shallow reef habitats. According to Reichenbach (1999), *H. fuscogilva* recruits onto shallow seagrass beds and moves to the lagoon floor in deeper waters prior to sexual maturity. Reichenbach (1999) also noted much lower abundances of *H. fuscogilva* at North Male Atoll than at Laamu Atoll, and attributed this to fishing pressure. Because *H. fuscogilva* occurs in deeper waters, scuba is the main method of collection; however, according to Ahmed et al. 1996, the ban on using scuba for collecting sea cucumbers in the Maldives was not effective. Fishing could therefore potentially have been one of the factors affecting the lack of *H. fuscogilva* in the present survey.

Species distribution was patchy and showed no geographic pattern across the atoll, although more individuals were found on the western sides of Vabbinfaru reef, which also has higher coral cover. Although the number of species varied between

**Table 4.** Sea cucumber density in  $100 \text{ m}^2$  belt transects in the reef lagoon, reef crest and reef edge at Vabbinfaru.

Habitat	Mean $\pm$ SEM	Comparison	P value
Reef lagoon	$7.38 \pm 4.51$	Between habitats	0.044 *
Reef crest	$3.06 \pm 0.95$		
Reef edge	$1.64 \pm 1.04$		
<i>B. atra</i>	$0.3 \pm 0.15$	Between species	0.164 ns
<i>H. atra</i>	$8.4 \pm 3.60$		
<i>P. graeffei</i>	$2.7 \pm 1.41$		
<i>S. chloronotus</i>	$2.5 \pm 1.03$		

\* Significant at  $p = 0.05$

sites, there was no significant difference in species richness between sites. Sea cucumber density was generally low, and varied between sites, which is also common in other areas in the Indo-Pacific (Conand and Muthiga 2007). There were, however, significantly more individuals in the reef lagoon than on the reef crest or reef edge, which is also the case in other western Indian Ocean sites (Muthiga et al. 2007). The density of sea cucumbers was significantly higher at Vabbinfaru, where conservation activities have resulted in significant fishing reduction. The low number of commercial species may be an indication that the ban on using scuba is not effective, as reported by Adam (2006). Because there are so few previous studies with which to make comparisons, it is difficult to make reliable recommendations. However, it is suggested that monitoring should be increased and enforcement of the current ban on using scuba should be maintained and improved.

### Acknowledgements

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## Pacific sea cucumber dataset from the Secretariat of the Pacific Community, Reef Fisheries Observatory

*Kim Friedman<sup>1</sup>*

The Reef Fisheries Observatory at the Secretariat of the Pacific Community is currently in the final stages of a European Union-funded research programme (PROCFish-Coastal and COFish), which has been examining coastal reef fisheries in 17 countries and territories across the Pacific since 2002. This work entailed a multidisciplinary assessment of fish, invertebrates and socioeconomic factors, at a minimum of four sites per country, to identify active fisheries (using a mixture of visual censuses, creel surveys and closed-structure questionnaires). A major part of this work focused on sea cucumbers and the importance of these commercial inshore resources to coastal communities (see Figs. 1 and 2).

The diversity and abundance of invertebrate species, including sea cucumbers, were independently determined using a range of survey techniques, including broad-scale assessment (using a “manta tow”) and finer scale surveys of shallow water environments (day and night assessments of lagoon and barrier reef) and deeper water environments (lagoon floor). The invertebrate assessment team, like the fish team, dived for approximately a week at each site, and collated a wide-ranging series of distribution and density estimates with related

habitat descriptors, for sea cucumber stocks under a range of fishing pressures. These results provide the first opportunity to make a truly comparable assessment of sea cucumber stock status across the Pacific region (see example of one site’s records in Table 1).

As we have mostly completed the in-water surveys, we are now consolidating and analysing data, and anyone wishing to access or add to the dataset, in the interest of delivering the best outcomes possible for our understanding of these fisheries, is welcome to contact the scientist in charge of these assessments, Dr Kim Friedman ([kimf@spc.int](mailto:kimf@spc.int)).

We are especially interested in contrasting the Pacific experience with information from pristine or highly impacted fisheries. Any data from well-protected reserves or extremely overfished sites would help to give added contrast to the Pacific situation. We hope to bring a novel and informative series of overviews to the attention of managers and researchers in 2008 and 2009, and will be these reports and papers available in the year ahead.



**Figure 1.**  
A community bringing wet sea cucumbers to agents in Vitu Levu (Fiji Islands).



**Figure 2.**  
A sea cucumber fisherman processing his catch in Wallis (Wallis and Futuna).

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Table 1. Sea cucumber species records from an example PROCFish site.

Species	Common name	Comm. value <sup>(5)</sup>	Broad scale transects (n = 72)			Reef benthos (n = 22), and soft benthos (n = 13) stations			Other stations Reef front = 9 RF Reef slope = 6 MOP			Other stations scuba lagoon deep = 6 Ds Night search = 2 Ns			
			D <sup>(1)</sup>	DwP <sup>(2)</sup>	Pp <sup>(3)</sup>	D	DwP	PP	D	DwP	PP	D	DwP	PP	
<i>Actinopyga echinites</i>	Deepwater redfish	M/H				16.0	52.1	31 SBt							
<i>A. lecanora</i>	Stonefish	M/H				1.9	41.7	5 RBt							
<i>A. mauritiana</i>	Surf redfish	M/H				3.2	41.7	8 SBt							
<i>A. miliaris</i>	Blackfish	M/H	0.4	15.7	3	3.8	41.7	9 RBt	5.2	11.8	44 RF				
<i>A.x.</i>	No name as yet	M				3682.7	6839.3	54 SBt	0.4	3.9	11 RF	0.4	2.4	2.4	17 Ds
<i>Bohadschia argus</i>	Leopardfish	M	24.3	60.3	40	41.7	183.3	23 RBt	0.9	3.9	22 RF	1204.4	2408.9	50 Ns	
<i>B. similis</i>	False sandfish	L				12.8	166.7	8 SBt	5.1	30.3	17 MOP	13.3	26.7	50 Ns	
<i>B. vitiensis</i>	Brown sandfish	L				496.8	1291.7	38 SBt				75.6	151.1	50 Ns	
<i>Holothuria atra</i>	Lollyfish	L	24.1	49.5	49	439.1	815.5	54 SBt				1528.9	1528.9	100 Ns	
<i>H. coluber</i>	Snakefish	L				125.0	171.9	73 RBt	3.9	8.8	44 RF	44.4	44.4	100 Ns	
<i>H. edulis</i>	Pinkfish	L	19.4	66.5	29	897.4	897.4	100 SBt	11.4	13.6	83 MOP				
<i>H. fuscogilva</i> <sup>(4)</sup>	White teatfish	H				5.7	62.5	9 RBt				13.3	26.7	50 Ns	
<i>H. fuscopunctata</i>	Elephant trunkfish	M	0.2	16.7	1	67.3	175.0	38 SBt							
<i>H. scabra</i>	Sandfish	H				30.3	133.3	23 RBt				5.2	7.7	67 Ds	
<i>H. whitmaei</i> <sup>(4)</sup>	Black teatfish	H	3.9	23.6	17	105.8	343.8	31 SBt				3.6	21.4	17 Ds	
<i>Pearsonothuria graeffei</i>	Flowerfish	L	3.9	21.8	18	455.1	1479.2	31 SBt	1.7	15.7	11 RF				
<i>Stichopus chloronotus</i>	Greenfish	H/M	23.6	70.8	33	3.8	41.7	9 RBt	1.3	5.9	22 RF	1.6	4.8	33 Ds	
<i>S. herrmanni</i>	Curryfish	H/M	7.2	32.3	22	7.6	32.3	22	7.6	17 MOP	0.4	2.4	17 Ds		
<i>S. horrens</i>	Dragonfish	M/L				1.9	41.7	5 RBt							
<i>S. vastus</i>	Brown curry	H/M				19.2	83.3	23 SBt							
<i>Synapta sp.</i>	-	-				17445.5	20617.4	85 SBt				1471.1	2942.2	50 Ns	
<i>Thelenota ananas</i>	Prickly redfish	H	5.6	30.8	13	22.4	58.3	38 SBt				4.4	8.9	50 Ns	
<i>T. anax</i>	Amberfish	M	0.2	16.7	1	1.9	41.7	5 RBt	3.5	10.5	33 RF	4.8	9.6	50 Ds	
									3.8	7.6	50 MOP				
												3.2	6.3	50 Ds	

Notes: <sup>(1)</sup> D = mean density per hectare; <sup>(2)</sup> DwP = mean density per hectare for transects or stations where the species was present; <sup>(3)</sup> PP = percentage presence (units where the species was found); <sup>(4)</sup> There has been a recent variation to sea cucumber taxonomy which has changed the name of the black teatfish in the Pacific from *H. nobilis* to *H. whitmaei*. There is also the possibility of a future change in the white teatfish name. <sup>(5)</sup> L = low value; M = medium value; H = high value

## Natural spawning observations

New observations are presented for four species from different sites. These are very interesting as the reproductive biology is important for conservation and needs to be investigated for many commercial species.

