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BECHE-DE-MER

information bulletin

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From Chantal Conand

Twenty years ago when I accepted to start the *SPC Beche-de-mer Information Bulletin*, I was far from thinking that holothurian fisheries, although important for some countries, would become a subject of worldwide interest. They have evolved progressively from the traditional tropical Indo-Pacific activities, to more industrial fisheries in most countries where the resource has been found. During these years, the needs and possibilities, via Internet, to share the originally scarce information have exploded! The *SPC Beche-de-mer Information Bulletin* bulletin developed and is presently very well known, read and used for references.

I am very thankful to SPC's Marine Resources Division director, officers and staff, with a special mention to Aymeric Desurmont, for their continuous efforts to edit, translate and disseminate the issues with enthusiasm and on time. It has been a pleasure for me to be a part of this long-lasting collaboration.

Many thanks to all the contributors; this bulletin is yours! You were mostly from fishery or biological fields at the beginning, but now the fields are very different and specialised and include, for example, taxonomy, genetics, and cellular biology to pharmaceutical uses.

During these years, I have tried to encourage young scientists to publish their observations, helping them in any way that I could, when they were preparing their first contribution on a fishery or on a country. Despite the fact that the bulletin is not a refereed journal (which in the present rush for indexed publications discourages some writers), the contributions are always cited and the general opinion is that the bulletin is very useful.

I finally thank Igor Eeckhaut who, notwithstanding his many responsibilities, has accepted to co-edit this issue and become the future editor. I am sure that he will help to develop this bulletin according to the wishes of the different contributors and readers interested in this particular fishery, which now deserves more international attention, but urgently needs management.

Chantal Conand

Brief tribute to Chantal Conand, outgoing editor

When I was a junior officer with the Fiji Fisheries Division in the 1980s, the boss asked me to draft a briefing paper on the state of the beche-de-mer industry for Cabinet. Worries were being expressed at the rapid escalation in the number of companies applying for export licences. Cabinet needed to know how much fishing was actually taking place and what level of exports could be sustained in this hitherto small-scale fishery.

I talked to old hands at the Fisheries Division, I talked to fishermen, I talked to exporters and I talked to the Customs Department. I even went to the library and looked up documents from the previous century, and was able to build a picture of the history of the beche-de-mer fishery in Fiji and put the latest spike of exploitation into some sort of context. But I wasn't able to include much science. There just didn't seem to be much published about tropical sea cucumbers, particularly from a fisheries management perspective. My Cabinet paper had plenty of local information in it, but didn't provide much guidance about sustainability, about growth rates, spawning seasons, preferred habitats, or what the population density should be for a healthy natural stock.

Chantal Conand's work came as a godsend. Through her FAO Technical Report, and through the 1988 SPC Inshore Fisheries Resources Workshop, she communicated her own seminal work on holothurians together with an authoritative overview of everything else that was known, and likely to be of value in managing the exploitation of these species, at the time. As a result, my next briefing was greatly improved.

That 1988 SPC workshop also led to the setting up of a number of Special Interest Groups — networks of experts on particular fishery resources of particular interest to Pacific Island fisheries managers — but for which there seemed to be a general scarcity of information. These networks were facilitated by the publication of a six-monthly (or so) bulletin, which would provide both an opportunity for Pacific Island fisheries scientists to disseminate their own practical knowledge to each other, and for research in the rest of the world to be distilled for the benefit of Pacific Island fisheries managers.

This *Beche-de-mer Information Bulletin* is one such Special Interest Group (SIG), and Chantal, as SIG coordinator and voluntary editor-in-chief, has been both stalwart and inspirational in leading its production since 1990. SPC, the Pacific Island fisheries community, and holothurian research in general, owe her a large vote of thanks.

This will be the 28th issue of the Bulletin. A measure of its relevance is the fact that it has grown from 12, to more than 50 pages during the course of its life so far, and it has found a much wider readership on the worldwide web. It is no longer just a Pacific resource, but an international resource.

We wish Chantal all the very best for the future, and we're very glad to be able to continue to call upon her wisdom during the transitional period as she co-edits this issue of the Bulletin together with the future editor, Igor Eeckhaut.

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



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

Editorial

When Chantal asked me to take over as the scientific editor of the *SPC Beche-de-Mer Information Bulletin*, I was first astonished because many contributors of the bulletin were much more involved in the biology of holothurians than I was. I was indeed first interested in echinoderm biology and in the ecology of organisms living in association with them. For 10 years now, I have been involved in sea cucumber aquaculture projects, which has allowed me to discover another world, different but very exiting too, where science interacts with socioeconomic issues. On reflection, I am really proud to take up the challenge and I hope to maintain, with the help of contributors, the quality and diversity of articles.

This issue begins with a summary of the FAO Fisheries Technical Paper “Sea cucumbers. A global review on fishery and trade”, now in press, following the FAO International Workshop on the Sustainable Use and Management of Sea Cucumber Fisheries (Toral-Granda et al., p. 4).

Friedman et al. (p. 7) report on the development of a management plan for Yap’s sea cucumber fishery. Yap State is one of four states that make up the Federated States of Micronesia. The status of sea cucumber fisheries and a management plan for Saudi Arabian sea cucumbers are discussed by Hasan (p. 14).

Eeckhaut et al. (p. 22) discuss how the first sea cucumber-based trade company in Madagascar was recently started. New processing methods used in the Toliara area of Madagascar are also reported on by Lavitra et al. (p. 24).

Mulochau and Conand (p. 34) inventoried the sea cucumbers of the Glorieuses archipelago. Today, these islands are nature reserves, which are useful for comparing anthropogenic effects on sea cucumber populations.

Aydin gives information on Turkey’s sea cucumber fisheries, which is rapidly expanding and is already exporting more than 70 metric tonnes per year (p. 40). Ruffez (p. 42) explains the dramatic situation of scuba divers in Viet Nam who catch sea cucumbers. Some fishers dive as much as five times a day, each dive lasting more than 30 minutes, which leads to serious illness.

Results from experiments testing the influence of commercial diets on *Holothuria scabra* var. *versicolor* are reported on by Giraspy et al. (p. 46). Purcell et al. (p. 53) note that there are no good tags for mark-recapture studies on tropical sea cucumbers. The authors estimate the effectiveness of passive induced transponder (PIT) tags on two species of sea cucumber.

Many abstracts (p. 56) on holothurians have been published recently. Two PhD theses concerning sea cucumbers were defended in 2008, and include “Impact of removal — A case study on the ecological role of the commercially important sea cucumber *Holothuria scabra* (Echinodermata: Holothuroidea) in Moreton Bay, Australia” presented by Svea Mara Wolkenhauer (CSIRO – Australia) and “Characterization, control and optimization of the processes involved in the postmetamorphic development of the edible holothuroid *Holothuria scabra* (Jaeger, 1833) (Holothuroidea: Echinodermata)” by Thierry Lavitra (University of Mons-Hainaut, Belgium).

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>. The database of all articles and abstracts published in the bulletin to date were put together by SPC’s Fisheries Information Section, and are available on SPC’s website at: http://www.spc.int/coastfish/news/search_bdm.asp. Each search result is presented with a hyperlink that allows downloading in pdf format.

Igor Eeckhaut

Sea cucumbers. A global review on fishery and trade

Verónica Toral-Granda, Alessandro Lovatelli, Marcelo Vasconcellos (eds)
and the Scientific Committee composed of:
Chantal Conand, Jean-François Hamel, Annie Mercier, Steve Purcell and Sven Uthicke

Introduction

Following the FAO International Workshop on the Sustainable Use and Management of Sea Cucumber Fisheries, held in Puerto Ayora, Galapagos Islands, Ecuador, in November 2007 (see Toral-Granda et al. 2008), the global sea cucumber fishery review has been finalized and will be published by the UN Food and Agriculture Organization. The document will be available in November 2008 under the following reference:

Toral-Granda V., Lovatelli A. and Vasconcellos M. (eds). 2008. Sea cucumbers. A global review on fishery and trade. FAO Fisheries Technical Paper No. 516. Rome, FAO. 319 p.

The executive summary of this document is reproduced below.

Executive summary

Sea cucumbers (Echinodermata: Holothuroidea), or their dried form (beche-de-mer), have been a dietary delicacy and medicine for Asians over many centuries. The collection of sea cucumbers to supply the market has seen a depletion of this resource in the traditional fishing grounds close to Asia and more recently the expansion of this activity to new and more distant fishing grounds. Currently, there are fisheries harvesting sea cucumbers across most of the resource range, including remote parts of the Pacific, the Galapagos Islands, Chile and the Russian Federation. This global review shows that sea cucumber stocks are under intense fishing pressure in many parts of the world and require effective conservation measures. It also shows that sea cucumbers provide an important contribution to economies and livelihoods of coastal communities, being the most economically important fishery and non-fish export in many countries. Reconciling the need for conservation with the socio-economic importance of sea cucumber fisheries is shown to be a challenging endeavour, particularly for the countries with limited management capacity. Furthermore, no single management measure will work optimally because of the many idiosyncrasies of these fisheries, which are shown in this document through a comprehensive review of their biological and human dimensions.

The present document reviews the population status, fishery, trade, management and socio-economic importance of sea cucumbers worldwide. It includes regional reviews and hotspot case studies prepared by leading experts on sea cucumber fisheries and their management. These preceded the FAO Work-

shop on Sustainable Use and Management of Sea Cucumber Fisheries, held in Puerto Ayora, Galapagos Islands, Ecuador, from 19 to 23 November 2007 (workshop agenda, list of participants and their profiles are appended).

Reviews were prepared for five regions: Temperate areas of the Northern Hemisphere (including Canada, Iceland, Russian Federation and the United States of America); Latin America and the Caribbean; Africa and Indian Ocean; Asia; and Western Central Pacific (including Australia). In each region, specialists conducted a case study of a "hotspot" country or fishery to highlight topical or critical problems and opportunities for the sustainable management of sea cucumber fisheries. The five hotspots are: Papua New Guinea (Western Central Pacific); Philippines (Asia); Seychelles (Africa and Indian Ocean), Galapagos Islands (Latin America and the Caribbean); and the *Cucumaria frondosa* fishery of Newfoundland in Canada (Temperate areas of Northern Hemisphere).

A multitude of sea cucumber species are being exploited worldwide, with new species being brought to market as established species become scarcer and more difficult to find. Across the five regions, the number of commercially exploited species varies widely, with the highest number of species exploited in the Asia (52 species) and Pacific (36 species) regions partially due to the higher natural diversity in these areas. But still, little is known about the ecology, biology and population status of most commercial species, and in many cases, species are being commercialised without a clear taxonomic identification (e.g. the "pentard" in the Seychelles, *Actinopyga* sp. in Yap). Information on

catches is also scarce, as these fisheries operate over large scales in often remote locations. In view of the importance of international trade, export and import statistics of beche-de-mer are in many cases the only information available to quantify the magnitude of fisheries catches. Based on the most recent available catch and trade data, Asia and the Pacific are the top producing regions despite the long history of exploitation. Depending on the conversion factor used for the dry:wet weight of sea cucumbers, it is possible to infer that the combined catches for the Asia and Pacific regions are in the order of 20,000 to 40,000 tonnes (t) per year (yr). The temperate areas of the Northern Hemisphere are also responsible for a substantial share of the world catches (in the order of 9,000 t yr⁻¹); catches being sustained almost exclusively by one species (*Cucumaria frondosa*). Sea cucumber catches are relatively less important in Africa and in the Indian Ocean (2,000–25,000 t yr⁻¹) region and, is particularly low in Latin America and the Caribbean region (<1,000 t yr⁻¹).

Sea cucumber capture fisheries generally target a large variety of species, which adds complexity to management and trade reporting; and those that started as single-species fisheries have now progressed to include “new” species in their catches (i.e. fisheries in Peru and Chile). Four of the five hot spots reviewed in this document present multispecies fisheries, and in all cases they have moved from low quantity-high value to high quantity-low value ventures, as the more valuable species become fully-exploited or overexploited. Some regions have seen a dramatic increase in the number of species under commercial exploitation (e.g. Galapagos Islands, Philippines, Papua New Guinea, Solomon Islands), yielding more species to fishery pressure, as well as masking overexploitation and species-specific decreases in catches.

The majority of sea cucumbers are exported for the beche-de-mer market and few species for the live trade (aquarium) market, which is currently under-reported. There is also an emerging market for the use of sea cucumbers in the pharmaceutical, nutritional and cosmetic industries. The type of fishery varies with the region and the species under exploitation. Examples of different fishery types, ranging from artisanal (Papua New Guinea and Philippines), to semi-industrial (Galapagos Islands) and industrial (*Cucumaria frondosa* fishery in northern Canada), are described in the hotspot case studies. Hand collecting, gleaning, lead bombs, SCUBA diving, hookah and dredging are examples of fishing methods used.

Effective management plans for sea cucumber fisheries are uncommon. For example, the Seychelles and Papua New Guinea have adopted management plans for their fisheries, which came into place fol-

lowing concerns about declines in catches caused by unregulated harvesting. The Galapagos Islands sea cucumber fishery also started as an open-access activity, but after a long ban it re-opened in 1999 with an adaptive and participatory management scheme. The Philippines do not have a management plan in place despite some species now becoming locally endangered through overfishing. The *C. frondosa* fishery in Newfoundland (Canada) is still under an exploratory stage but aims at being managed through ecosystem-based guidelines. This fishery, unlike other sea cucumber fisheries, has the advantage of using a precautionary approach at the start of commercialisation, and has some of the most complete set of biological and population information on which to base a management plan. In spite of the lack of management plans in most locations described in the regional reviews, some management measures have been adopted to regulate fishing pressure, including closed seasons, minimum sizes, total allowable catches, gear restrictions, spatial and temporal closures and the establishment of marine protected areas. However, the lack of enforcement capacity has posed considerable constraints on the effectiveness of such management measures. The lack of enforcement and compliance is a common denominator for the majority of the fisheries reviewed in this document, and has exacerbated illegal, unreported and unregulated fishing and trade.