### 1- *Holothuria whitmaei* (black teatfish)

**Observer:** Svea-Mara Wolkenhauer (CSIRO, Australia; swolkenhauer@hotmail.com)

**Location:** East of Lotty's Lagoon, Coral Bay, Western Australia. Coral sand among dead coral rubble and live coral, 5–6 m depth.

**Date:** August 2002.

**Notes:** Single male specimen. No evidence of spawning (or reproductive behaviour) in nearby specimens.

**Observer:** Glenn Shiell

**Location:** East of Lotty's Lagoon, Coral Bay, Western Australia. Coral sand among dead coral rubble and live coral, 5–6 m depth.

**Date:** January 2003.

**Notes:** Twelve male specimens observed spawning within a confined area (~ 40 m<sup>2</sup>). Investigation of specimens located nearby found no evidence of spawning (or reproductive behaviour) on a larger scale. No females were observed spawning at any stage, nor were they observed exhibiting behaviour consistent with reproductive activity.

**Observer:** Glenn Shiell

**Location:** Southwest of Pt Maud, Coral Bay. Coral sand among live coral, 5–6 m depth.

**Date:** April 2003.

**Notes:** Single male specimen. No evidence of spawning (or reproductive behaviour) in nearby specimens. None of the observed spawning events appeared to correlate with any physical environmental factors. No consistent patterns emerged with respect to tidal or lunar influences; water temperature varied markedly between spawning events.

### 2- *Pearsonothuria graeffei* (flowerfish)

**Observer:** Nick Hill (Maluane/Zoological Society of London; nicholas.hill04@imperial.ac.uk).

**Location:** Vamizi Island, Mozambique (on the northern side of the island), reef flat, ~ 2–8 m depth.

**Date:** 26 May 2003 (late afternoon, the exact time was not recorded)



**Notes:** During a coral reef survey conducted on the northern side of Vamizi Island, in the north of the Querimbas Archipelago, Mozambique, on 26 May 2003, the holothurian *Pearsonothuria graeffei* was observed spawning in a shallow reef area on the reef flat, in depths of 2–8 m. There were multiple sea cucumbers doing this at the same time that we observed on that particular dive, although none were closer than a few meters away from each other. They all looked like the same species. Although there were other holothurians on the reef, only *P. graeffei* was observed spawning

**Figure 1.**

*Pearsonothuria graeffei* in the spawning position (Photo Nick Hill).



**Observer:** Nyawira Muthiga (Wildlife Conservation Society, Mombasa Kenya; nmuthiga@wcs.org).

**Location:** Vabbinfaru Island, North Male Atoll, Maldives. (on the west side of the island adjacent to Banyan Tree Resort ) (N325042 E476451)

**Depth:** ~ 1–2 m

**Date:** 7 June 2005

**Observation time:** late afternoon.

**Moon phase:** new moon

**Notes:** During a coral reef survey conducted by the Wildlife Conservation Society (WCS) in collaboration with the Banyan Tree Resort in the Maldives in June 2005, the holothurian *Pearsonothuria graeffei* was observed spawning on the reef edge off Vabbinfaru Island, North Male Atoll. Along belt transects laid parallel to the reef, two researchers observed only a few individuals of *P. graeffei*, located short distances from each other, spawning – *P. graeffei* density along these transects was 2–3 ind 100 m<sup>2</sup>. Individuals were raised up in the classic spawning position (Fig. 2), spurting a discontinuous stream of gametes on the late afternoon of 7 June 2005 on a cloudy day.



**Figure 2.**

*Pearsonothuria graeffei* in the spawning position  
(Photo Christian Perthen).

**Observer:** Udo Engelhardt (Reefcare International Pty Ltd; reefcare@ozemail.com.au) and Riaz Aumeeruddy (Island Conservation Society; icsscience@seychelles.sc)

**Location:** Aride Island, Seychelles

**Date:** 5 November 2007 (15:10)

**Notes:** Aride Island forms part of the granitic islands of the Seychelles and it is the northern most granitic one. The island is a Nature Reserve, which also comprises a band of 200 m of sea around the island. Fishing is prohibited inside the reserve. The island is surrounded by a reef, which is partly granitic and partly carbonate.

In November 2007, a survey was conducted to establish the ecological status and characteristics of corals and reef-associated invertebrate communities at Aride Island. Sea cucumbers were part of the invertebrates that were surveyed. *Pearsonothuria graeffei* was found to be one of the most abundant species along with *Stichopus chloronotus* and *Actinopyga mauritiana*. On 5 November 2007, two individuals of *P. graeffei* were found spawning on the reef at around 15:10. These individuals had the typical characteristics of spawning sea cucumbers, with the anterior part of the body stretched and in a vertical position, while the posterior part of the body remained on the substrate (see Figs. 3 and 4). These are the first known observations of sea cucumbers spawning at Aride Island.



**Figure 3.**

*Pearsonothuria graeffei*  
in the spawning position,  
Seychelles  
(Photo U. Engelhardt).



**Figure 4.**

Male *Pearsonothuria graeffei*  
spawning,  
Seychelles  
(Photo U. Engelhardt).



### 3. *Stichopus herrmanni* (curryfish)

**Observer:** Aymeric Desurmont (Fisheries Information Specialist, SPC, New Caledonia; aymericd@spc.int).

**Location:** Baie des Citrons, Noumea, New Caledonia. (22°15'S and 166°25'E)

**Depth:** 2–4 m

**Dates:** 7, 8 and 9 January 2008

**Observation time:** 17:00–18:30.

**Tide:** high at 19:21, 20:03 and 20:42, respectively.

**Moon phase:** new moon on 8 January

**Notes:** The Baie des Citrons is a popular city beach in Noumea, New Caledonia. The bay is host to many sea cucumber species that are not fished. It has been the scene of several sea cucumber natural spawning observations, already described in past issues of this bulletin (Issues #18, p. 38; #20, p. 37; #21, p. 28; and #23, p. 38).

The bay is fringed on both sides by coral reefs, which form a small “drop off”, with the top of the reef at 1–2 m depth, while the sandy-muddy bottom lies at 3–4 m. On the southern side of the bay, a dozen specimens of *Stichopus herrmanni* usually lie on the sand at the foot of the reef, spread almost regularly every 10–15 m.

On the first day of the observation (7 January), most of the *S. herrmanni* usually found in this area were not visible. One of them was found on top of a big coral head spawning. It was releasing gametes every 2–3 minutes during the time of the observation (50 min). It is interesting to note that this movement towards a high location to spawn has been observed for the same species in the same area (Desurmont 2003).

On the same day, in the middle of the bay, in a flat sandy-muddy area with patches of seagrass, another specimen of *S. herrmanni* was found spawning on top of a 20-cm high sand “pinnacle”, with another specimen beside it showing no sign of spawning behaviour.

On the second day (8 January), the same specimen that was found spawning on the reef the previous day, was in exactly the same spot, spawning again (Fig. 5). Another specimen had climbed the reef close to the first one ( $\pm 3$  m) (Fig. 6). Both were releasing gametes every 2–3 minutes, not necessarily synchronically, during all the time of the observation (60 min). A third specimen was found 50 m away, also on top of a big coral head, spawning.

On the third day (9 January), the specimen observed spawning on the reef on days 1 and 2 was still at the same location, on top of the same small coral head, but showed no sign of spawning behaviour. The other two animals observed spawning the previous day were in the exact same places, and were spawning again.

On the fourth day (10 January), at approximately the same time, the three animals had moved down to the bottom of the reef, on the sandy area where they are usually found. No other spawning events were observed.

During the four days of observations, none of the many other sea cucumber species present in the bay (*Bohadschia vitiensis*, *Holothuria atra*, *H. coluber*, *H. edulis*, *H. scabra versicolor* and *Stichopus chloronotus*) showed any sign of spawning behaviour.

#### Reference

Desurmont A. 2003. Natural spawning observation of *Stichopus herrmanni*. SPC Beche-de-Mer Information Bulletin 23:38.



**Figure 5.** This *Stichopus herrmanni* had climbed to the top of a coral head to spawn. It was observed spawning, at the same spot, on two consecutive days (Photo A. Desurmont).



**Figure 6.** Damselfish feeding on the sperm spawned by *Stichopus herrmanni* (Photo A. Desurmont).

## 4- *Holothuria tubulosa*

### ***In situ* observation of sexual reproduction of *Holothuria tubulosa* Gmelin, 1788 (Echinodermata: Holothuroidea) in the Azores (NE Atlantic)**

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The aspidochirote *Holothuria tubulosa* Gmelin, 1788 is widely distributed in the Mediterranean Sea and in the Atlantic from Gibraltar to the Bay of Biscay (Tortonese 1965). It lives on rocky substrata, soft sediments and phanerogam seagrass beds, in depths that vary between 5 m and 100 m, being one of the predominant species of the benthic macrofauna in the *Posidonia oceanica* meadows (Boudouresque and Meinesz 1982).

*H. tubulosa* is one of the four species of sea cucumbers — *H. sanctori* Delle Chiaje, 1823; *H. forskali* Chiaje, 1841; *Eostichopus regalis* (Cuvier, 1817) — found in the Azores. Although *H. forskali* Chiaje, 1841, is considered to occur in the area, systematic studies are urgently needed for confirmation.

Since it plays a central role in recycling bottom detritus (Massin 1982; Bulteel et al. 1992), *H. tubulosa* would thus be particularly interesting to complement the set of bioindicators for surveying metal contamination in ecosystems (e.g. the *P. oceanica* meadows) (Warnau et al. 2006).

*H. tubulosa*, as with most Holothuroidea species, has separate sexes, albeit with no sexual dimorphism, and fertilization is external. It has an annual reproductive pattern, in which different phases of gonadal development are differentiated: reabsorption of the gonad after the post-spawning period; gonad recovery stage; growing stage; maturity stage, spawning stage and post-spawning stage (Despalatovic et al. 2004).

In the Mediterranean, and specifically in the case of *H. tubulosa*, spawning has been observed in the Adriatic Sea (Despalatovic et al. 2004), the Spanish Mediterranean coast of Costa Brava (Valls 2004), the Alboran Sea (Ocaña and Tocino 2005), and the Aegean Sea (peninsula of Chalkidike) as reported by Moosleitner (2006) in the years 1972, 1994, 1997 and 2003.

In the Azores, *H. tubulosa* spawning occurs in the summer months (so far observed in July and August) during the afternoon, which may follow the annual pattern, during warm sea temperatures (22–26°C) and being synchronous in both sexes, as stated by Despalatovic et al. (2004) in the Adriatic Sea.

Spawning of *H. tubulosa* in the Azores was first recorded by FADC on 16 August 1996, at Monte da Guia (Faial Island, Azores), close to Ilhéu Negro (Porto Pim beach) (38°52.29'N 28°62.90'W) at a depth of 19 m, but due to the low water visibility photo records were compromised.

The second record (AAB and LFM on 26 July 2007, three days before full moon) occurred in the southern coast of Terceira Island (Azores) at Salgueiros rocky shore (38°64.85'N 27°09.68'W). The tide was low (0.6 m), water temperature was 22°C, depth ranged from 2 m to 4 m, and the bottom comprised sandy areas with sparse boulders. Observation time was during daylight from 18:30–19:30, solar time.

For the Salgueiros site, spawning was already occurring by the start of observations (18:30), where numerous individuals (>50) were visibly active and by the end of it (19:30) some individuals were already recovering from their spawning vertical position.

Photographic records of the spawning are presented in Figure 7 (male posing vertically on the rock surface, raising half of its body and releasing sperm); Figure 8 (female posing vertically on the rock surface and releasing eggs); Figure 9 (closeup at the sperm release); Figure 10 (closeup of the egg release).

During this one-hour observation, it was noticed that not only males were in a higher density, but sperm release (Figs. 7 and 9) was more constant in short intervals varying from one to three minutes. On the other hand, a single observed female released eggs (Figs. 8 and 10) in intervals of 10 minutes, during a 30-minute-long observation.

As proposed for other species (see Ocaña and Tocino 2005; Moosleitner 2006), some males begin the spawning event, and their sperm includes informative substances that push other males and females to participate

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in the spawning. Posing with half (or up to two-thirds) of the body vertically provides a maximum dispersion of the gametes into the environment.

The relationship between spawning events and moon phases can not be clearly established from the data collected, but there seems to be a preference for spawning close to a full moon as already stated by other authors (Despalotovic et al. 2004; Moosleitner 2006).

No predation on the reproductive material was observed. Although *Coris julis* (Linnaeus, 1758) is a common and abundant species in the Azores, no fish were observed feeding on the spawning event, as Moosleitner (2006) did in the Aegean Sea.

#### Acknowledgements

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**Figure 7.** Male *H. tubulosa* posing vertically on the rock surface, raising half of its body and releasing sperm.



**Figure 8.** Female *H. tubulosa* posing vertically on the rock surface and releasing eggs.



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Figure 9. Detail of male *H. tubulosa* sperm release.

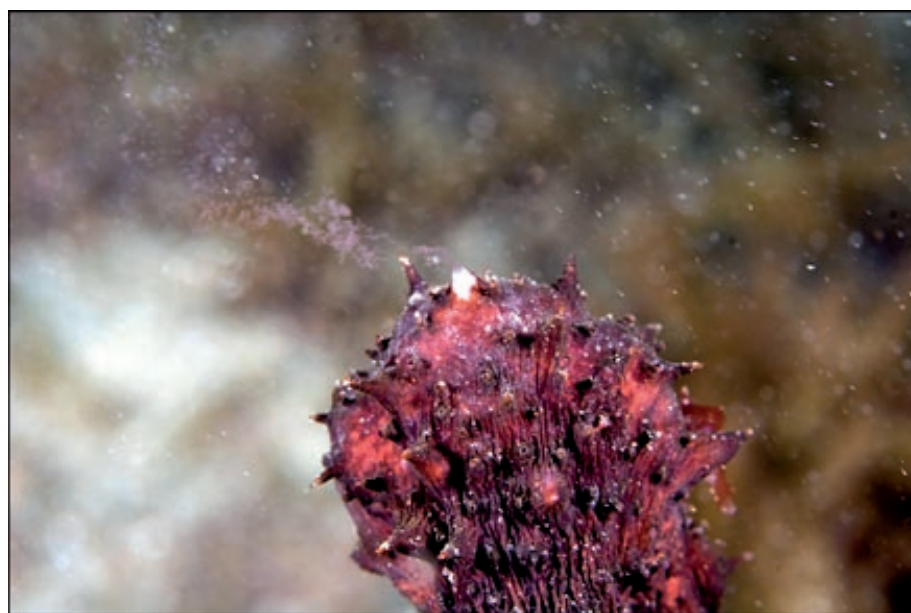


Figure 10. Detail of female *H. tubulosa* egg release.



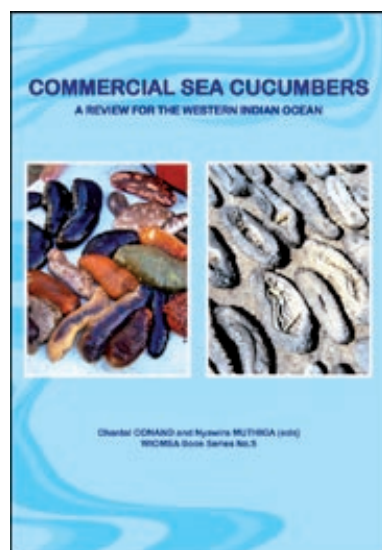
# Abstracts & new publications...