Sea cucumber populations are in dire straits in many parts of the world. This unfortunately includes high profile conservation sites such as the Great Barrier Reef Marine Park and the Galapagos Islands National Park (both World Heritage listed). These locations have well documented cases of sea cucumber population collapse, and subsequent population surveys showed no recovery of overfished stocks. The temperate areas of the Northern Hemisphere offer perhaps the few exceptional cases of abundant stocks still moderately exploited and with some potential for expansion. Despite the paucity of information available on sea cucumber fisheries in Latin America and the Caribbean, it appears that high valued commercial species have been depleted and the risk of fishery collapses is high due to the small size of stocks, the strength of market forces and the unregulated nature of these fisheries. In Africa and the Indian Ocean region, at least 12 out of 17 countries where sea cucumber fisheries have been documented show evidence of overfishing of sea cucumber stocks. Species are under heavy fishing pressure throughout the Asian Pacific region, whilst the most soughtafter species in the western Pacific are largely depleted.

Recognizing the importance of international trade as a threat to the conservation of sea cucumber species, consideration has been given to the pos-

sible role of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) as a complementary measure for regulating the sustainable use of sea cucumber fisheries. One species is currently listed in a CITES Appendix (*Isostichopus fuscus* in Appendix III by Ecuador) and the Galapagos Islands hotspot case study (this document) lists advantages and disadvantages based on this experience. The analysis of the situation in the Seychelles, Papua New Guinea and the Philippines asserts the possible benefits of CITES to sea cucumber populations, but indicate that a listing could lead to socioeconomic impacts as well as an increased administrative burden where institutional capacity is limited.

In many countries, particularly in the Western Pacific region, some sea cucumbers or their organs are consumed as delicacies or as a protein component to traditional diets. However, in the majority of the countries reviewed in this document, sea cucumbers are harvested to supply the Oriental market of beche-de-mer. Indonesia is the major exporter of sea cucumber from capture fisheries. On all importing countries and territories, China Hong Kong Special Administration Region (SAR), is the most important, with product arriving from most countries worldwide; whilst some countries, such as the United Arab Emirates in the Indian Ocean, have become “intermediate” markets. Although in most current fishing grounds, sea cucumber fishing is not a traditional activity the majority of rural coastal communities have developed a strong dependency on it, as alternative opportunities for income are often limited. High prices and the increasing demand from consumers have seen the expansion of the range covered by marine products agents, the development of capacity in these fisheries and an ongoing search for new species. In many regions, the socio-economic dependency on beche-de-mer is so vast, that fishers continue collecting sea cucumbers despite scant catches, further affecting the stocks capacity to reproduce and repopulate the fishing grounds. Generally, when one commercial species is depleted, or “economically extinct”, traders will encourage fishers to search for new species, or fish deeper or further a field, in order to continue their business.

Aquaculture, sea ranching and restocking have been evaluated as possible solutions to wild sea cucumber overexploitation, and some countries have started such ventures (e.g. Australia, China, Kiribati, Philippines, Viet Nam and Madagascar). Restocking has been considered an expensive remedy to overfishing. Presently, China is successfully producing an estimate of 10,000 tonnes dry weight of *Apostichopus japonicus* from aquaculture, mainly to supply local demand. This value, when converted into wet weight, is in the same order of

magnitude of the total world wild catches. A feasibility study is undergoing in Chile to evaluate the possible introduction of *A. japonicus*, as an alternative to capture fisheries of two wild species of sea cucumbers. In the Asia Pacific region aquaculture is still in the early development stages, with one species of sea cucumber (*Holothuria scabra*) in trials to ascertain the commercial viability of culture and farming options.

Many additional threats have been identified for sea cucumber populations worldwide, including global warming, habitat destruction, unsustainable fishing practices (e.g. blasting), the development of fisheries with little or no information on the species, and lack of natural recovery after overexploitation. Illegal, unregulated and unreported (IUU) fisheries are widespread in all regions, representing an indirect threat, as it fuels unsustainable practices and socio-economic demand. The critical status of sea cucumber fisheries worldwide is compounded by different factors including the lack of financial and technical capacity to gather basic scientific information to support management plans, weak surveillance and enforcement capacity, lack of political will and socio-economic pressure exerted by the communities that rely on this fishery as an important source of income. The fast pace of development of sea cucumber fisheries to supply the growing international demand for beche-de-mer is placing most fisheries and many sea cucumber species at risk. The pervasive trend of overfishing, and mounting examples of local economic extinctions, urges immediate actions for conserving stocks biodiversity and ecosystem functioning and resilience from other stressors than overfishing (e.g. global warming and ocean acidification), and therefore sustaining the ecological, social and economic benefits of these natural resources.

Reference

Toral-Granda V., Lovatelli A., Vasconcellos M. and the Scientific Committee composed of Conand C., Hamel J.F., Mercier A., Purcell S. and Uthicke S. 2008. International Workshop on the Sustainable Use and Management of Sea Cucumber Fisheries, Puerto Ayora, Galapagos Islands, Ecuador, 19–23 November 2007. SPC Beche-de-Mer Information Bulletin 27:2–3.

Copies of FAO Fisheries Technical Paper No. 516 can be obtained by contacting Alessandro Lovatelli (Email: alessandro.lovatelli@fao.org).

Development of a management plan for Yap's sea cucumber fishery

K. Friedman¹, E. Ropeti¹ and A. Tafleichig²

Introduction

Yap State is one of four states that make up the Federated States of Micronesia (FSM); the others are Pohnpei, Chuuk and Kosrae. Yap is the westernmost island in FSM, located roughly midway between Guam and Palau. Yap's outer islands stretch eastward for about 1,200 km. Its main islands (also referred to as Yap Proper) consist of Yap, Gagil, Tomil and Rumung (Manoa Mapworks and Sea Grant College Program 1988, see Fig. 1). Yap has 10 municipalities that oversee both Yap Proper and the atolls of Eauripik, Elato, Fais, Faraulep, Gaferut, Ifalik, Lamotrek, Ngulu, Olimarao, Piagailoe (West Fayu), Pikelot, Sorol, Ulithi and Woleai, Satawal, Elato and Faraulap. The total area of Yap's shallow water reefs and lagoons is less than 120 km².

The population of Yap State is estimated to be 12,000, with 66% of the population residing on the main islands of Yap Proper, while the remaining 34% live in the outer islands.

Like most other small island states, coastal communities in Yap have limited income earning potential, but their coastal waters are rich in marine life (Hasurmai and Fanafal 2004; Hasurmai et al. 2005) and valuable fisheries resources, including sea cucumbers (Beardsley 1971; Smith 1992; Richmond 1999; Kerr et al. 2007). Although sea cucumbers are not traditionally harvested as a protein source by Yap communities, the fishery has been active for short periods since the 1800s, mainly for export to Asian markets. In the early 1900s, harvests resumed when the Japanese were present after 1914.

Background to recent fishing activity and management interventions

There was a pulse of sea cucumber fishing activity in Yap around 1995, although commercial fishing was quickly stopped due to concerns over the status of sea cucumber stocks and the sustainability of such a fishery within a relatively small reef system. More recently, with an increase in size and demand

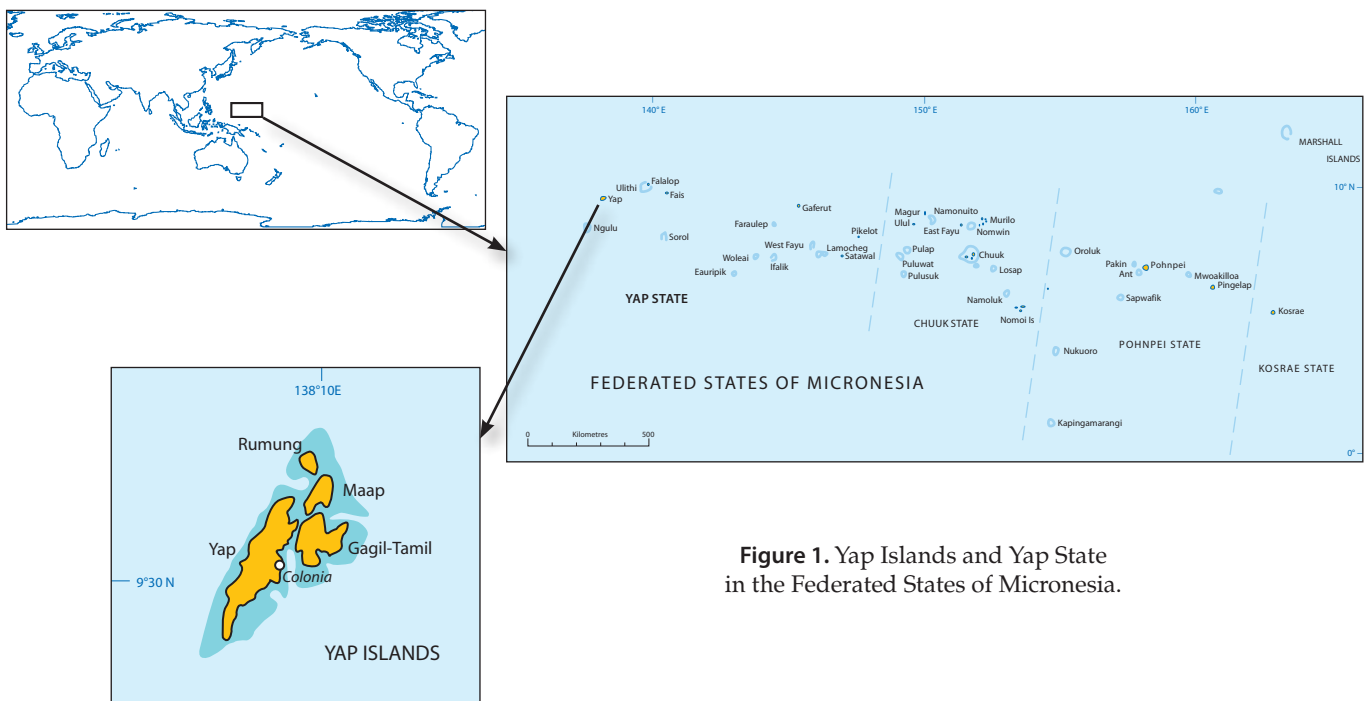


Figure 1. Yap Islands and Yap State in the Federated States of Micronesia.

1. Secretariat of the Pacific Community (SPC), Noumea, New Caledonia
2. Marine Resources Management Division (MRMD) of Yap

from markets in China, which has occurred concurrently with production declines in other parts of the Pacific, fishing effort has again focused on Yap. Fishing activity resumed in 2003, although in late September 2007, there was another moratorium on exports, due to concerns over unregulated fishing. This moratorium was declared to allow time for the development of a management plan that would regulate the fishery. Unlike the situation in other parts of the western Pacific (e.g. Papua New Guinea, Fiji, Solomon Islands) where large interconnected reef systems are associated with large land masses, Yap's smaller and more isolated reef system was recognized as being more susceptible to overfishing.

Recent surveys have documented the status of sea cucumber resources in Yap (Smith 1992; SPC 2006; Kerr et al. 2007), and have identified at least 20 commercial species (Table 1). The surveys revealed signs of impact from fishing pressure (or deficiencies in environmental capacity), but highlighted the fact that stocks were not as depleted as other sea cucumber fisheries in the Pacific, and therefore offered

some potential for commercialisation. Although these studies also noted the ecologically important role played by sea cucumbers, the potential environmental impacts of beche-de-mer harvesting are poorly understood. For example, all sea cucumbers extract bacteria and organic matter from bottom sediments, and some are responsible for bioperturbation and oxygenation of the sea floor. Consequently, intensive collection may cause changes to the condition and nature of seafloor sediments with associated unknown impacts on water quality and other resources.

Data from the beginning of the most recent period of export activity are not comprehensive, however when the fishery gained momentum in 2006 and 2007, some data were collected by Yap's Marine Resources Management Division (MRMD). From these records (sourced from the three agents/processors active in this latest activity), the amalgamated exports from Yap State (Yap Proper and the outer islands) reached 17.3 tonnes (t) dry weight for 2007 alone (equivalent to approximately 230 t wet weight). This represents an alarmingly large catch given the limited scale of

Table 1. Marketable sea cucumber species groups found in Yap State. The "premium" and "standard" labelling relates to different management requirements for beche-de-mer exportation.

No	Qualification	Marketable species group	Scientific names
1	"premium"	Black teatfish (BTF)	<i>Holothuria whitmaei</i>
2	"premium"	White teatfish (WTF)	<i>Holothuria fuscogilva</i>
3	"premium"	Prickly redfish (PRF)	<i>Thelenota ananas</i>
4	"premium"	Sandfish and golden sandfish (SandF)	<i>Holothuria scabra</i> , and <i>H. scabra versicolor</i>
5	"premium"	Surf redfish (SRF)	<i>Actinopyga mauritiana</i>
6	"premium"	Stonefish (StoneF)	<i>Actinopyga lecanora</i>
7	"premium"	Blackfish (BF)	<i>Actinopyga miliaris</i> and <i>Actinopyga</i> spp.
8	"premium"	Leopardfish or tiger (TF)	<i>Bohadschia argus</i>
9	"premium"	Curryfish (CF)	<i>Stichopus herrmanni</i> and <i>Stichopus vastus</i>
10	"premium"	Amberfish (AF)	<i>Thelenota anax</i>
11	"premium"	Greenfish (GF)	<i>Stichopus chloronotus</i>
12	"premium"	Elephant trunkfish (ETF)	<i>Holothuria fuscopunctata</i>
13	"premium"	Brown sandfish (BSF)	<i>Bohadschia vitiensis</i> and <i>B. bivittata</i> and <i>B. koellikeri</i>
14	"premium"	Deepwater redfish (DRF)	<i>Actinopyga echinites</i>
15	"standard"	Lollyfish (LF)	<i>Holothuria atra</i> ; can include (PF)
16	"standard"	Pinkfish (PF)	<i>Holothuria edulis</i>
17	"standard"	Snakefish (SnakeF)	<i>Holothuria coluber</i> and <i>Holothuria (semperothuria) non flavomaculata</i>
18	"standard"	Flowerfish (FF)	<i>Pearsonothuria graeffei</i>
19	"standard"	Peanutfish (PF)	<i>Stichopus horrens</i> and <i>S. monotuberculatus</i>
20	"standard"	Chalkfish (CF)	<i>Bohadschia similis</i>
21	non commercial	Candycanefish (CCF)	<i>Thelenota rubralineata</i>

the fishing grounds. The income derived from the catch would have been significant if large beche-de-mer were exported at market rates.