## Commercial sea cucumbers: A review for the Western Indian Ocean

Conand C. and Muthiga N. (eds)

Source: WIOMSA Book Series No. 5. 66 p.

Sea cucumbers (Holothurians) are a group of marine invertebrates that are harvested worldwide, mostly for human consumption in Asian countries. Over the past decades, a significant increase in the demand for sea cucumbers has led to an explosion in exploitation, which often results in population declines in many producing nations. Because of the importance of sea cucumbers as a source of livelihood for many artisanal fishers from developing countries, and as a globally traded product, there is considerable interest in information on their biology, ecology and fisheries management. Although management agencies and fishing communities recognize that sea cucumber fisheries are in trouble worldwide, attempts at management have been largely unsuccessful due to several factors including: 1) the vulnerability of sea cucumbers to harvesting, 2) the artisanal nature of the fishery, which prevents fishing communities from using alternative coping mechanisms, 3) the institutional and socioeconomic barriers to management. Sea cucumber production has been declining in nations of the Western Indian Ocean in the last 10 years. The reasons for the overexploitation include: 1) a lack of ecological information for understanding species life histories, 2) a lack of understanding of the socioeconomic realities of the fishery, and 3) inadequate monitoring and enforcement of fishery regulations.



The Western Indian Ocean Marine Science Association (WIOMSA) — as part of its aim to serve the information needs of resource managers and communities for the sustainable management of marine resources in the western Indian Ocean (WIO) — approved a “Regional Sea Cucumber Project” in 2006. This review was prepared as the baseline study of the project and aims to provide a comprehensive synthesis of the current state of knowledge on sea cucumbers in the WIO. The information used in the review comes from many sources including journal articles, theses and dissertations, and reports on all aspects of sea cucumbers in the region. Although the report focuses on the five countries (Kenya, La Reunion, Madagascar, Seychelles, Tanzania) that are involved in the project, a brief description of the status of sea cucumbers in other countries of the WIO is also included.

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It is hoped that this review contributes scientific information that will support management efforts of sea cucumbers in the WIO and will also serve as a useful reference for scientists and students interested in echinoderms in general and sea cucumbers in particular. The authors thank WIOMSA for financial support for the Regional Sea Cucumber Project and the publication of this review. Authors who contributed to the review are gratefully acknowledged.

Note: The book is available for free from the WIOMSA secretariat: [secretariat@wiomsa.org](mailto:secretariat@wiomsa.org)

## Abstracts from papers presented at the 5th WIOMSA Scientific Symposium, Durban, 22–26 October 2007

### The reproductive biology of the commercial sea cucumbers *Holothuria fuscogilva* and *Holothuria scabra* along the Kenyan coast

N.A. Muthiga, J.A. Kawaka and S. Ndirangu

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The tropical sea cucumbers *Holothuria fuscogilva* and *Holothuria scabra* are amongst the most highly valued sea cucumbers that are widely distributed across the Western Indian Ocean. Despite their fisheries value, their biology, ecology and population dynamics remain poorly understood. The reproductive biology and ecology of these species was investigated in order to provide information that contributes to the improved management of sea cucumbers along the Kenyan coast. Distribution and abundance surveys were carried out using belt transects (2 x 100 m) from Kiunga south to Shimoni. Standard measurements of size, observations of gonad condition and sex and calculations of gonad and gut indices were used to analyze reproductive patterns of both species collected monthly between 2006–2007 and compared with data from a previous study in 1998–1999. Both species occurred at low densities ~ 0.1 ind 200 m<sup>2</sup>, *H. scabra* was more widely distributed occurring at sites from Kiunga to Shimoni while *H. fuscogilva* was only recorded south of Diani. Mean monthly gonad indices were significantly correlated between males and females ( $r = 0.89$  and  $0.60$  for *H. fuscogilva* and *H. scabra* respectively) indicating synchronous gonad development between sexes. The pattern of gonad growth was less correlated between years ( $r = 0.31$  and  $0.46$  for *H. fuscogilva* and *H. scabra* respectively). Gametogenesis commenced between April and May and peaked in November for *H. fuscogilva*. Gonad growth in *H. scabra* showed two peaks in March–June and September–October in 1998–1999 and only one peak in November–January in 2006–2007. The sexes did not differ in size in either species although females had significantly higher gonad indices in *H. fuscogilva* than males. *H. scabra*, the smaller sea cucumber had significantly lower gonad index and higher gut index, and the sex ratio was skewed towards more males. The life history strategies of these species include spawning at the time favourable for larval growth and a high reproductive effort that may serve to increase reproductive success.

### Reproductive biology of sea cucumbers from La Réunion: a contribution for a regional management of the fishery

S. Kohler, C. Conand and S. Gaudron

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The sea cucumber fishery is important in several countries of the Western Indian ocean (WIO) but generally not adequately managed. A regional programme (Masma) granted by Wiomsa is bringing data on the reproduction of most important beche de mer species. In La Reunion the two target species are *Holothuria leucospilota* and *Actinopyga echinites*. They are very abundant on the fringing reefs and were sampled monthly in 2005–2006. Data on the morphology, the histology of the gonads and the Gonad-Index were analysed. The main results concern the following parameters: the size distribution of the individuals within the population, the sex ratio, the anatomy of the gonads, the annual reproductive cycle and the size at first sexual maturity. These results are compared with data on other holothurian species such as *H. atra* and *Stichopus chloronotus* previously studied in La Reunion. The importance of fission is also discussed for the population parameters. These results will be useful for the research on the reproductive biology of sea cucumbers conducted in the other countries of WIO. The spawning season and the size at maturity will be useful for a future regional management of the stocks.

### Relation between nutrition of Holothurians and microbenthos of soft-bottoms in a shallow coral reef (Reunion Island)

Dorothee Taddei, Patrick Frouin, Jean Blanchot and Chantal Conand

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Deposit feeding holothurians are among the most conspicuous invertebrates in marine benthic coral reef communities, particularly in La Saline reef (Reunion Island, Indian Ocean). Therefore nutrition of the two dominant species, *Holothuria atra* (Jaeger, 1883) and *Holothuria leucospilota* (Brandt, 1835), was studied during winter season. Chlorophyll *a*, bacteria, organic carbon and nitrogen contents were quantified in

four compartments: sediment under holothurian tentacles (Sed), the foregut (FG), the hindgut (HG) and the faeces (F). These two species selectively ingested chlorophyll *a* and bacteria as shown by significant increases (from 235 to 935 %) between Sed and FG. The digestion of microbenthos occurred between FG and HG (with 21 to 75 % decrease of the content). Conversely, bacteria and chlorophyll *a* did not vary significantly between HG and F. Despite microbenthos was not the main component of total organic carbon in sediment, it appeared as the main carbon source for these selective feeders: 55 % of ingested for *H. atra* and 30 % for *H. leucospilota*. A mixed population of both species at the study site (Planch'Alizés) removed  $109 \text{ mgC m}^{-2} \text{ j}^{-1}$ , among which  $57 \text{ mgC m}^{-2} \text{ j}^{-1}$  came from living microbenthos. Availability of microbenthos therefore appeared to be very important in regulating distribution and dynamics of these two holothurian species. With densities reaching  $3.1 \text{ ind m}^{-2}$ , these deposit feeders played an important role in the carbon cycling through soft-bottoms of the coral reef ecosystem.

### Toxicity biomarkers responses in holothurians species (La Reunion, Indian Ocean)

*J. Kolasinski*

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The objective of this study was to assess toxicity biomarkers, acetylcholinesterase activity (AChE) and ethoxyrufin-O-deethylase activity (EROD), to elucidate any correlation with the eutrophication gradient. AChE is the functional target of insecticides, nematocides and chemical nerve agent. EROD activity is the main biotransformation process concerning the organic xenobiotics and then inform on any physiological induced stress. Significant variation was measured in AChE activity for *H. leucospilota*. The lowest value was found at the reference station ( $293,9 \pm 72,4 \text{ nmoles mgP}^{-1} \text{ min}^{-1}$ ) compared with the values in eutrophicated areas ( $548.0 \pm 84.1$  and  $607.3 \pm 72.2 \text{ nmoles mgP}^{-1} \text{ min}^{-1}$ ), what represent a 48% inhibition in the reference station. The EROD activity was measured for the first time on *H. leucospilota* and *H. atra*, and showed no significant difference between stations with  $27.73 \pm 25.19$  to  $68.73 \pm 52.20 \text{ pmoles mgP}^{-1} \text{ min}^{-1}$  for *H. leucospilota* and  $10.78 \pm 7.55$  to  $20.33 \pm 24.56 \text{ pmoles mgP}^{-1} \text{ min}^{-1}$  for *H. atra*.