An examination of 10 t of this export revealed that nine marketable species groups were exported, with the “blackfish group” (*Actinopyga miliaris* and *Actinopyga* spp.) and the “lollyfish group” (*Holothuria atra* and sometimes *H. edulis*) being the most important in terms of weight (Fig. 2). Other records, which shed light on day fishing, showed that in late 2007, up to 1.5 t (wet weight) of the “blackfish group” was being taken by one agent/processor alone, prior to the fishery’s closure. This agent bought wet sea cucumbers from resource owners for 21 of the last 30 days before the fishery’s closure. This represents an unusually heavy period of exploitation, especially if fishers are solely targeting the correct adult size groups and processing a quality product for market. Anecdotal evidence suggests that the fishery was not operating at an optimum rate during this period, with product sizes and quality compromised. The moratorium and the development of management options were therefore timely.

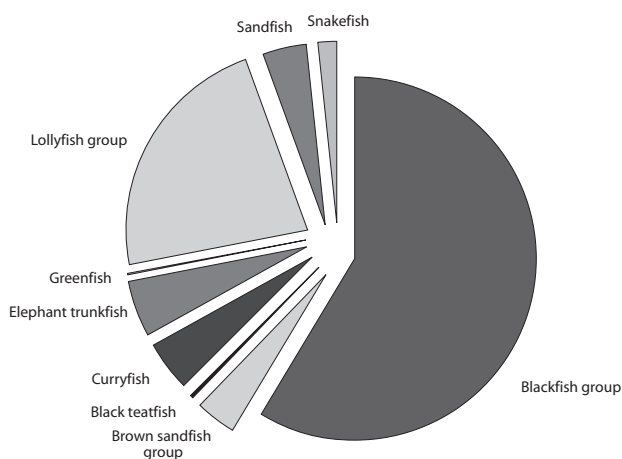


Figure 2.

Indicative breakdown of 10 t of beche-de-mer exports.
Data collected by MRMD.

Formulation of a management plan

In June 2008, a management plan for the commercialisation of sea cucumber resources was developed in response to a request for technical assistance by Yap MRMD to the Secretariat of the Pacific Community (SPC).

SPC’s Coastal Fisheries Programme assisted through both its management and research sections. SPC draws on data collected by its Reef Fisheries Observatory (a comprehensive database of over 74 week-long, in-water surveys conducted across 17

Pacific Island countries since 2002), and the organization’s experience in various management initiatives conducted across the Pacific.

The management plan was developed through a process driven by the government of Yap, resource custodians, and other industry stakeholders, and facilitated by SPC. This ensured the process was as inclusive as possible, and that there was wide ranging, local ownership of the direction and outcome of the management plan from the very start. Management undertakings were identified through discussions held with the Governor of Yap State, the Honourable Sebastian L. Anefal, Lieutenant Governor Hon Anthony M. Tareg, director of the Department of Resources and Development, Michael Gaan, plus resource custodians and stakeholders in general consultations and a two-day workshop conducted in Colonia 17–18 July 2008 (Fig. 3).



Figure 3. Stakeholders’ consultations during a two-day sea cucumber management workshop.

The purpose of the management plan is to guide the exploitation, processing and export of Yap’s sea cucumber resources. In the absence of any substantive historical data and technical information, and with the limited scale of scientific assessment that has been completed to date, the management plan imposes sensible and locally relevant principles, using a “precautionary approach”, to the exploitation of sea cucumbers in order to achieve the overall management vision articulated by stakeholders: “Have community and government cooperation, to sustain harvests and optimise incomes, whilst maintaining reef and local coastal environments”. The ultimate goal of the management plan was also stated: “To promote economic improvement for peoples of Yap whilst maintaining sustainable harvest and stock levels.”

The management plan is in the process of being finalised, and provides the framework for the state authority to guide the exploitation and harvesting of sea cucumbers in Yap. The recommended management actions require a joint effort and close collaboration between government, resource owners,

communities and agents in order to ensure sustainable utilisation, and to optimise economic returns for everyone.

Below are some important issues related to the process.

- 1) A management framework for the exploitation of sea cucumbers in the State of Yap (SOY) is only now being developed. In 2008, the SOY put in place an amendment of Chapter 10 of Title 18 of Yap's State Code, especially relating to sea cucumbers (Bill no. 7-57, D2, Yap State Law No. 7-35). Regulations that are to be developed around management undertakings stipulated in the management plan will operate under this new legislation.
- 2) There is some work needed to get the MRMD, which is a divisional branch office by law under the Department of Resources and Development, formally charged with conservation, management and development of SOY's marine resources, as by statute, the Yap Fishing Authority (YFA) is also mandated to carry out similar, if not the same, role. Efforts to address this overlap in the past have been unsuccessful.
- 3) The development of a management plan benefits from the social and geographic scale and structure of Yap, and the centralisation of export activity to the capital, Colonia. However, it also needs to address deficiencies in the availability of human capital and finance for ongoing management actions and enforcement.
- 4) There was consensus in consultative meetings that the management plan be developed around a number of recognised actions that needed to be taken by the main authority (state government and MRMD) and commercial agents. It was recognised early on in consultations that community level initiatives would be difficult to enforce, and therefore these would be allocated, but were usually non-proscriptive (see Foale 2007).
- 5) The management plan should be clear and readable for the average user, and flexible, so as to allow ongoing development, as more stock information and an understanding of the fishery emerge.

The main initiatives in the management plan are listed below.

- The management plan should cover all operations of the sea cucumber fishery in the SOY, including the outer islands
- Fishing should only be permitted for part of the year (suggested season August–December).
- The Authority should restrict the harvesting and collection of sea cucumbers for export to a specific list (commercial species groups in Table 1). In the matter of new species suggested for export, scientific advice will be sought before they may be considered for inclusion in the export list.
- MRMD should conduct “out of season” independent checks of stock and habitat. An independent survey or stock assessment should be conducted on designated fishing areas at least every two years
- An industry meeting should be convened during the closed season each year, to discuss last season's catches, independent survey results, and submissions from community leaders and fishers. This will allow time for reflection on the status of the fishery and a period for any realignment of management plan settings prior to the opening of the fishery. The option of discussing information prior to a new season, also allows the governor an opportunity to cancel fishing, if there are indications of an intractable problem.
- The number of agents' licences should be limited to a maximum of three.
- Agents should be required to supply completed “Sea Cucumber Buying Sheets” to MRMD (Table 2A).
- Agents should be required to complete “Sea Cucumber Export Sheets” for MRMD (Table 2B).
- All exported sea cucumber products should leave the SOY through one exit point, namely the shipping port / airport at Colonia.
- Agents should be required to present packed products to the Authority two weeks prior to shipping, in order to allow the authority time for product inspection to determine if it complies with the management plan's guidelines.
- Commercial species groups that should be included in this management plan are described as either “premium” or “standard” (Table 1). A quota shall be set for “standard” species groups individually, while a more comprehensive quality control should be implemented for “premium” species groups (Table 3a & b). For export controls of “premium” species groups, shipments will be made and checked in 10-kg packages of beche-de-mer. Each package must only include beche-de-mer from a single “species group” and be labelled so as to be easily determinable for inspections made by the checking authority (for weight and counts). All “premium” species 10-kg packages need to include a maximum rate of dry sea cucumbers set out in Table 3a. The 10-kg packages allow agents to include product with a small weight variation around the specifications for individual dried sea cucumbers, as long as the 10-kg package as a whole complies with the maximum number of sea cucumbers allowed. The 10-kg packaging system also allows the Authority some ease of checking.
- This management plan should be reviewed and adapted to respond to activity and reports, which emerge from the fishery on an annual basis at first. Once the fishery matures, it should be possible to have more secure estimates around man-

agement measures and a review might be completed every two years.

- The use of any compressed air or underwater breathing apparatus (i.e. scuba and hookah) and trawl style nets should be strictly prohibited for commercial fishing.
- Although actions of communities were not controlled by the management plan, due to a lack of capacity for training and enforcement, there was an initiative to assist customary resource owners to designate part of their fishing grounds as reserve areas where the collection of sea cucumbers is prohibited (at least one area in every municipality).

- Increasing sea cucumber productivity through cutting (splitting) should be discouraged in the fishery, and is generally not a recommended approach to increasing the fishery's productivity.

Despite the fact that available information on the fishery's history was scant, and that stakeholders needed to assimilate a large amount of industry and scientific information in order to progress with formulating the management plan, the process went well. The most critical issue now is to ensure that the management plan is legally recognised under the authority of MRMD. This will need the state

Table 2. Record sheets.

A: Buyer Record Sheet
Marine Resources Management Division, Department of Resources & Development, P.O. Box 251, Colonia Yap FSM 96943

Date: ____/____/____ Sheet Number: ____/____

Name of processing company: _____ Recorder: _____

Fisher: _____ Municipality / Outer Island Group: _____

Marketable species group	Wet weight (lb and ounces)	Dry weight (not obligatory)	Comments

B: Export Record Sheet
Marine Resources Management Division, Department of Resources & Development, P.O. Box 251, Colonia Yap FSM 96943

Date: ____/____/____ Sheet Number: ____/____

Name of processing company: _____ Recorder: _____

Premium species groups			Standard species groups		
Marketable species group	Number of 10 kg packages	Total dry weight	Marketable species group	Number of bags	Total dry weight

Marketable species group codes.
 Premium species groups:
 Black teatfish (BTF); White teatfish (WTF); Prickly redfish (PRF); Sandfish and Golden sandfish (SandF); Surf redfish (SRF); Stonefish (StoneF); Blackfish (BF); Deepwater redfish (DRF); Leopardfish or tigerfish (TF); Curryfish (CF); Amberfish (AF); Greenfish (GF); Elephant trunkfish (ETF); Brown sandfish (BSF).

Standard species groups:
 Lollyfish (LF); Pinkfish (PF); Snakefish (SnakeF); Flowerfish (FF); ChalkFish (CF).

Table 3. Controls for “premium” and “standard” species groups for dry sea cucumbers (beche-de-mer).

a) Suggested maximum rate of “premium” species groups for dry sea cucumbers (beche-de-mer).

Species group	Wet (live) weight of required product (g)	Recovery rate wet to dry (%)	Dry weight of beche-de-mer (g)	Piece per kg	Maximum piece per 10-kg package
Black teatfish (BTF)	2,400	7.0	168.0	6	60
White teatfish (WTF)	2,500	8.0	200.0	5	50
Prickly redfish (PRF)	3,500	5.0	175.0	6	60
Sandfish (SandF)	750	5.0	37.5	28	280
Golden sandfish (SandF)	1,400	5.0	70.0	15	150
Surf redfish (SRF)	850	5.5	46.75	22	220
Stonefish (StoneF)	650	5.5	35.75	30	300
Blackfish (BF)*	500	5.5	27.5	37	370
Large blackfish (BF)* (<i>A. palauensis</i> ?)	1,500	5.5	82.5	12	120
Deepwater redfish (DRF)	400	5.5	22.0	45	450
Leopardfish or tiger (TF)	1,000	4.0	40.0	27	270
Curryfish (CF)	2,100	4.0	84.0	14	140
Amberfish (AF)	3,500	5.5	192.5	5	50
Greenfish (GF)	300	3.0	9.0	115	1,150
Elephant trunkfish (ETF)	2,000	10.0	200.0	5	50
Brown sandfish (BSF)	1,000	4.0	40.0	26	260

b) Suggested quota for “standard” species groups per season (2008).

Standard marketable species group	Scientific names	Quota (dry weight, kg)
Lollyfish (LF)	<i>Holothuria atra</i>	1,000
Pinkfish (PF)	<i>Holothuria edulis</i>	(included with Lollyfish)
Snakefish (SnakeF)	<i>Holothuria coluber</i> and <i>Holothuria (Semperothuria) non flavomaculata</i>	200
Flowerfish (FF)	<i>Pearsonothuria graeffei</i>	0
Peanutfish (PF)	<i>Stichopus horrens</i> and <i>Stichopus monotuberculatus</i>	0
Chalkfish (CF)	<i>Bohadschia similis</i>	0

code to legally recognise MRMD with the relevant powers to promulgate relevant policies and management plans to facilitate fisheries management in the state.

The ongoing overview of Yap’s sea cucumber fisheries and the management plan are “works in process” (Richmond 1991). The goal of better managing resources will never be encompassed and finalised in a simple document, and is necessarily tied to 1) changes in law, 2) ongoing capacity building in beche-de-mer recognition, 3) monitoring in-water stock status, and 4) industry development (including post harvest processing). Such developments might also include new initiatives. For example, a private company in Yap is planning to raise sea cucumbers, and there needs to be a process that allows the management plan to incorporate new rules for stock originating from

hatchery production, if these sea cucumbers are released into the wild.