### The social and economic features of the sea cucumber fishery in Kenya

*Jacob Ochiewo and Maricela de la Torre-Castro*

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This paper presents the results of part of the Socio-economics component of a MASMA funded three-year sea cucumber project in the Western Indian Ocean (WIO) region. The objectives of this component of the project are 1) to determine the national marine resource use patterns, the social and economic characteristics of the fisher communities and the contribution of sea cucumbers to the national economies and local livelihoods of the coastal areas, and 2) to analyze the management system present in the area. The study has been conducted at Vanga, Shimoni, Majoreni and Gazi villages in the Kenyan south coast. The results indicate that sea cucumber collectors (fishers) are mainly men who fish in the sub-tidal areas between 3 and 10 metres deep. These fishers do not use scuba-diving gear and fishing is heavily done during the northeast monsoon season when the sea is calm and water is clear. About 50% of the sea cucumber fishers also collect other marine products such as octopus. The sea cucumbers are sold fresh from the sea to local dealers (middlemen) who process them and sell to more prominent middlemen in Mombasa and Kaloleni in the neighborhood of Mombasa. The fishers occasionally borrow money from dealers especially when they fail to catch sea cucumbers. This in turn makes them loyal to the dealers who lend them money thus creating conditions for exploitation. Almost all sea cucumber fishers have stated that they are not willing to make sea cucumbers part of their daily diet. Sea cucumber fishing is regulated by the Fisheries Department that issues fishing licenses. According to this law, fishers pay Kenya shillings 100 for the fishing license annually. However, a part from the main Fisheries legislation, there is no special law or policy that is devoted specifically to govern the sea cucumber fishery.

### Fate of sea cucumber populations and fisheries in the south-west coast of Madagascar

*Richard Rasolofonirina and Thierry Lavitra*

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Sea cucumber fisheries were investigated in 13 coastal villages in the south west coast of Madagascar, from Morombe to Androka in 1996 and 2006. Catch rates, trepang production and species abundance in the catches of each village were examined and compared. In addition, sea cucumber population structures were also investigated on two corals reefs, the Great Barrier Reef of Toliara and the Nosity-ve Reef, during the

two periods where population density, species biomass and distribution on the reefs were analysed. About 30 species of holothurian were recorded in the studied villages. Targeted species in each village changed with their availability on the field and with market prices. Moreover, in recent years, lower valuable species became the most targeted species in some villages. After ten years, sea cucumbers resources declined considerably and the number of harvested species decreased. In 1996, about 20 species formed usually the catches of fishermen villages. In 2006, the mean number of harvested species decreased to ten. *Holothuria notabilis*, *Holothuria scabra* and *Stichopus horrens* were the main collected species and *Holothuria notabilis* formed the major part of the catch in some villages. Decreasing catch rates were also observed in the villages and, in the same time, mean density and biomass of all species observed on both investigated reefs dropped between the two periods. At the opposite, sea cucumber prices increased from 5 to 30 times.

### **Effect of food quality and settling density on growth and survival of epibiotic juveniles of the sea cucumber *Holothuria scabra***

Thierry Lavitra, Richard Rasolofonirina, Michel Jangoux and Igor Eeckhaut

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*Holothuria scabra* is one of the most valuable commercial sea cucumber species in the world. It is also the first species farmed in Madagascar. Today, breeding, larval rearing and juvenile settlement are totally controlled in the Aqua-Lab hatchery of Toliara; juvenile farming optimisation is still in process. After larval metamorphosis, *H. scabra* individuals are firstly epibiotic for 6 to 8 weeks (they stand the whole day on the substrates) before becoming endobiotic for the rest of their life (they burrow into the muddy sand from sunrise to sunset). Here we report the effect of food quality and settling density on the growth and survival of epibiotic individuals.

Seven types of food were tested: extracts of *Thalassia hemprichii* with spiruline, *Thalassia hemprichii*, *Sargassum isoetifolium* with spiruline, *Sargassum isoetifolium*, *Thalassodendrom ciliatum*, *Siryngodium isoetifolium* and organic biofilm. Control consisted in epibionts kept in seawater without any biofilm. The results showed that the extracts of *Sargassum isoetifolium* with or without spiruline gave the best growth and high survival rate: the mean epibiotic volumes were of 118,9 and 83,7 mm<sup>3</sup> and the survival rates of 65 and 61% at the end of the experiments. In the control tests, epibionts had a mean volume of 1,27 mm<sup>3</sup>, which is 65 times less important.

We tested epibiont densities of 150, 300, 450 and 600 juveniles m<sup>-2</sup>. The best growth and survival rates were observed for densities less than 450 juveniles m<sup>-2</sup>. The highest mortality rate in all experiments was observed during the two first weeks of rearing.

To reach adequate growth and survival rates, these experiments suggest the use of *Sargassum isoetifolium*-spiruline extracts and a settling density less than 450 juveniles m<sup>-2</sup>. In case of *Sargassum* depletion, extracts of seaweed could also be used.

### **Annual reproduction in the Indo-Pacific sea cucumber *Holothuria leucospilota* as a response to variability in the environment**

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The world-wide decline in wild stocks of holothurians or sea cucumbers has generated a great deal of interest for reproduction and fisheries biology information that could lead to the development of better management programs as well as aquaculture of this valuable resource. Sea cucumbers have been collected for export in the WIO since the early 1900s, however, reports of declining stocks has led to concerns about the better management of this fishery. This paper discusses the findings of a study on the distribution, abundance and reproduction of the sea cucumber *Holothuria leucospilota* a commercial species that is widely distributed throughout the Western Indian Ocean (WIO). The species was selected as an appropriate model as part of a broader program to assess the status, biology and ecology of sea cucumbers of the WIO funded by the Western Indian Ocean Marine Science Association. Our objective was to assess the status of this sea cucumber under different management regimes (protection vs. fishing), as well as study the reproductive strategy and how environmental factors influence this strategy. The population assessment was carried out along the Kenyan coast using belt transects (100 m x 2 m) and time searches. The Gonad Index (GI) method was used to investigate the changes associated with gonad development of individuals collected in the Mombasa Marine Reserve. Results indicated that *H. leucospilota* is distributed throughout the Kenyan coast and that the abundance and biomass of sea cucumbers is dependent on habitat (higher abundances in



coral reefs, and reef lagoons) as well as management regime (population densities were higher in protected than unprotected reefs). In addition, the pattern of reproduction indicated that *H. leucospilota* has a seasonal reproductive pattern, with gametogenesis beginning in November and spawning occurring in March. The estimated size at sexual maturity for this sea cucumber was 18 cm. The study provides information on stocks as well as sea cucumber biology that should contribute to the sustainable management of sea cucumbers as well as information for the development of mariculture in this region.

## Poster presented at the WIOMSA Symposium

### Spatial patterns of holothurian populations on the shallow reefs in Reunion Island

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In the scope of a MASMA programme dealing with sea cucumbers fisheries in the WIO, we investigated holothurians populations in shallow fringing reefs from Reunion Island. These small reefs (total of 12 km<sup>2</sup>) can show extremely high densities of *Holothuria atra* populations that have formerly been studied, as well as the *Stichopus chloronotus* and *H. leucospilota* ones. However, no global survey of the shallow reefs from Reunion Island has been realised up to now. Southern reef (St Pierre) was particularly poorly known. This study was designed to bring such information at the island scale, covering all the holothurian populations present in back reefs and inner reef flats. From the west to the south coast, 9 sites and 16 stations were counted in rainy season with replicated belt transects (100 m<sup>2</sup> each). In each site back reefs and inner reef flats were sampled, when present. Mean grain size, total organic load and chl<sub>a</sub> content were quantified concurrently and correlated with holothurian densities. Richness of holothurian communities was poor in all sites (10 species max.), with strongly dominant species in Etang Salé (*S. chloronotus*, up to  $203.7 \pm 2.5$  ind 100 m<sup>-2</sup>) and St Gilles sites (*H. atra*). Large spatial variability was observed at the reef complex scale and between reefs along the west and south coasts. The difference pattern between reefs could not be related to the considered physical variables, despite some impact of nutrients could be hypothesized in Saint Gilles back reefs. Strong patchiness characterized these reefs from Reunion.