There are also a number of weaknesses in the management plan that will need to be addressed over time, notably the control over monitoring the quality of export product. Although cheap to administer, this end-point control needs to be backed up with awareness raising for community fishers and agents alike, to ensure there is little wastage during fishing and processing. There is also the potential for some larger species, especially in the “blackfish group” (e.g. *Actinopyga palauensis*), to be exported under the current management plan format, but at a size that may compromise the “precautionary approach” ethos. Extra funding will be sought to answer these particular questions as they are identified to strengthen the management process as it moves forward.

The draft management plan has now gone through its last set of changes, as communities and stockholders had a final chance to review the draft document and make comments and suggestions. It is planned that the management plan be professionally edited in August–September 2008, and then printed for distribution in Yap. Presently, SPC and MRMD are formalising management undertakings stipulated in the management plan, as “regulations”, which will be promulgated in the near future.

Acknowledgements

This assignment would not have been possible without the kind assistance and support of the Governor, Lt Governor and staff of MRMD. The support of the Director of the Department of Resources and Development, Michael Gaan, needs special mention. Special thanks also to all the stakeholders, resource owners, community representatives and marine products agents who shared their vision and provided valuable information during the consultation.

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Fisheries status and management plan for Saudi Arabian sea cucumbers

Mohamed Hamza Hasan¹

Abstract

Sea cucumber resources in Saudi Arabia have long been exploited by an open access fishery with no management in place. The lack of information on the fishery makes it difficult to ascertain its characteristics, as well as determine sea cucumber stocks. Seven sea cucumber species are exploited mainly for the export market. Signs of stock reduction have become evident as fishers search for new fishing grounds and dive deeper and deeper to reach sea cucumber stocks.

The catch per unit of effort (CPUE) for the three major fishing grounds (Al-Wajh, Thowal and Farasan Islands) dramatically decreased during the two survey periods: April to August 2000 and February to July 2003.

A management plan was put in place to prescribe types of licence eligibility, licence requirements, export requirements, prohibition, closure and reporting requirements. It was suggested that licences should be closely monitored by the Saudi Ministry of Agriculture to ensure they comply with all management measures. In particular, reporting by exporters is important as these reports provide the only trade information that the Ministry of Agriculture collects. A total allowable catch must be set for all species. Trade of under-sized beche-de-mer must be completely banned to protect populations.

Introduction

The highest diversity of holothurians occurs in the tropics where multispecies fisheries take place. The Red Sea, as a part of the tropical system, suffers from multispecies overfishing (Hasan 2003, 2005; Hasan and Hasan 2004; Lawrence et al. 2004; El-Ganainy et al. 2006; Kalaeb et al. 2008). The rapid decline of sea cucumber populations worldwide for the beche-de-mer trade (Conand 2001) was the beginning of this fishery in Saudi Arabia's Red Sea in 1999. In the Saudi Arabian Red Sea, sea cucumbers are collected by hand while snorkelling or scuba diving at depths ranging from 2–40 m. Since the start of the fishery, a considerable number of sea cucumbers have been harvested, both legally and illegally, which has resulted in huge population declines. The constant reduction of sea cucumber populations in the Saudi Arabian Red Sea drives populations to very dangerous limits, which can yield changes in ecosystem functioning due to their important role as nutrient recyclers (Bakus 1973; Conand 1993). Saudi Arabia's sea cucumber fishery has undergone cycles in which the total catch decreases despite an increase in fishing effort. This in turn leads to the overexploitation of the species and low economic returns. The same phenomenon

has been reported in many other places around the world (Ibarra and Soberon 2002).

Due to the accelerating overexploitation of holothurians worldwide (Holland 1994; Conand and Byrne 1993; Conand 1998, 2004; Jaquemet and Conand 1999; Trianni 2002; Altamirano et al. 2004), management strategies must be adopted to address these stock depletions. Conservative management should be the key to sustainable sea cucumber fisheries.

Over the last decade, sea cucumbers in Saudi Arabia's Red Sea have been the target of a continuous fishery. The increasing growth of this activity and its potential impacts prompted Saudi Arabia's Ministry of Agriculture to ban the entire fishery. The current study is initiating a participatory management programme to assess and preserve sea cucumber stocks in Saudi Arabia. The objectives are to ensure that the economic and social benefits, together with environmental impacts of the fishery, are recognized. In recognition of data deficiencies and the strong incentives for rapid overexploitation, this work aims at discussing the available fishery data and preparing and implementing a management plan for sea cucumber stocks in Saudi Arabia's Red Sea.

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Materials and methods

Study sites

Site selection was based on the extent of sea cucumber fishing. In this respect, three areas were considered to be the main fishing grounds (Fig. 1): Al-Wajh, Thowal and the Farasan Islands.



Figure 1. Saudi Arabia and the three main sea cucumber fishing sites: Al-Wajh, Thowal and the Farasan Islands.

Al-Wajh area

This area is located in the northern part of the Saudi Arabian Red Sea coast, about 600 km north of Jeddah. Along its shores lies a spectacular group of islands with offshore shallow reefs that are considered to be ideal habitat for sea cucumbers. The area accommodates various types of habitat, including small to moderate patches of sand among coral heads. Live corals flourish, rising up to 2 m from the sea bed and forming circular patches that trap sand. This habitat is ideal for sea cucumbers, especially the white teatfish, *Holothuria fuscogilva*. Also, in many of the sites, huge areas of sandy bottom with large seagrass beds gradually sloping downward to 15 m depth where there are small rocky patches.

Thowal area

This area is located at the middle of the Saudi Arabian Red Sea coast. It has a variety of physical features and substrates, including underwater islands beginning at depths of 10 m below the surface, and exposed offshore reefs. The substrate is composed of live and dead corals, rocks and huge sandy areas. A steep sandy slope descends to 30 m to a 100 m-wide terrace. The substrate is composed mainly of white sand interspersed with dead and live coral patches. The area has very favourable conditions for sea cucumbers, but shows clear signs of overfishing.

Farasan Islands

The Farasan Islands lie 50 km offshore opposite the Jazan area at the southern end of Saudi Arabia. Sites within this area contain underwater islands, live and dead corals, rocks, exposed reefs, and offshore and nearshore sites that are favourable for sea cucumbers, including sandy areas and extensive seagrass beds. Despite this, sea cucumber stocks in this area are very low and populations are severely depleted. Illegal overfishing is widespread in the islands and many boats were seen fishing in different areas.

Data collection

Data collected from sea cucumber harvesters included date of harvest, harvest location, number of harvesters, number of hours fished, species harvested, and total weight of sea cucumbers harvested. From these data, catch size each year was calculated and CPUE was computed as kilograms of sea cucumber per fisherman per day, with an average of eight working hours per day. Data were obtained from the Jeddah Fishery Research Centre (JFRC) and directly from fishermen.

The exploitation system

After harvesting, sea cucumbers are gathered by collectors and then processed into dried beche-de-mer. Shipments are delivered to exporters who transfer the product to Southeast Asian markets. It was very difficult to obtain information about sea cucumber exploitation from fishers, collectors or exporters due to distrust.

In Saudi Arabia, the beche-de-mer trade has four levels of stakeholders: 1) the fisherman who catches the sea cucumbers and sells them to the collector; 2) the collector who buys sea cucumbers from fishermen, and processes them as beche-de-mer and sells them to operators; 3) the operator who buys batches of beche-de-mer from various collectors, gathers them and sells them to an exporter; and 4) the exporter who sends the beche-de-mer to Asian markets (Fig. 2).

Fishery system

Fishers mostly use small motorized boats for collecting sea cucumbers. Each fishing boat carries four to five divers, with one diver remaining onboard, both for security reasons and to receive the catch. Each diver gets a continuous air supply from a hose and pump that are onboard. Divers spend from seven to nine hours a day diving. After all the sea cucumbers in an area are collected, the fishers move to another site. In shallow waters, fishers use a snorkel to gather sea cucumbers.



Figure 2. Three sea cucumber processing steps used in Saudi Arabia.

Results

Species exploited

Nine sea cucumber species were commercially harvested from the Red Sea coast of Saudi Arabia between 1999 and 2004 (Table 1). At the beginning of the fishery in 1999, only three species were collected. Fishing increased into 2001, with nine species of sea cucumber being harvested. Beginning in 2002, the number of harvested species decreased to six, with the disappearance of the high value species *Holothuria scabra* and *Stichopus herrmanni* from

the catch. In 2004, only three medium and low value species were being harvested (Table 1).

Sea cucumber production

In 1999, the beginning of Saudi Arabia's sea cucumber fishery, the total catch for the year was 1,997 metric tonnes (t) (wet weight). The highest production occurred in 2001 and 2002, with recorded catches of 7,201 t and 5,132 t (wet weight) for those years, respectively. As a result of overfishing, the total sea cucumber catch dramatically decreased to 1,150 t in 2003, and continued to decrease to 230 t in 2004 (Table 2).

Catch per unit of effort

Due to a lack of data on the sea cucumber fishery, the CPUE ($\text{kg fisher}^{-1} \text{ day}^{-1}$) was acquired for only two periods: April to August 2000, and February to July 2003. CPUE was obtained for the three major sea cucumber fishing grounds.

Monthly analysis of CPUE for the three major sea cucumber fishing grounds showed significant variations among periods and locality. The Farasan Islands had a very high CPUE during the period April–August 2000, ranging from 118.7–126.9 $\text{kg fisher}^{-1} \text{ day}^{-1}$, while there was a dramatic decline from February–July 2003, with a CPUE of 16.1 $\text{kg fisher}^{-1} \text{ day}^{-1}$ in February, rapidly decreasing to 1.9 $\text{kg fisher}^{-1} \text{ day}^{-1}$ in July. The same pattern was seen at Al-Wajh, which in 2000, recorded a CPUE of 97.5–1,03.4 $\text{kg fisher}^{-1} \text{ day}^{-1}$, and a significant decrease beginning in February 2003 of 11.5 $\text{kg fisher}^{-1} \text{ day}^{-1}$ to 6.3 $\text{kg fisher}^{-1} \text{ day}^{-1}$ in July. There was no sea cucumber fishing in the Thowal area in 2000, but in 2003, CPUE decreased from 69.4 $\text{kg fisher}^{-1} \text{ day}^{-1}$ in February to only 0.7 $\text{kg fisher}^{-1} \text{ day}^{-1}$ in July.

Resource management

Because of unreliable fisheries data and poor control over actual catches, it is difficult to construct analytical models for managing sea cucumber resources. It is important that a well defined management plan be adopted in order to maintain sea cucumber resources. The imposition of improper protection methods could intensify problems.

Several important measures are needed for managing holothurians. Some of these include establishing conservation management guidelines and baseline surveys prior to the start of the fishing season. A management plan should also impose a ban on harvesting during the breeding season, introduce a quota system and minimum landing sizes, establish permanent survey sites and preserved areas, require the maintenance of records on harvesting data, and impose a ban on using scuba equipment,

Table 1. Holothurian species harvested in the Red Sea waters of Saudi Arabia.

Species	1999	2000	2001	2002	2003	2004
<i>Holothuria fuscogilva</i>	+	+	+	+	+	
<i>Holothuria nobilis</i>	+	+	+	+	+	
<i>Holothuria scabra</i>		+	+			
<i>Holothuria atra</i>			+	+	+	+
<i>Actinopyga mauritiana</i>		+	+	+	+	
<i>Actinopyga echinities</i>			+	+	+	+
<i>Bohadschia vitiensis</i>			+			+
<i>Thelonota ananas</i>	+	+	+	+	+	
<i>Stichopus herrmanni</i>			+			

Table 2. Sea cucumber landings from Saudi Arabia's Red Sea coast.

Year	1999	2000	2001	2002	2003	2004
Production (in t wet weight)	1,997	5,031	7,201	5,312	1,180	230

which enables fishers to spend much more time underwater collecting sea cucumbers.

Scope and approach

The increased international demand of beche-de-mer exerts more pressure on sea cucumber stocks. Overfishing of highly commercial sea cucumbers in Saudi Arabia has caused depletion of stocks, which will lead to a shift to less valuable species. Management regimes control the fishery's harvest, but more importantly, they maintain resource sustainability.

The suggested management plan of Saudi Arabia's sea cucumber takes into account the different habitats, ecosystems and socioeconomic aspects of the country. This plan contains the following terms:

- **Maximum sustainable yield** — The highest possible catch of beche-de-mer that can be harvested without, or with minimum, effect on the stock's ability to replenish itself.
- **Precautionary approach** — Setting down restrictions to control harvesting in the absence of adequate scientific data.
- **Scientific advisor** — This person advises decision makers (Ministry of Agriculture, Jeddah Fishery Research Centre, JFRC). The scientific advisor provides scientific information about stock status and the effects of opening fishing, and gives recommendation on the total allowable catch (TAC), the species allowed to be fished, and other matters.
- **Sustainability** — Refers to the ability of a resource to maintain its stock at a fishable level.

- **Total allowable catch (TAC)** — This is the amount of catch allowed to be taken out of a fishery in any one season or year. The TAC is set at a safe level based on stock assessment data.
- **NMAC** — National Management Advisor Committee.

Species targeted

All sea cucumber species on the Saudi Arabian Red Sea coast are targeted.

Precautionary approach

Consistent with the FAO Code of Conduct for Responsible Fisheries (1982) and management objectives of the National Fisheries Authority, precautionary management approaches shall apply in the following matter:

- a) In the absence of adequate scientific data, the Ministry of Agriculture and JFRC shall take into account any uncertainties with respect to the size and productivity of the stock, to other management reference points such as maximum sustainable yield, the level and distribution of fishing mortality, and the impact of fishing activities on associated and dependant species and including climatic, oceanic, environmental and socioeconomic conditions.
- b) In managing targeted species, the Ministry of Agriculture and JFRC shall consider the associated reef ecosystems of the Saudi Arabian Red Sea. The Ministry shall develop research projects

to assess the impact of fishing on non-targeted species and their environment, adopt plans (if necessary) to ensure the conservation of non-target species and consider the protection of habitat of special concern.