## Abstracts from journals

### Grow-out of sandfish *Holothuria scabra* in ponds shows that co-culture with shrimp *Litopenaeus stylirostris* is not viable

Johann D. Bell, Natacha N. Agudo, Steven W. Purcell, Pascal Blazer, Matéo Simutoga, Dominique Pham and Luc Della Patrona

Source: Aquaculture 273:509–519. (2007)

We examined the potential for producing the large numbers of sandfish (*Holothuria scabra*) needed for restocking programmes by co-culturing juveniles with the shrimp *Litopenaeus stylirostris* in earthen ponds. Our experiments in hapas within shrimp ponds were designed to detect any deleterious effects of sandfish on shrimp, and vice versa. These experiments showed that a high stocking density of juvenile sandfish had no significant effects on growth and survival of shrimp. However, survival and growth of sandfish reared with shrimp for 3 weeks were significantly lower than for sandfish reared alone. Increased stocking density of shrimp also had a significant negative effect on survival and/or growth of sandfish. A grow-out trial of juvenile sandfish in 0.2-ha earthen ponds stocked with 20 shrimp post-larvae m<sup>-2</sup>, and densities of sandfish between 0.8 and 1.6 individuals m<sup>-2</sup>, confirmed that co-culture is not viable. All sandfish reared in co-culture were dead or moribund after a month. However, sandfish stocked alone into 0.2-ha earthen ponds survived well and grew to mean weights of ~ 400 g within 12 months without addition of food. The grow-out trial demonstrated that there is potential for profitable pond farming of sandfish in monoculture. Further research is now needed to identify the optimal size of juveniles, stocking densities and pond management regimes.

## A new era for restocking, stock enhancement and sea ranching of coastal fisheries resources

Johann D. Bell, Kenneth M. Leber, H. Lee Blankenship, Neil R. Loneragan and Reiji Masuda

**Source:** Reviews in Fisheries Science, 16(1):1–9. (2008)

The growing number of countries investigating the potential for releasing cultured juveniles to augment coastal fisheries resulted in the First International Symposium on Stock Enhancement and Sea Ranching (ISSESR) in Norway in 1997. The 1st and 2nd ISSESR, in Japan in 2002, were instrumental in developing methods for mass production of environmentally fit juveniles and for releasing them in responsible ways. The 3rd ISSESR, held in the U.S.A. in 2006 ([www.SeaRanching.org](http://www.SeaRanching.org)), ushered the discipline into a new era. The major advances included: (1) definitions of the various objectives for releasing cultured juveniles (restocking, stock enhancement, and sea ranching); (2) a framework for integrating releases within their fisheries management context, including tools for quantitative assessment; (3) a systematic, transparent, and stakeholder participatory planning process to determine whether releases have a cost-effective role to play in managing a fishery; (4) a comprehensive case study (blue crabs in Chesapeake Bay) describing the multi-disciplinary approach needed to evaluate the potential benefits of releases; and (5) a suite of other lessons to guide stakeholders in evaluating the potential for and implementation of releases. The papers in this Special Issue of *Reviews in Fisheries Science* elaborate how restocking, stock enhancement and sea ranching programs can create synergies between aquaculture and some coastal fisheries to help meet the future demand for seafood and aid in restoring depleted stocks.

## Spatio-temporal and size-dependent variation in the success of releasing cultured sea cucumbers in the wild

Steven W. Purcell and Matéo Simutoga

**Source:** Reviews in Fisheries Science 16:204–214. (2008)

Large-scale releases of cultured “sandfish,” *Holothuria scabra*, were used to examine size- and density-dependent effects on survival among sites. Juveniles were marked by fluorochromes in 3 size classes and released into open 500-m<sup>2</sup> sea pens. A preliminary trial involved the release of 4,000 juveniles at two sites. In a subsequent large-scale experiment, we released 9,000 juveniles at 0.5, 1, or 3 individuals m<sup>-2</sup> at 4 sites. Growth and survival up to 2 years post-release were estimated from successive recapture surveys and marker verification. Most of the surviving animals attained the size at first maturity (180 g) within 12 months in the preliminary trial but grew slower in the second experiment. Growth was density dependent, with carrying capacity at one site of 200–250 g sandfish m<sup>-2</sup>. Survival varied greatly among sites, explained in part by microhabitat features, but site suitability was ephemeral; previous success at sites did not guarantee success later. Juvenile size at release significantly affected long-term survival, but survival was density-independent within the experimental range. Juveniles should be released at a minimum size of 3 g and at multiple sites and occasions to mitigate spatio-temporal variation in survival. We predict that 7–20% of sandfish released at a size of 3–10 g in optimum habitat could survive to market size, which gives qualified support for restocking. Our results also help to assess the viability of sea ranching, which will depend on sale price, harvest efficiency, and reduced costs of producing juveniles.

## In vivo investigation of oocyte transit and maturation in a broadcast-spawning holothurian

Jean-François Hamel and Annie Mercier

**Source:** Invertebrate Biology 126(1):81–89. (2007)

A sequential in vivo approach was used to examine the transformations undergone by oocytes during transit in the gonoduct of the sea cucumber *Holothuria leucospilota*, from ovulation until fertilization competency. Spasms of the ovarian muscle bands, during the prespawning locomotor activity of the females, coincided with the extrusion of oocytes from the follicle cells (ovulation). No germinal vesicle breakdown (GVBD) was visible and the oocytes were not fertilizable. As the animal began to display the anterior sweeping movements characteristic of spawning, the oocytes streamed out of the gonad and were stored in the gonad basis. The oocytes, which were still non-fertilizable, were then pressed forward through the first (proximal) section of the gonoduct. GVBD was completed during this rapid transit, but oocytes could not be fertilized unless they had soaked  $\pm 20$  min in seawater. In the second (distal) section of the gonoduct, most oocytes were readily fertilizable; fertilization rates increased noticeably after the formation of a bulge beneath the gonopore, which favored the entry of seawater. Hydration of the jelly coat was apparent (i.e., a 60% increase in oocyte surface area). Gamete release occurred in one powerful spurt 85 min after the onset of ovulation. This oocyte maturation sequence is expected to occur in holothurian species with similar anatomy and spawning behavior.

### **Exogonadal oogenesis in a temperate holothurian**

Jean-François Hamel, Pierre Becker, Igor Eeckhaut and Annie Mercier

**Source:** The Biological Bulletin 213:101–109. (2007)

Unusual structures were detected on the visceral peritoneum of the ovarian tubules in about 5%–10% of female sea cucumbers (*Cucumaria frondosa*) collected off Newfoundland, eastern Canada. The condition varied from mild to severe, with localized castration observed in the most heavily affected tubule sections. Investigation of the structures using histology, transmission electron microscopy (TEM), and gene analysis revealed that they were oocytes at different stages of development, growing singly or in groups of up to six. Their size and composition were consistent with those of oocytes found in the lumen of the ovaries, although “exogonadal” oocytes were devoid of a vitelline coat and presented few cortical granules. TEM sections suggest that the atypical oocytes emerged from the peritoneum and grew toward the coelomic cavity, and that they were not in direct contact with the basal lamina or the inner germinal layers. Similar masses have been observed in *C. frondosa* from the Gulf of St. Lawrence (Québec, Canada) and the Barents Sea (Russia), and in *C. japonica* and *Psolus fabricii* from Canada and Russia. The possibility that exogonadal oogenesis is attributable to anthropogenic disturbances should be investigated even though some of the affected specimens originate from presumably pristine locations.