- c) The precautionary approach shall be based on the best scientific information available.

National management arrangement

The beche-de-mer fisheries will be managed nationally and at the highest levels of government. The Ministry of Agriculture will work closely with JFRC and the scientific advisor to implement the management plan. The plan will be revised by the Deputy Minister at least once every three years.

It is suggested that a committee, called the National Management Advisor Committee (NMAC), be created to review the success of the management plan and advise on any modifications to improve it. NMAC will also determine the TAC for each species, closed seasons and areas, and periods of restriction.

Management measures

The following management measures set out in the management plan shall be enforced.

Licensing

- Two types of licences will be required: 1) A fishery licence that will be given to the investor. The licence includes the number of boats permitted, maximum length of the boats, number of collectors, the area of fishing, and the total allowable catch. 2) An export and storage facility licence, which will be given to the exporter. This licence will be valid for one year and subject to renewal.

Total allowable catch (TAC)

- Each location will have TACs, applicable to a 12-month period that is calculated using the best information available.
- The TAC will be divided into two groups: high value species and low value species. These will be referred to as value groups.
- NMAC will advise the Deputy Minister on TACs. TACs will be set after the yearly closure of the fishery in each area and prior to the opening of the fishery the following year. Once a TAC has been set, it shall not be changed until the next year.
- JFRC will monitor the TAC for each value group in each area.

Note: If the allocated TAC for any area is reached and exceeded by a considerable amount, that excess amount will be taken off the next season's TAC.

Export requirements

- Exports will be only for the allowable sizes.
- The export of part or parts of or broken beche-de-mer is prohibited.

Prohibitions

- Non-citizens shall not take part in any aspect of the beche-de-mer fishery.
- The use of trawl and scuba for the fishery is prohibited.
- The collection, buying, selling of all species of beche-de-mer is prohibited during the closed seasons or when a TAC is reached.

Closure of the fishery

- NMAC will close the fishery when a TAC is reached or when the compulsory season closure date is reached, whichever occurs first.
- Closing areas may be done, with some areas opened for fishing while other areas will be closed for two to three years. The areas must be switched. The closure or opening of areas will be determined by NMAC after consultation with JFRC.
- NMAC may specify a date by which all holdings of beche-de-mer must be exported.
- NMAC and JFRC reserve the right to close any area of the fishery for conservation regeneration purposes if it is considered necessary to do so for the sustainable management of the fishery.

Processing

- An important way by which the management of the sea cucumber fishery can be improved is to upgrade the skills of processors through training. A substantial proportion of animals may be rejected by purchasers due to incomplete drying or improper storage.

Reporting

- Standard trade names and scientific names must be used in all reporting when possible.
- Licensed exporters must submit holding data to JFRC on all beche-de-mer products handled. This includes species composition, grades, supplier's name, ward of origin, weight in kilograms, and any other information that JFRC may deem necessary.
- Failure to submit the required report within 10 days, or submitting incorrect data, including incorrect trade names may result in suspension or cancellation of the export licence.

Discussion

Sea cucumber populations on the Saudi Arabian Red Sea coast are seriously endangered due to commercial exploitation. Declining exports and strong competition between collectors indicate overexploitation of this resource, which affects

both the local economy and the environment. Only a comprehensive management plan involving the best available scientific information together with a serious commitment from the fishing sector to follow the rules imposed in the plan and the continuous control by Saudi Arabia's Ministry of Agriculture, will allow any commercial activities to be sustained over time.

It is difficult to obtain accurate data on fishing effort along the Saudi Arabian coast, and quantitative estimates for fishing effort are rare. Apart from limited catch data collected by JFRC and from personal communication with sea cucumber fishers, little is known about the catch, catch effort, catch per unit of effort, and other fishery parameters. It was clearly observed that the fishers deliberately withheld their catch statistics and the little data they provided were incomplete.

Saudi Arabia's sea cucumber fisheries began in a very limited way, and it is difficult to state the exact date. In fact, no fisheries information exists before 1999 and it is concluded that before that date, sea cucumber fisheries were scattered and on a very small scale due, in part, to the fact that the people involved perform a wide range of other work activities. The number of species exploited began with three high value species in 1999. Fishers were selective in their catch due to the availability of populations. They therefore directed their efforts on the largest and highest value species. The number of species fished increased to five species in 2000. Up until this time, the fishery was selective as a result of stock availability and the low number of fishers involved. In 2001, nine species were exploited without differentiation. The highest catch and maximum pressure on sea cucumber stocks were exerted in 2001, leading to the disappearance of *Holothuria scabra* from the catch composition in the following years. Moreover, the number of species harvested declined to six species in 2002 and 2003. Finally, the catch collapsed in 2004 to only three medium and low value species. The overexploitation of high value species during the period 2000–2003 led to a total collapse in stocks. Experience elsewhere indicates that recovery of overfished sea cucumber stocks is a lengthy process, taking several years (Purcell et al. 2002), because holothurians, like many other invertebrates, are broadcast spawners, and their fertilization success is highly dependant on population density (D'Silva 2001). It is predicted that recovery of these species will be very difficult.

Data on total sea cucumber landings indicate that fishers initially had harvest success at the commencement of the fishery. This is reflected by increased landings of 1,997 t wet weight in 1999, to 7,201 t in 2001. After 2002, the harvest rate dropped,

with the 2003 total catch amounting to 1,180 t. This was followed by a collapse of the fishery in 2004, with landings of only 230 t. This drop was due to a combination of seasonal conditions and overexploitation of accessible areas, with the seasonal advent of calmer areas previously unexploited were targeted (Trianni 2002) resulting in high harvest rates. The decline of sea cucumber stocks due to overfishing occurred not only on Saudi Arabia's Red Sea coast, but also in many other places of the world, even in the largest sea cucumber producing countries (Conand 2004).

Other Red Sea countries, such as Yemen, Egypt and Eritrea, showed similar patterns of sea cucumber stock collapse. For example, in 1992 in Yemen, the catch was 48 t dry weight, and increased over the following two years to reach 65 t dry weight. The catch then began to decrease, reaching 60 t in 1996. Yemen's sea cucumber fishery collapsed in 1999, when the total catch was only 1 t (Conand 2004). The sea cucumber fishery in Egypt, at the northern end of the Red Sea, started in 2000 with a total catch of 20 t dry weight that year, increasing to 139 t dry weight in 2001 (Lawrence et al. 2004). The fisheries collapsed between 2002 and March 2003, forcing the Egyptian government to ban all sea cucumber fishing in the country. In Eritrea, sea cucumber production steadily increased from 11 t of gutted and dry weight in 2000, to reach a maximum production of 452 t in 2003. In 2004, production dropped to 283 t and fluctuated between 380 t in 2005 and 278 t in 2006 (Kalaeb et al. 2008). These reported declines encouraged other countries to begin exploiting sea cucumbers, and Saudi Arabia was among these countries. As elsewhere, Saudi Arabia is experiencing problems in managing this resource.

The mean CPUE calculated from the submitted data showed two distinct patterns: high CPUE for all areas for the period April to August 2000, and a dramatically decreased CPUE for the period February to July 2003, indicating overfishing. During the first period, CPUE was higher than that recorded from Madagascar, which ranged from 4.96–10.67 kg fisher⁻¹ day⁻¹ (Rasolofonirina et al. 2004) and the Northern Mariana Islands, which ranged from 68.2–118.0 kg fisher⁻¹ day⁻¹ (Trianni 2002). According to data, 2000 was a promising year for Saudi Arabia's sea cucumber fishery, while in 2003, the fishery nearly collapsed. This is coincident with catch data, which also revealed that the years 2000 to 2002 recorded a maximum production, while beginning in 2003, production had declined significantly.

Despite the ban on all sea cucumber fishing operations in Saudi Arabia, illegal fishing continues to play a key role in the depletion of sea cucumber populations. The primary aim of fisheries manage-

ment is the protection of stocks in order to provide a continuing and sustainable income for fishers. The depletion of sea cucumber stocks as a result of resource management problems is related to overfishing, legislation and/or administration (Altamirano et al. 2004; Conand 2004). The absence of effective control, surveillance and enforcement of regulations has resulted in widespread illegal fishing of sea cucumber populations, and depletion and destruction of the resource's habitat. There is little awareness of the benefits that may be gained from an effective sea cucumber fishery managed by investors in this sector and this is a critical cause for the overexploitation and depletion of sea cucumbers. More effective training opportunities for fisheries managers, fisheries scientists, personnel for shoreline protection, environmental protection officers, cooperative staff, and fishers are required for proper surveillance and management of sea cucumber stocks. Overfished sea cucumber populations could take decades to recover if current harvesting methods continue, unless new and more effective procedures to protect and manage stocks are implemented.

Two types of illegal fishing take place. One occurs in southern Saudi Arabia near the Farasan Islands, and is mainly done by Yemeni fishers who enter Saudi Arabian waters with numerous small boats. The danger from this illegal fishery comes from the high number of fishing boats and the destructive *kapandara* collection method they employ. In this method the fisher receives a continuous supply of compressed air from the fishing boat through a hose and mouth piece so that he can spend more time underwater. With the second type of illegal fishing, used in the north near Al-Wajh, local fishers use professional scuba divers to collect sea cucumbers. The Saudi Arabian Red Sea coastline is long with many islands and offshore reefs that make the control of illegal sea cucumber harvesting difficult. The landing of catch poses difficulties for effective surveillance, monitoring and control. It is concluded that banning of sea cucumber fishing alone is very effective in the conservation of the resource. More appropriate methods for controlling the fishery include raising awareness among the general public to report any person who illegally collects or deals with sea cucumbers, and strengthening surveillance on the roads and at sea cucumber processing points.

Because of issues with overfishing, illegal fishing, and the potential for total and permanent destruction of Saudi Arabia's sea cucumber stocks, it is critical for Saudi Arabia to adopt an effective management plan. As a result of sea cucumber stocks becoming depleted in many other areas of the world, management plans began to be adopted. For exam-

ple, in the Pacific Adams (1993) recommended the management of individual South Pacific holothurian fisheries, which served as the basis for beche-de-mer fisheries management in that region. Other examples include Papua New Guinea (Polon 2004), the Philippines (Gamboa et al. 2004), and Australia Baine (2004).

Before sustainable management measures can be enforced, it is vital that stocks are allowed to recover to a near pristine biomass level. Only then can management regimes such as TACs, closed seasons, restricted areas and size limits, be effective in achieving maximum benefits from the resource. Sea cucumber populations have been overexploited, which calls for immediate closure of the fishery to enable stocks to recover to levels where they can be managed sustainably. Whatever management measures are officially enacted, the underlying success of management will depend on effective enforcement.

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Madagascar Holothurie SA: The first trade company based on sea cucumber aquaculture in Madagascar

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Sea cucumber fishing in Madagascar is a widespread activity (Laroche and Ramanarivo 1995; Conand et al. 1997; Rasolofonirina and Conand 1998; McVean et al. 2005) and natural populations are currently overexploited (Conand 1998; Conand et al. 1997). In 1999, a sea cucumber mariculture project was launched in Madagascar (Jangoux et al. 2001). The work was funded by the Belgian University Corporation for Development (CUD) and the Malagasy government. It involved the universities of Brussels and Mons (Belgium) and the Malagasy University of Toliara (Jangoux et al. 2001). Initial work consisted of building a sea cucumber hatchery on the grounds of the Toliara Marine Sciences Institution (IHSM). The hatchery was functional in 2003 and currently produces tens of thousands of juveniles of the valuable sea cucumber *Holothuria scabra*. Its main section consists of a 120 m² air-conditioned building, containing six rooms for growing seaweed, rearing larvae, caring for genitors, and undertaking microscopic and computer analyses. The hatchery's aquaria are connected to a saltwater pumping station, whose reservoir fills up at high tide and whose water pours into a 30 m³ settling pond. Decanted water is then cleaned by repeated filtration before being used in the larval rearing tanks.

The second phase of the project, launched in 2004, consisted of setting up a sea cucumber farm to grow out juveniles until they reached a marketable length. The farm was erected at Belaza, 20 km south of Toliara. This setting, which borders mangroves, fulfils the ecological requirements of *H. scabra*, and possesses a natural freshwater spring that allows an optimal functioning of the laboratory and houses. The farm raises sea cucumber juveniles produced by the hatchery to a marketable size and weight (more than 20 cm and 300 g) in 10–12 months. The method for rearing sea cucumbers includes three successive phases, each requiring specialized infrastructures (internal aquaria, external tanks and sea fences) related to the animal's size. Aquaria in which small juveniles are reared are located in the hatchery. Each aquaria contain 200 L of filtered seawater in which juveniles grow to a length of 2 cm (Fig. 1). Sea cucumbers are then transferred onto sandy-muddy substrates in 25,000 L external tanks (Fig. 2) where they are maintained until they reach a

length of 6–8 cm (Fig. 3). Seawater is changed twice a week and new substrates are added between each run. The optimal density is 20 individuals per square meter. Once individuals reach 6–8 cm, they are placed in sea fences (Figs. 4 and 5), but below this size, they can be attacked by predators such as crabs or fish. Sea fences are of ca 600 m², and are made of wood sticks and plastic nets with a mesh size of 1 cm. Fences are built in intertidal zones where sea cucumbers are immersed even during low tides. The maximum density in fence areas is 3 individuals per square meter. The farm is currently producing thousands of sea cucumbers (Fig. 6).