### **Diurnal observations of sheltering behaviour in the coral reef sea cucumber *Holothuria whitmaei***

Glenn Shiell and Brenton Knott

**Source:** Fish Research 2007

Management of commercial sea cucumber stocks relies, in part, on estimates of population densities which, in turn, depend on knowledge of habitat preferences, and of the influence of biological cues on sheltering and/or aggregation behaviour. Here, we document a diurnal shift in the sheltering behaviour of the Pacific and eastern Indian Ocean black teatfish, *Holothuria whitmaei*, and discuss the implication of this behaviour for surface based population density surveys. Diurnal studies of thirty black teat fish on Ningaloo Reef, Western Australia, found that the proportion of animals sheltered (and therefore hidden when viewed from directly above) was significantly greater in the morning (3–23%; 08:30–12:30) relative to the afternoon (0–6%; 12:30–17:30). As with sheltering behaviour, the straight-line distance between individual sea cucumber and the nearest shelter also showed marked diurnal variation, with animals observed at greater distances from shelter between 12:30 and 17:30 (PM: 4–22 cm; AM: 1–7 cm). Based on these results, we suggest that surfaced-based census techniques (e.g. manta tows) may underestimate population densities if conducted during times of reduced activity and increased incidence of sheltering behaviour. Appropriate calibration factors for daytime black teatfish surveys are proposed.

### **Reproductive biology of the commercial sea cucumber *Holothuria spinifera* (Echinodermata: Holothuroidea) from Tuticorin, Tamil Nadu, India**

P.S. Asha and P. Muthiah

**Source:** Aquaculture, published online: 27 October 2007

The annual reproductive cycle of the commercial sea cucumber *Holothuria spinifera* was studied in Tuticorin, Tamil Nadu, India, from September 2000 to October 2001, by macroscopic and microscopic examination of gonad tubule, gonad index and histology of gametogenic stages, to determine the spawning pattern. The gonad consists of long tubules with uniform development. It does not confirm the progressive tubule recruitment model described for other holothurians. The maximum percentage of mature animals, gonad and fecundity indices, tubule length and diameter, with the observations on gonad histology, ascertained that *H. spinifera* had the peak gametogenic activity during September and October 2001 followed by a prolonged spawning period from November 2000–March 2001.

### **Redescription of *Stichopus naso* Semper, 1868 (Echinodermata, Holothuroidea, Stichopodidae)**

C. Massin

**Source:** Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, Biologie 72:123–130. (2007).

Specimens from Japan, Thailand, Papua New Guinea and Madagascar have allowed a complete redescription of *Stichopus naso* Semper, 1868. The species, with a wide Indo-Pacific distribution, is new to the fauna of Papua New Guinea and Madagascar. Similar to several other shallow-water holothurians it has the poten-

tial to reproduce by transversal fission. When disturbed, the body undulates in a typical fashion and it is capable of limited swimming movements.

### **New cucumariid species from southern Australia (Echinodermata: Holothuroidea: Dendrochirotida: Cucumariidae)**

P. Mark O'Loughlin

**Source:** *Memoirs of Museum Victoria* 64:23–34. (2007). [also available at: <http://museumvictoria.com.au/pages/3660/64-o-loughlin.pdf>]

Four cucumariid species, new to science, are described for the rocky shallows and off-shore sediments of southern Australia: *Apsolidium falconerae*, *Neoamphicyclus altoffi*, *Neoamphicyclus materiae*, *Neocucumella turnerae*. *Neocucumella turnerae* sp. nov. is unique within the genus in not having table ossicles. The five syntypes of *Cucumaria mutans* Joshua are reviewed, restricted to three, and a lectotype and two paralectotypes are designated. The genus *Neoamphicyclus* Hickman is reviewed. *Cucumaria mutans* is referred to *Neoamphicyclus* Hickman. One former syntype of *Cucumaria mutans* is assigned to *Neoamphicyclus materiae* sp. nov. One former syntype of *Cucumaria mutans* has lost all ossicles and is assigned to *Neoamphicyclus* sp. A key is provided for the species of *Neoamphicyclus* Hickman.

### **New *Holothuria* species from Australia (Echinodermata: Holothuroidea: Holothuriidae), with comments on the origin of deep and cool holothuriids**

P. Mark O'Loughlin, Gustav Paulay, Didier Vandenspiegel and Yves Samyn

**Source:** *Memoirs of Museum Victoria* 64:35–52. (2007). [also available at: <http://museumvictoria.com.au/pages/3660/64-o-loughlin-paulay-vandenspiegel-samyn.pdf>]

Two aspidochirotid species, new to science, from the continental slope of southern Australia are described: *Holothuria* (*Panningothuria*) *austrinabassa* O'Loughlin sp. nov. and *Holothuria* (*Halodeima*) *nigralutea* O'Loughlin sp. nov. The first represents the southernmost documented holothuriid, and is the sister species of the northernmost holothuriid species *Holothuria* (*Panningothuria*) *forskali* Delle Chiaje. The second is a very recent offshoot of the wide-ranging Indo-west Pacific *Holothuria* (*Halodeima*) *edulis* Lesson. Morphological and molecular genetic differences between these species pairs are detailed. *Holothuria* (*Halodeima*) *signata* Ludwig is raised out of synonymy with *H. edulis*. A lectotype for *Holothuria* (*Halodeima*) *signata* Ludwig is designated. The status of the subgenera *Panningothuria* Rowe and *Halodeima* Pearson is discussed. The occurrence of multiple madreporites in *Halodeima* is discussed.

### **New apodid species from southern Australia (Echinodermata: Holothuroidea: Apodida)**

P. Mark O'Loughlin and Didier Vandenspiegel

**Source:** *Memoirs of Museum Victoria* 64:53–70. (2007) [also available at: <http://museumvictoria.com.au/pages/3660/64-o-loughlin-vandenspiegel.pdf>].

A new chiridotid genus is erected: *Archedota* O'Loughlin gen. nov. In addition, seven apodid species, new to science, are described (O'Loughlin as author) for the rocky shallows, continental shelf and continental slope of southern Australia: chiridotids *Archedota lapidea*, *Taeniogyrus papillis*, *Taeniogyrus tantulus*, *Trochodota epiphyka*; myriotrochids *Prototrochus burni*, *Prototrochus staplesi*, *Prototrochus taniae*. *Taeniogyrus heterosigmus* Heding, *Taeniogyrus roebucki* (Joshua), *Trochodota allani* (Joshua) and *Trochodota shepherdii* Rowe are discussed. Keys are provided for southern Australian species of *Taeniogyrus* Semper and *Trochodota* Ludwig. A table is provided distinguishing Tasman Sea myriotrochid species.

### **Additions to the holothuroid fauna of the southern African temperate faunistic provinces, with descriptions of new species**

A.S. Thandar

**Source:** *Zootaxa* 1697:1–57. (2008)

This paper is the third and the final one in the series reporting on the numerous lots of unidentified holothuroids received from the South African and Natal Museums. While the first two papers were limited to the fauna of the subtropical east coast, this paper is limited to the fauna of the temperate region of southern Africa, west of the Port St. Johns-East London area, encompassing the warm and cold temperate faunistic provinces, stretching into Namibia. It records and/or describes 23 nominal and four indeterminate spe-



cies of mostly dendrochirotid holothuroids. Altogether seven new species and three new records for the region under consideration are included and some new data presented for previously described but poorly known species, where this was lacking. The new species are *Sclerothyone unicolunus*, *Ocnus rowei*, *Cladodactyla brunspicula*, *Panningia trispicula*, *Psolidium pulcherrimum*, *P. pseudopulcherrimum* and *Synallactes samyni* whereas the new records for South Africa are *Pannychia moseleyi* Théel; for the temperate region, *Pawsonellus africanus* Thandar; and for Namibia, *Pseudoaslia tetracentriophora* Hedding.

### Report on the survey of sea cucumbers conducted at St. Brandon, Mauritius

A. Laxminarayana, Adviser in Fisheries

A survey of sea cucumbers was made at St. Brandon during 6<sup>th</sup> to 10<sup>th</sup> November, 2006. In the Ille du Sud, the major species was *Actinopyga mauritiana* with a mean weight of 500 g and mean length of 8 cm. The total quantity present in the area was 7200 kg (un-processed wet weight). Fairly good numbers of *A. milaris* with a mean weight of 1 kg and mean length of 18 cm were present in the location. The chalkyfish, *Bohadschia marmorata* was also present in good numbers with a mean weight of 550 g and mean length of 20 cm. Three specimens of *Holothuria nobilis* with a mean weight of 1.5 kg and mean length of 20 cm were found. Good numbers of *A. echinites* were also found in the site. The dominant species found was *H. atra* with a mean weight of 250 g and mean length of 18.5 cm.

A survey was made around the Coco Island. In the east of the island, specimens of *Theilonota ananas* with a mean weight of 6.25 kg and mean length of 54 cm were found. *B. marmorata* was found in good concentration with a mean weight of 1 kg and mean length of 18 cm. The species found in fairly good numbers were *Stichopus chloronotus* (mean weight of 300 g and mean length 20 cm) and *A. milaris* (mean weight 1 kg and mean length 18 cm). In all the sites surveyed around Coco Island, the dominant species found was *H. atra*.

Fourteen sites were identified around Ille Rephael at various depths from 1.5 m to 19 m. The species found during the survey were *S. chloronotus*, *A. milaris*, *H. pervicax*, *H. fuscofunctata* and *H. atra*. Some of the sites were ideal locations for *H. scabra*, *H. scabra versicolor* and *H. fuscogilva* but no specimens were found during the survey.

A survey made around Ille Paul showed the presence of large quantities of *H. atra* and *S. chloronotus*.

### Density and size distribution of the sea cucumber, *Holothuria scabra* (Jaeger 1935), at six exploited sites in Mahout Bay, Sultanate of Oman

Khalfan M. Al-Rashdi, Michel R. Claereboudt and Saud S. Al-Busaidi

Source: Agricultural and Marine Sciences, 12:43-51 (2007)

A rapid survey of the density and size distribution of recently exploited populations of *Holothuria scabra* in Mahout Bay (Ghubbat Hashish Bay) was carried out at six fishing sites. The results showed that population densities varied between 1170 and 4000 individuals ha<sup>-1</sup> and biomass ranged between 393 and 2903 kg ha<sup>-1</sup>. The mean size of sea cucumbers and population densities were much lower in populations closer to human settlements, suggestive of overfishing. The sex ratio was estimated to be 1:1 and the size distributions of males and females did not differ significantly. The length-weight relationship for both sexes was calculated as  $W (g) = 0.033 \text{ Length (mm)}^{2.178}$ .

### Stimuli-responsive polymer nanocomposites inspired by the sea cucumber dermis

Jeffrey R. Capadona, Kadiravan Shanmuganathan, Dustin J. Tyler, Stuart J. Rowan, Christoph Weder

Source: Science 7 March 2008: Vol. 319(5868):1370–1374. [also available at: <http://www.sciencemag.org/cgi/content/short/319/5868/1370>]

Sea cucumbers, like other echinoderms, have the ability to rapidly and reversibly alter the stiffness of their inner dermis. It has been proposed that the modulus of this tissue is controlled by regulating the interactions among collagen fibrils, which reinforce a low-modulus matrix. We report on a family of polymer nanocomposites, which mimic this architecture and display similar chemoresponsive mechanic adaptability. Materials based on a rubbery host polymer and rigid cellulose nanofibers exhibit a reversible reduction by a factor of 40 of the tensile modulus, for example, from 800 to 20 megapascals (MPa), upon exposure to a chemical regulator that mediates nanofiber interactions. Using a host polymer with a thermal transition in the regime of interest, we demonstrated even larger modulus changes (4200 to 1.6 MPa) upon exposure to emulated physiological conditions.

## Articles from the magazine *Fish for the People*

### Conserving and managing the sea cucumber resources in Southeast Asia: SEAFDEC Initiative

R. Bumrasarinpai

**Source:** *Fish for the People* 5(2):8–9. (2007)

The present trend in the ASEAN towards overfishing of sea cucumbers in commercial species especially under the Families Holothuriidae and Stichopodidae to support international market demand, has become an urgent concern in the international community, particularly at the Convention on International Trade in Endangered Species (CITES). There have been very limited studies and collection of information on the biology and production of sea cucumbers in the ASEAN countries. Nonetheless, sea cucumbers clearly represent an economically important fisheries resource in the region but inadequate attention is given to the management of these species and its fisheries status is not very well known.

The ongoing global initiative to possibly include sea cucumber in commercial species in the CITES Appendices has alarmed the ASEAN countries as this would greatly affect the region's sea cucumber fisheries. In order to address such concern, ASEAN and SEAFDEC convened the Preparatory Meeting on Environmental Related Tasks in October 2005 in Bangkok, Thailand to discuss this issue. The outcome was submitted to the 8th Meeting of ASEAN- SEAFDEC Fisheries Consultative Group (FCG) and the 38th Meeting of SEAFDEC Council held in April 2006 in Brunei Darussalam, during which the following proposals were approved:

- Conduct of a regional comprehensive compilation of data and information on sea cucumbers; and
- The management of sea cucumber resources should be the purview of competent national fisheries agency

Subsequently, SEAFDEC organized the ASEAN-SEAFDEC Regional Technical Consultation on International Fisheries Related Issues in September 2006 in Phuket Thailand, where updated information on sea cucumber in commercial species proposed for listing under CITES and the relevant initiatives undertaken by FAO were provided. The Consultation reaffirmed the need to conduct a regional study on sea cucumber fisheries, utilization and trade and reiterated its recommendation that economically important sea cucumber species should not be listed under any of the CITES Appendices.

### Efforts to conserve sea cucumber resource

L.L. Labe, L.K.C. Acera, N.A. Romena, V.V. Manlulu

**Source:** *Fish for the People* 5(2):10–12. (2007)

## Reports from the University of Guam Marine Laboratory

The two following reports and others are available from: <http://mangilao.uog.edu/marinelab/technical-reports.html>

### The shallow-water echinoderms of Yap – Results of a survey performed 27 July to 9 August 2007, including a stock assessment of commercially valuable species

A.M. Kerr, K.H. Netchy and S.M Hoffman

**Source:** University of Guam Marine Laboratory Technical Report 121. (2007).

[also available at: <http://mangilao.uog.edu/marinelab/publications/uogmltechrep121.pdf>]

Yap has an abundance of commercially valuable species of holothuroids (sea cucumbers) and is currently being targeted by at least three foreign buyers of the processed product, beche-de-mer. The Yap State government has realized the danger of overharvesting this valuable resource and is currently seeking to develop a management plan that will permit a sustainable level of harvesting. We performed a survey of holothuroids and other echinoderms around the main island to 1) assist in a stock assessment of commercially valuable species and 2) document Yap's echinoderms as part of a global survey of coral reef biodiversity. In a total of nine days of surveying, 19 sites were visited around the island. Several commercially valuable species of holothuroids inhabited Yap's waters, some in abundance. The most valuable species seen were *Holothuria (Microthele) whitmaei* (trade name: black teatfish), *Holothuria (Metriatyla) scabra* (sandfish) and *Thelenotananas* (prickly redfish). A total of 66 taxonomic units attributable to species have now been identified

from Yap's waters: 33 holothuroids, 14 echinoids, 14 asteroids and 5 crinoids. At least four (12%) of the holothuroids are in all likelihood new to science and formally undescribed. Based on our brief survey, our preliminary recommendations for a beche-de-mer management plan include: 1) Institute a moratorium on fishing until a management plan is in place. 2) Conduct an inventory of the island's commercially valuable species. 3) Institute minimum harvestable lengths for each species. 4) Institute temporary closures to increase stock size and value. 5) Increase public awareness and teach monitoring methods to villages. 6) Continually assess the effectiveness of the management plan and modify it when necessary. We discuss all these measures at greater length in the report.

### **Survey of the shallow-water sea cucumbers of the central Philippines**

*A.M. Kerr, K. Netchy and A.M. Gawel*

**Source:** University of Guam Marine Laboratory Technical Report 119 (2006) [also available at: <http://mangilao.uog.edu/marinelab/publications/uogmltechrep119.pdf>]

## **Announcement:**

### **4th Workshop of German & Austrian Echinoderm Research, 24–26 October 2008**

**Location:**

Naturhistorisches Museum Wien, Burgring 7, Vienna, Austria

**Organisation and contact:**

Andreas Kroh and Brigitta Schmid

Naturhistorisches Museum Wien

Geologisch-Paläontologische Abteilung / Abteilung für Ausstellung und Bildung

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Please consult the circular for registration and further information:

[http://www.nhm-wien.ac.at/Content.Node/forschung/geologie/mitarbeiter/pdfs/Zirkular1\\_EN.pdf](http://www.nhm-wien.ac.at/Content.Node/forschung/geologie/mitarbeiter/pdfs/Zirkular1_EN.pdf)

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