Funds from the Belgian CUD ended in March 2008. At that time, a tripartite partnership, involving a spin-off from Belgian universities, the IHSM and a private company (Copefrito SA), have formed the first trade company — Madagascar Holothurie SA — based on sea cucumber aquaculture in Madagascar, and involving coastal villagers. The company's expected production in the next five years is 200,000 sea cucumbers per year. Farm productivity is not limited by the number of hatchery-bred juveniles (a single pair of genitors, one male and one female, produce tens of thousands of fecundated eggs), but rather by the surface of the available farming structures (surface of enclosed spaces). The trade company currently supplies various local organizations (groups of fishermen, coastal villages) so that they can be trained in farming operations. Management of farmers is ensured by scientists working in the company and by people from non-governmental organizations (NGOs) based in the Toliara region. If the experience is positive, it could be extended to many villages on Madagascar's west coast and will hopefully be the seed of a new type of aquaculture in this country.

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Figure 1. External tanks where *H. scabra* juveniles are reared until they reach 2–6 cm. Tanks are protected from the sun by umbrellas during the hot season.

Figure 2. Juvenile *H. scabra* (2 cm long) coming from the hatchery. At this size, they begin to hide into the substratum during the day, and are transferred from the hatchery to the farm's external tanks.

Figure 3 Juvenile *H. scabra* (6–8 cm long) after pre-growing in external tanks. Upon reaching this size, they are transferred into natural sea fences.

Figures 4 and 5. Sea fences set up in front of the farm's buildings.

Figure 6. *H. scabra* ready to be sold on the local trade market or to be treated as trepang and exported to Asian countries.

Processing and marketing of holothurians in the Toliara region, southwestern Madagascar

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Abstract

In Madagascar, sea cucumbers are processed into dried product (trepang) before being exported. Careful processing is necessary in order to yield high quality trepang (e.g. aspect, form, consistence, smell). Nowadays, processing is carried out mainly by collectors whose methods depend on the exporter's demand. Processing methods, especially for *Holothuria scabra* (sandfish), have continued to evolve over the last decade.

Investigations in several villages have been made to determine the different processing methods used in the Toliara region. For *H. scabra*, the traditional method of burying sea cucumbers in sand to remove the chalky spicules from their body wall is becoming rare. Collectors scrape the animals using stones or bivalve shells or they use ground papaya leaves. All processing steps end with cooking the sea cucumbers in brine, then rinsing them and finally sun drying. Experiments carried out on *H. scabra* by the aquaculture company, Madagascar Holothurie SA, demonstrate that, whatever the initial size of individuals, there is a 91% reduction in weight and 52 % reduction in length after processing.

In Toliara, five categories of stakeholders form the commercial chain: fishers, middlemen, collectors, operators and exporters. In general, fishers sell their fresh products directly to collectors who are the main holothurian processors, and who sell their products, most often semidried, to exporters. Exporters process sea cucumbers into trepang for Asian markets. Prices rely on species type and specimen size. Other criteria such as appearance, smell, mould, and water content are also often taken into account. For *H. scabra*, properly processed trepang of the 1st category presently sells for between USD 33 kg⁻¹ and 50 kg⁻¹ to exporters.

Introduction

Holothurians are mostly marketed as dried product, and rarely as fresh or frozen (Conand 1990, 2004; Conand and Byrne 1993; Ferdouse 2004; Poh-Sze 2004; Aumeeruddy 2007). The trade in sea cucumbers is an important source of income for the local community of fishers (Conand 1990; Preston 1993; Conand and Muthiga 2007) and for everyone within the processing and marketing chain in producing countries who are collectors, operators and exporters (Conand 2004; Rasolofonirina 2004; Rasolofonirina 2007). The processing of sea cucumbers has a major influence on price (Conand 1990, 2004; Hamel et al. 2001), as any fault in the process may decrease the value of the product (Conand 1999).

In all Indo-Pacific countries, sea cucumber processing, which needs very simple and cheap materials, is carried out by villagers. General processing methods, used for the majority of sea cucumber species, involve three main steps: removal of viscera, cooking and drying (Conand 1990; Li 2004). Specific methods have been developed to process *H. scabra* and *H. scabra versicolor* in order to remove the chalky spicules from their body wall (Hamel et al. 2001); for example, by burying sandfish in sand for about 18 hours (Conand 1999; Anonymous 1994) or using grounded papaya leaves (Poh-Sze 2004; Rasolofonirina 2004).

Several sea cucumber processing methods are used in Madagascar. Processors employ the best method for reducing weight and length losses, but also to

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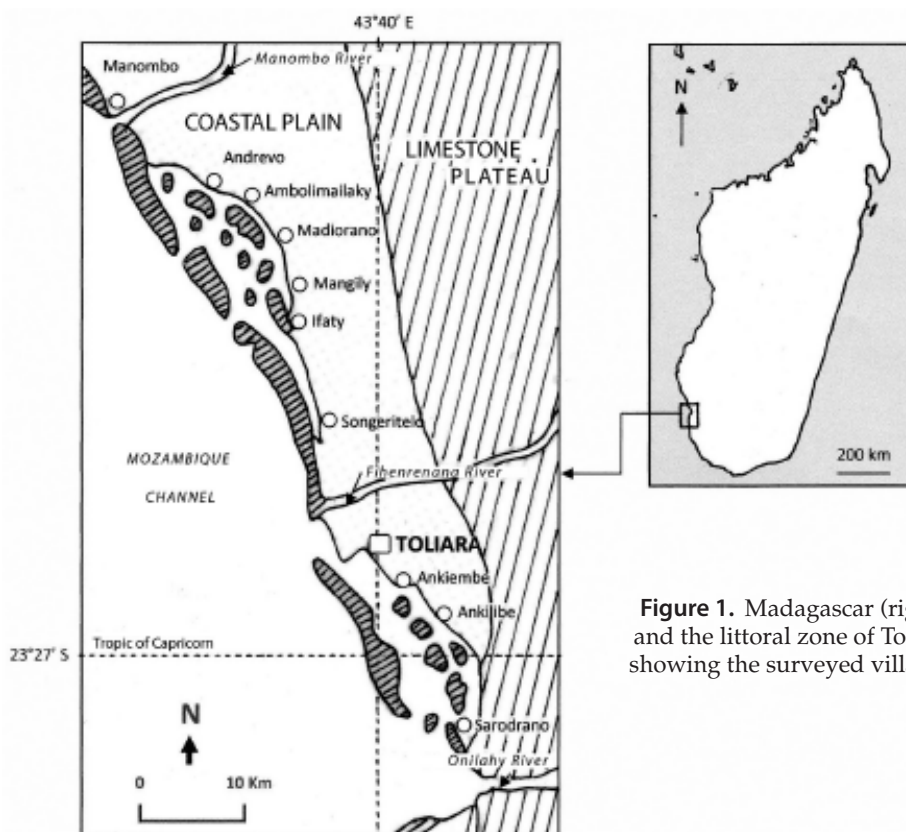


Figure 1. Madagascar (right) and the littoral zone of Toliara showing the surveyed villages.

make the task easier. Processing procedures continue to evolve. The aim of the present work is to 1) identify the different processing methods that exist in villages around Toliara, especially for *H. scabra*, 2) analyze the variations in morphometric parameters linked with processing, and 3) update the data on the holothurian trade from collectors to exporters.

Materials and methods

In order to identify the different methods used for processing sea cucumbers in the Toliara region, field observations were carried out in 2006 and 2007 in nine villages between Sarodrano in the south and Andrevo in the north (Fig. 1). These villages were chosen because they are accessible by car and because there is an active sea cucumber fishery. The

first general observations consisted of noting the different processing methods used by trepang processors. Investigations were also conducted in order to determine: 1) the different contributors in the commercial chain, from the collection of sea cucumbers to their export, 2) the different processing steps along the commercial chain, and 3) the fluctuations of the prices along the chain. Interviews were carried out with fishers (10 per village), all collectors in the villages, and with some operators and exporters in Toliara. Operators and exporters were not cooperative so that it was difficult to carry out investigations and to get information on trepang prices. Questions commonly asked of fishers and collectors are summarized in Table 1. Length and weight measurements of specimens during the purchase were recorded.

Table 1. Commonly asked questions to fishers and collectors in the investigated villages

Fishers	Collectors
- material and fishing methods	- price of products
- frequency and fishing time	- different species bought
- commonly captured species and their abundance	- present methods of processing (different steps)
- processing or not of the products. If yes, processing methods	- past methods of processing
- actor and area where they sell their products	- destination of their products
- price and selling methods	- method of the purchase
	- price of the products for the resale

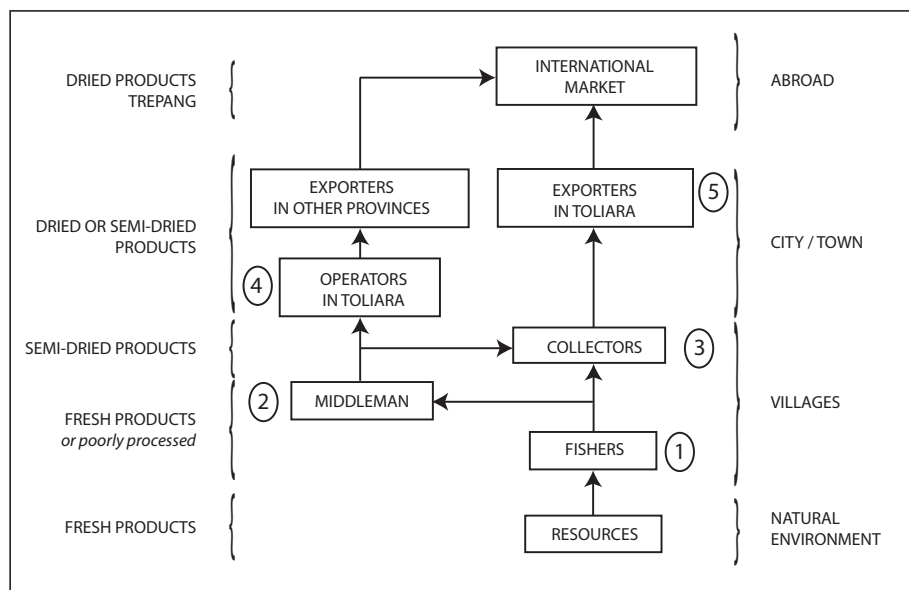


Figure 2. The sea cucumber processing and marketing chain (from natural habitat to export) in Toliara.

Most used circuit: 1–3–5 (80 %)
 Often used circuit: 1–3–4–5 (15 %)
 Rarely used circuit: 1–2–3–5 or 1–2–3–4–5 (5 %)

In addition, we examined fresh and dried sandfish produced and sold by the aquaculture company Madagascar Holothurie SA. An analysis was made of morphometric parameters during processing. For this study, 24-month-old sea cucumbers (larval phases included) from Madagascar Holothurie SA were used. Morphometric parameters taken during the processing of two batches of 10 individuals of two different sizes — 280 g (18 cm) and 430 g (21 cm) — were compared in order to evaluate the percentage of weight and length loss. For each experiment, weight and length of specimens were recorded at each step of processing and the mean calculated.

Results

Commercial chain

Fishers collect sea cucumbers during low tides, by walking on the reef or by free diving. From collection to export, the sea cucumber processing and marketing chain involves five different types of stakeholders (Fig. 2).

- The fisher — a villager, man or woman, anywhere from 7 to 60 years old, who collects holothurians from the natural environment.
- The middleman — a villager, man or woman, anywhere from 25 to 60 years old, who buys sea cucumbers from fishers and resells the sea

cucumbers to collectors. This person does not process sea cucumbers. In all investigated villages, people do this job occasionally. Sometimes, fisher or collector may serve in this capacity.

- The collector — a villager, man or woman, between the ages of 25 and 60 years, who buys products from fishers or middlemen. This person processes holothurians and sells the processed product to operators or exporters in town. One collector may move to other villages, and stay there, depending on the resource availability. During the investigation, the number of collectors recorded per village was two in Sarodrano, four in Ankilibe, six in Ankiembe, one in Songeritelo, zero in Ifaty, one in Mangily, one in Ambolimailaky and three in Andrevo.
- The operator — a man from the city or town who buys the product from several collectors, completes the processing (if necessary), and sells it to exporters. We recorded four operators in Toliara.
- The exporter — a man from the city or town who delivers the product to the international market. There are three exporters in Toliara. They often buy semi-dried products from collectors and, in that case, must complete the processing.

In more than 80% of all cases, fishers sell their fresh products to collectors who buy them by the piece.⁴ Collectors sell processed products (semi-dried) to

4. We note that it is not the way it was done 10 years ago, when most fishers processed the sea cucumbers themselves and waited until the end of a period of good tides to sell their processed product to operators or exporters. In rare cases, where products were sold fresh, collectors bought them by the bucket.

Table 2. Price range of species of high and medium commercial value encountered in Toliara region. Prices of individual in 2007 at fresh state come from investigation into collectors; trepang price was obtained from Toliara exporters. Prices in 1996 are from Rasolofonirina 2004.

Scientific name	Price when fresh (Ar piece ⁻¹) ⁵		Trepang price (Ar kg ⁻¹) ⁵	
	1996	2007	1996	2007
Category I: High				
<i>Holothuria fuscogilva</i>	50–800	3,000–5,000	2,600–7,000	30,000–90,000
<i>Holothuria nobilis</i>	50–800	3,000–5,000	2,600–7,000	30,000–90,000
<i>Holothuria scabra</i>	400–1,500	500–4,000	5,000–15,000	25,000–90,000
<i>H. scabra versicolor</i>	100–1,500	500–4,000	5,000–15,000	25,000–90,000
Category II: Medium				
<i>Thelonota ananas</i>	20–100	3,000–5,000	600–3,000	15,000–35,000
<i>Stichopus horrens</i>	20–120	600–1,200	2,400–3,600	11,000–30,000
<i>Stichopus hermanni</i>	20–120	600–1,200	2,400–3,600	11,000–30,000
<i>Actinopyga lecanora</i>	30–140	200–300	600–3,000	10,000–18,000
<i>Actinopyga mauritiana</i>	20–100	200–300	2,000–3,000	10,000–18,000
<i>Actinopyga echinites</i>	20–100	200–300	2,000–3,000	10,000–18,000

exporters in the city who finalise the processing and ensure that exports reach their final destination. In 15% of observed cases, fishers sold sea cucumbers to collectors who processed them. Collectors sold their products afterward to operators in town who were in contact with exporters from other provinces, such as Antananarivo. For the few remaining cases, fishers sold to middlemen, and the products followed the chain as mentioned above.

In general, fresh products are classified according to species and size. For trepang, other factors are taken in consideration, such as appearance, smell, the presence of mould, and water content. Depending on the price, holothurian species are classified into three commercial categories (Conand 1990, 2004): high, medium and low. Species of high and medium commercial value observed in the Toliara region are presented in Table 2. This table shows current prices by species and compares them to prices 10 years ago, in 1996. Species of low commercial value, which are not presented in this table, consist of *Bohadshia*, *Pearsonothuria* and species within the genus *Holothuria*, such as *H. atra*, *H. cinerascens*, *H. edulis*, *H. excellens*, *H. fuscopunctata*, *H. impatiens*, *H. leucospilota*, *H. maculosa* and *H. rigida*. Among the species of low commercial value, we also find now *H. notabilis* and *H. arenicola*, both of which had no commercial value before. They are the most captured species in the region nowadays and are sold in small buckets, ranging in price from 1,500–3,000 ariarys, the local money.⁵ One small bucket may contain 60–80 specimens, depending on size.

For the high and medium values, prices also depend on specimen size. In all investigated villages, collectors buy fresh products by the piece. The purchase is always done visually without making any measurements (either weight or length). The price varies according to buyers and the area. Collectors near the city always buy products at higher prices than those from isolated villages. This study of *H. scabra* allowed us to determine prices according to their size; fresh products are divided into four size classes: XL, L, M and S (Table 3).

Different processing methods observed in the region

Since 1997, sea cucumber processing methods have constantly evolved in the Toliara region. These methods aim at reducing both weight and length during processing, and make the task easier and so reduces the workforce. Nowadays, scraping sea cucumbers or using ground papaya leaves to remove the spicules of the integument, are common, with some variants depending on the processors and the area. However, the general principle of each step is the same as it was 10 years ago (Mara et al. 1998; Rasolofonirina 1997). In the Toliara region, processing may be carried out by fishers, collectors or exporters.

Ten years ago, most fishers processed sea cucumbers themselves. Sea cucumbers started to become scarce in 2000, and nowadays, most fishers, except those from some villages in the north of Toliara, pre-

5. Ar = Madagascar ariary. As of September 2008, the change rate was: Euro 1.00 = Ar 2,400; USD 1.00 = Ar 1,624.

fer to sell their products directly to middlemen or collectors. Processing methods employed by fishers in the north of Toliara yield products that are semi-processed, the end of the processing being done by collectors. A very simple processing method is used in Andrevo village, where holothurians are scraped with stone to remove spicules, then eviscerated, and cooked for 10 min and then sun dried for several hours.

In all villages surveyed, collectors are the main processors. They employ several processing methods that vary somewhat and that involve processing with or without grounded papaya leaves (Table 4). The processing method without papaya leaves consists of scraping the integument of the animal with a stone to remove the chalky spicules. This may be done by 1) scraping the integument after evisceration, and then salting and doing a first cooking, or 2) scraping the fresh specimens followed by evisceration. Processing with grounded papaya leaves is the most common method: collectors always use it when they have large quantities of sea cucumbers. The ground papaya leaves remove the chalky

spicules through the action of papain. This method is not time consuming, makes the task easier, and reduces the necessary workload. Nevertheless, it demands delicate care because the long acting papain may destroy the integument's structure. Certain processors employ this method as the only way to remove the chalky spicules, while others use it only to clean the chalky spicules that were not removed from scraping.

Table 4 summarizes the four processing methods observed in the region. There are seven to nine steps, depending on the method, and each takes anywhere from seven to eight days. Without considering the salting and drying time, the necessary processing time for 20 specimens varies from three to six hours, depending on the method. Processors start by scraping specimens, which is then followed by evisceration (or processors may force the evisceration by making a small cut beneath the posterior part of the animal) (Figs 3A,B). All processing ends by cooking in brine, rinsing and sun drying (Figs. 3 F-H). Two methods require the use of papain (Fig. 3E). In three of the methods, sea cucumbers

Table 3. Price range of *H. scabra* in Toliara region. Price of fresh individuals in 2007 come from investigations with collectors. Trepan prices were obtained from Toliara exporters. Exchange rate (Sep. 08): Euro 1.00 = Ar 2,400; USD 1.00 = Ar 1,624.

Size	Length (cm)	Weight (g)	Price when fresh (Ar piece ⁻¹)	Price of trepan (Ar kg ⁻¹)
XI	> 22	> 450	> 2,600	> 60,000
L	20–22	350–450	2,000–2,600	30,000–60,000
M	18–20	250–350	1,600–2,000	< 30,000
S	< 18	< 250	< 1,600	< 30,000

Table 4. Processing methods employed by collectors. (Ind: individual)

I	II	III	IV	Time
	Scraping		Scraping	10 min ind ⁻¹
Evisceration	Evisceration	Evisceration	Evisceration	2 min ind ⁻¹
	Salting	Salting	Salting	24 to 96 h
Cooking		Cooking	Cooking	10 to 15 min
Salting				96 h
Scraping				5 min ind ⁻¹
Air drying	Air drying			10 to 24 h
		Use of ground papaya leaves	Uses of grounded papaya leaves	4 to 10 min
		Brushing and rinsing	Brushing and rinsing	5 min ind ⁻¹
Cooking in brine (100 g of salt L ⁻¹)	Cooking in brine (100 g of salt L ⁻¹)	Cooking in brine (100 g of salt L ⁻¹)	Cooking in brine (100 g of salt L ⁻¹)	20 to 30 min
Rinsing	Rinsing	Rinsing	Rinsing	0.5 min ind ⁻¹
Sun drying	Sun drying	Sun drying	Sun drying	3 h to 3 days



Figure 3. The main processing steps for *H. scabra* and *H. scabra* var. *versicolor* employed by collectors. A: evisceration; B: scraping; C: salting; D: 1st cooking; E: using ground papaya leaves; F: cooking in brine; G: rinsing; H: sun drying.

are boiled two times, while the last process requires only one cooking (Fig. 3D). In three of the methods, specimens are salted at the beginning of the process (Fig. 3C). In general, collectors sell semi-dried products (three hours of sun drying) in order to quickly have cash for buying new products.

For exporters, the final processing methods employed depend on the quality of the semi-dried product. If the cooking is not perfect, the semi-dried products are rehydrated, cooked for 15 minutes, and then sun-dried. If the product is not well scraped, the semi-dried product is put in water for 24–48 hours, scraped, cooked for 10 min, brushed and sun-dried. If the product still contains a considerable amount of salt, the semi-dried product is washed, cooked for two minutes, and sun-dried. Finally, if the product is not properly dried it is directly sun-dried for three days. At the end of processing, the product is dried in an oven at 60°C for six hours and then packed into plastic bags before being exported.

Evolution of morphometric parameters during processing

Before processing, the two batches (I and II) of *H. scabra* had a mean weight of 280 g (I) and 430 g (II), which corresponded to 18 cm and 21 cm in length, respectively. After processing, the average trepang weight in batch (I) was 26 g and 8.97 cm in length (the equivalent of 9.20% and 50.25% of their initial weight and length, respectively) (Figs. 4 A and B). In batch II, the trepang weighed 40.63 g and measured 10.27 cm, which corresponded to 9.40% of their weight and 47.99% of their length in a fresh state (Fig. 4 A and B). The reduction after processing were the same for the two batches ($p = 0.889$ and $p = 0.479$ for the weight and length respectively): weight and length loss was the same, whether *H. scabra* was of a medium (280 g) or large size (430 g).

The relationship between the parameters “fresh specimen weight/dried trepang weight” and “fresh specimen length/trepang length” have been analyzed (Fig. 5 A and B), and provides a rough idea of trepang weight and length after processing. The relationship between weights is significant ($r = 0.756$). Figure 5 B clearly shows that the relationship between the length parameters is not significant. The low relationship between lengths is related to the fact that this parameter is variable in the fresh state (live specimens may extend or shorten) while weight is more stable.

Discussion and conclusion

The most important sea cucumber marketed product is the dried body wall, called trepang (Conand 2004). The main processing steps are the same in all Indo-Pacific countries and always involves the

removal of viscera, cooking and then drying of the body wall. Nevertheless, there are some light differences between processes (Poh-Sze 2004), and methods may vary slightly depending on areas (Chen 2004; Baine 2004; present work), species (Chen 2004; Baine 2004), or the stakeholders encountered along the processing and marketing chain (Poh-Sze 2004). Evisceration is often performed by making an incision on the ventral side of *Thelecnota ananas*, on the dorsal side for the other large species (Anonymous 1994; Conand 1990; Li 2004), or by making a small cut of 2–3 cm in small species (including *H. scabra*). The cut is made either in the posterior part (Anonymous 1994) or beside the mouth (Alfonso et al. 2004; Li 2004). Cooking is the most important step because it may damage the product in an irreversible way (Anonymous 1995). If not cooked properly, trepang may soon rot and acquire an undesirable smell (Li 2004). Some processors employ one cooking only during the processing, such as some collectors in Madagascar, processors in Mayotte (Pouget 2004), and some fishers in Malaysia (Poh-Sze 2004). But, a second cooking is generally employed, as reported in Madagascar (present work), China (Chen 2004), Malaysia (Poh-Sze 2004), and many countries in the Pacific (Conand 1990; Anonymous 1994). Drying may be by sun or smoke, and may take several days to several weeks, depending on the species, specimen sizes, the fire pit for smoking, and the weather.

An additional step to remove the abundant chalky spicules on the integument of *H. scabra* is essential. Ten years ago, the traditional method consisted of burying cooked and chilled sandfish in sand 20–30 cm deep. This method uses bacterial action (12–18 hours) to soften the external part of the integument. *H. scabra* are washed in seawater and rubbed vigorously afterward in order to remove the remaining decomposed integument containing the chalky spicules (Anonymous 1994). Nowadays, in Madagascar, processors scrape the animal with a stone or bivalve shell, or use ground papaya leaves. This new method began in 2002 and remains the only method used in the region. The method of burying sea cucumbers in sand has been completely abandoned. The same change has occurred in Malaysia, where processors use ground papaya leaves or lime to remove chalky spicules (Poh-Sze 2004). Salting or salting in brine is also becoming very popular. This process limits desiccation and minimizes weight and length loss during processing (Rasolofonirina 2004). Processors in the Toliara region began using salt in 1999 and, at present, all processing in the southwest of Madagascar involves salting and/or salting in brine. This process is also very common in China (Chen 2004), Malaysia (Poh-Sze 2004) and Cuba (Alfonso et al. 2004). After processing, specimens lose weight and length considerably (Conand 1979, 1990; Preston 1990; Vuki 1991). In general,

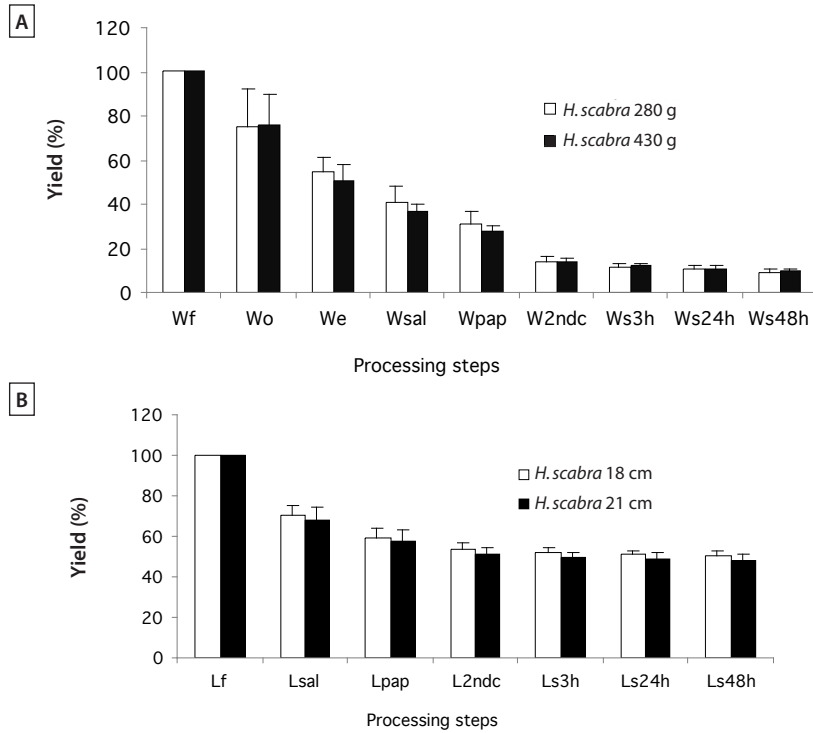


Figure 4. Variations of *H. scabra* weight (in percentage) and length according to individual sizes (n=10; vertical bars indicate the standard deviation).

A: weight (in percentage). Wf: fresh weight; Wo: opened weight; We: eviscerated weight; Wsal: weight after salting; Wpap: weight after papaya (spicules are removed); W2ndC: weight after second cooking; Ws3h: weight after three hour of sun drying; Ws24h: weight after 24 hours of sun drying; Ws48h: weight after 48 hours of sun drying;

B: length (in percentage). Lf: fresh length; lsal: length after salting; lpap: length after papaya (spicules are removed); l2ndc :length after second cooking; ls3h : length after three hour sun drying; ls24h : length after 24 hours of sun drying; ls48h: length after 48 hours of sun drying.

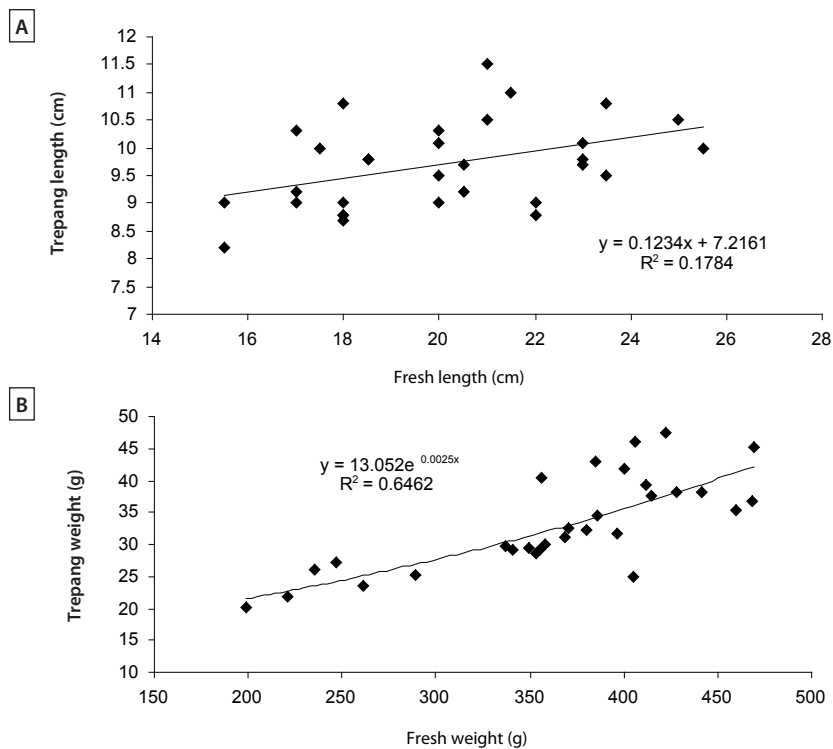


Figure 5. Relationship between fresh individuals and dried (i.e. processed) weights (A) and fresh individual and dried lengths (B) of *H. scabra*.

there is a 90–97% weight reduction recorded after processing, depending on the species (Conand 1990). For *H. scabra*, there is a 90–95% weight loss after processing (Bascar and James 1989; Anonymous 1995; Gamboa et al. 2004) and 42 to 52 % in length (Bascar and James 1989).

There are several criteria for classifying processed products. For *H. scabra*, trepang of the first category must 1) be straight or slightly curved, with numerous furrows around the body, 2) have a suitable smell, 3) have a small incision, only at the posterior part, throughout the anus, 4) have a dorsal side that is brownish to black, and a ventral side that is grey to white, and 5) be 10–15 cm in length, and about 8–12 specimens per kilogram. These trepang may be sold for between USD 33 kg⁻¹ and 50 kg⁻¹ to exporters of the local market, and may reach USD 80 kg⁻¹ on the international market (Tuwo 2004). In fresh state, these specimens are sold between USD 2.5 and 3 piece⁻¹, the equivalent of USD 24–30 for 8–12 specimens. With this difference, processors may make a benefit of USD 9 to 20 kg⁻¹ of trepang. Exporters may benefit about USD 30–47 kg⁻¹ of trepang. It is also important to note that the price of sea cucumbers and trepang have increased significantly over the last decade (Alfonso et al. 2004). In Madagascar, the price increased three to six fold since 1996. Nevertheless, the benefit for fishermen and villages communities remains uncertain for the future because there is no scale of charges in place. This is not only because collectors buy products from fishermen without making any measurements (weight or length), but also because selling to exporters is totally blurred. Exporters fix the prices of the products themselves, and they can buy the same product at very different prices from different fishermen.

Acknowledgements

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Holothurians and other echinoderms of the Glorieuses Islands (Scattered Islands of the Indian Ocean)

T. Mulochau¹ and C. Conand²

Introduction

As part of an assignment for Agence Nationale pour la Recherche (French National Research Agency), we sampled the echinoderms of the Glorieuses Islands (Fig. 1) from 24–28 April 2008.³ We particularly surveyed the holothurians found on the reef flats and outer slopes. These islands' reef flats were sampled by Vergonzanne in 1977. Other research on this area relates to holothurians of Mayotte (Pouget 2004, 2005; Conand et al. 2005), the Comoros (Samyn et al. 2005) and the Geyser Bank (Mulochau et al. 2007). Some Reunion Island holothurian data (Conand and Mangion 2002) were also consulted.

The coral reefs of the Glorieuses Islands (Fig. 1) have a surface area of 7 km², and have been classified as a Nature Reserve (Gabrié 1998).

The current expansion in the world holothurian fishery is causing overfishing in most countries

in the tropical Indo-Pacific (Conand 1999, 2004, in press). As suggested by Uthicke and Conand (2005), research on a site classified as a Nature Reserve and remote from coastal human influences can help us improve our understanding of holothurians and their role within the reef ecosystem, and enable a comparison of the various research sites in terms of anthropic impacts.

Materials and methods

Research site

Together with Tromelin, Juan de Nova, Bassas da India and Europa, the Glorieuses Islands form part of the five Scattered Islands in the western Indian Ocean. They are French territories, lying in various locations around Madagascar and representing an exclusive economic zone (EEZ) of nearly 650,000 km² (Gabrié 1998). These islands were classified as nature reserves in 1975 and have been administered as the fifth district of the French Southern and Antarctic Lands since 2007.⁴ The Glorieuses Islands are in the northern Mozambique Channel, 258 km northeast of Mayotte and 220 km northwest of Diego Suarez (Madagascar). The group comprises two main coral islands (Fig. 2): Grande Glorieuse, an oval-shaped, incomplete atoll that is 3 km in diameter; and Île du Lys or Petite Glorieuse, which is 0.6 km in diameter. Two rock islands, Roches Vertes and Île aux Crabes, together with two sandbanks that are exposed during low tide, make up the rest of the group.



Figure 1. Location of the Glorieuses Islands within the Indian Ocean.

1. Aquarium of Reunion Island (aquarium.reunion@wanadoo.fr)

2. Ecomar Laboratory, University of Reunion Island (conand@univ-reunion.fr)

3. This assignment is part of a larger project concerning the Glorieuses Islands (Bigot et al. 2007). The project falls under the French National Research Agency's Interface Programme — a multi-disciplinary study on the vulnerability of environments to climate change.

4. Law No 2007-224, dated 21 February 2007 providing for the legal and institutional status of overseas entities

Altogether, this coral island formation amounts to an area of 7 km². It is a bank reef that has developed in shallow water (Vergonzanne 1977) and there are no distinct geomorphologic divisions, apart from some fringing formations around the two main islands. Ranges of habitats with different geomorphologic features were investigated at nine stations (Fig. 2) at the outer slope in the north and northwest, and the inner reef flats to the north, south, east and west (Table 1).

Figure 2. The nine research stations on Grande Glorieuse.

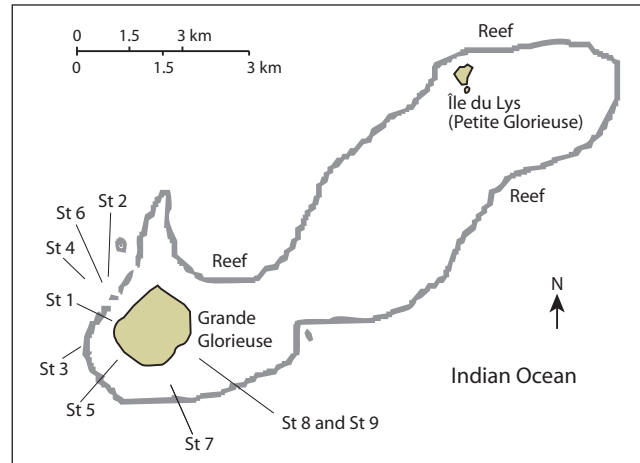


Table 1. Biotopes and communities of the nine research stations on Grande Glorieuse

Station	Depth	Biotope	Biocenosis
Station 1 24.04.08 AM jetty reef flat	1 m	Reef flat north Hard substrate: 20 % Rubble: 10 % Sand: 50 %	5% coral cover 5% algal cover
Station 2 24.04.08 PM GCRMN 1	15 m	Outer slope north Large coral blocks Hard substrate: 70% Rubble: 15% Sand: 15%	30 % coral cover 30 % algal cover
Station 3 25.04.08 AM GCRMN 2	12 m	Outer slope northwest Bottom of smaller slope Hard substrate: 40% Rubble: 30% Sand: 30%	30 % coral cover 20 % algal cover
Station 4 25.04.08 PM Mooring zone	15 m	Outer slope north Bottom of slope – Large coral blocks on sandy bottoms Hard substrate: 50% Rubble: 10% Sand: 40%	20% coral cover 50% algal cover
Station 5 26.04.08 PM Cap vert rocks	1 m	Reef flat west Hard substrate: 20% Rubble: 20% Sand: 60%	1% coral cover 30% algal cover
Station 6 27.04.08 AM Camera testing zone	6 m	Outer slope north Large coral blocks on sandy bottoms Hard substrate: 60% Rubble: 20% Sand: 20%	30% coral cover 30% algal cover
Station 7 27.04.08 AM Ile aux crabes	1 m	Reef flat south Hard substrate: 40% Rubble: 40% Sand: 20%	5% coral cover 20% algal cover
Station 8 28.04.08 PM Reef flat southeast	1 m	Reef flat southeast Hard substrate: 50% Rubble: 30% Sand: 20%	20% coral cover 10% algal cover
Station 9 28.04.08 PM Reef flat southeast	1 m	Reef flat southeast Hard substrate: 50% Rubble: 30% Sand: 20%	20% coral cover 10% algal cover

Sampling technique

Sampling was carried out by scuba diving and free diving at depths of 1–15 m. The nine stations, spread over part of the bank reef (Fig. 2), were surveyed by a diver who followed a random route for one hour and recorded the various species of echinoderms present and the number of specimens per species. This timed dive made it possible to visualise various habitats within the same biotope and to view larger areas than with the more conventional transects or quadrats (Leeworthy and Skewes 2007; Hart 2006). Nine hours of diving were spent counting and photographing the various species. Sampling at the nine stations comprised systematic investigation of the reef surface, cavities, dead coral blocks that could be turned over, and sediment.

Results

Holothurians

The total density of holothurians recorded during our investigation was 86 specimens in nine hours of diving, or approximately 9.5 specimens per hour. Ten species of holothurians were observed. Table 2 shows the species observed, their relative abundance and the frequency of observation of the various species.

Holothuria nobilis (Fig. 3A1 and A2), with a relative abundance of 75%, is the most abundant species. This species is also the one showing the highest observation frequency (55.5%) and was primarily sampled on the reef flats. *Bohadschia atra* (Fig. 3B1 and B2) is the most abundant species and the most frequently observed on the outer slopes. This species was not seen on the reef flats. Few of the other species were observed more than once.

All the stations sampled had at least one species of holothurian. Station 7, a reef flat station with a large rubble field and low coral cover (Table 1), is the station with the greatest species richness (5 species) (Table 2). Stations 8 and 9, southeastern reef flat stations, had lower species richness than Station 7 with only two species. However, Stations 8 and 9 had the greatest abundance, particularly with species *Holothuria nobilis*. To a lesser degree, Station 4 on the north outer slope appears to offer potential, with three species found.

All species observed are shown in Figure 3. For some species, such as *Holothuria lineata* (Fig. 3I), ossicle examination was required; other identifications, *Labidodemas rugosum*, *Holothuria impatiens* and *Holothuria hilla*, were done by consulting taxonomists (Dr Y. Samyn, Dr C. Massin); other species were easier to identify from photographs, such as *Holothuria nobilis* (Fig. 3A), which needed handling to remove the layer of sediment covering them (Fig. 3B).

Other echinoderms

Concerning other organisms, we recorded eight species of ophiuroids, four species of echinids, no species of asterid and no species of crinoid. Table 3 shows the species of ophiuroids observed, their relative abundance and the frequency of observation of the species in this class.

The total density of ophiuroids recorded during the survey was 53 specimens per seven hours of diving, or approximately seven specimens per hour. Eight species of ophiuroids were sampled (Table 3).

All the species of ophiuroids were found on the reef flats of Grande Glorieuse and none on the outer

Table 2. Abundance of the various species of holothurians sampled by station on Grande Glorieuse in nine hours of diving (one hour per station), relative abundance (number of specimens of a species/total number of holothurians) and frequency of observation (number of stations at which the species was observed/total number of stations) as a % of total.

Station (St)	St1 **	St2 *	St3 *	St4 *	St5 **	St6 *	St7 **	St8 **	St9 **	Relative abundance	Frequency observed
<i>Holothuria nobilis</i>	2			1			8	24	28	73 %	55.5 %
<i>Bohadschia atra</i>		3	1	6		1				13 %	44.4 %
<i>Bohadschia subrubra</i>			1	1				1		3.5 %	33.3 %
<i>Synapta maculata</i>							1		1	2.3 %	22.2 %
<i>Euapta godeffroyi</i>							2			2.3 %	11.1 %
<i>Holothuria hilla</i>							1			1.2 %	11.1 %
<i>Holothuria cf. impatiens</i>							1			1.2 %	11.1 %
<i>Holothuria lineata</i>					1					1.2 %	11.1 %
<i>Holothuria cf. pardalis</i>								1		1.2 %	11.1 %
<i>Labidodemas cf. rugosum</i>							1			1.2 %	11.1 %

* Outer slope stations; ** Reef flat stations

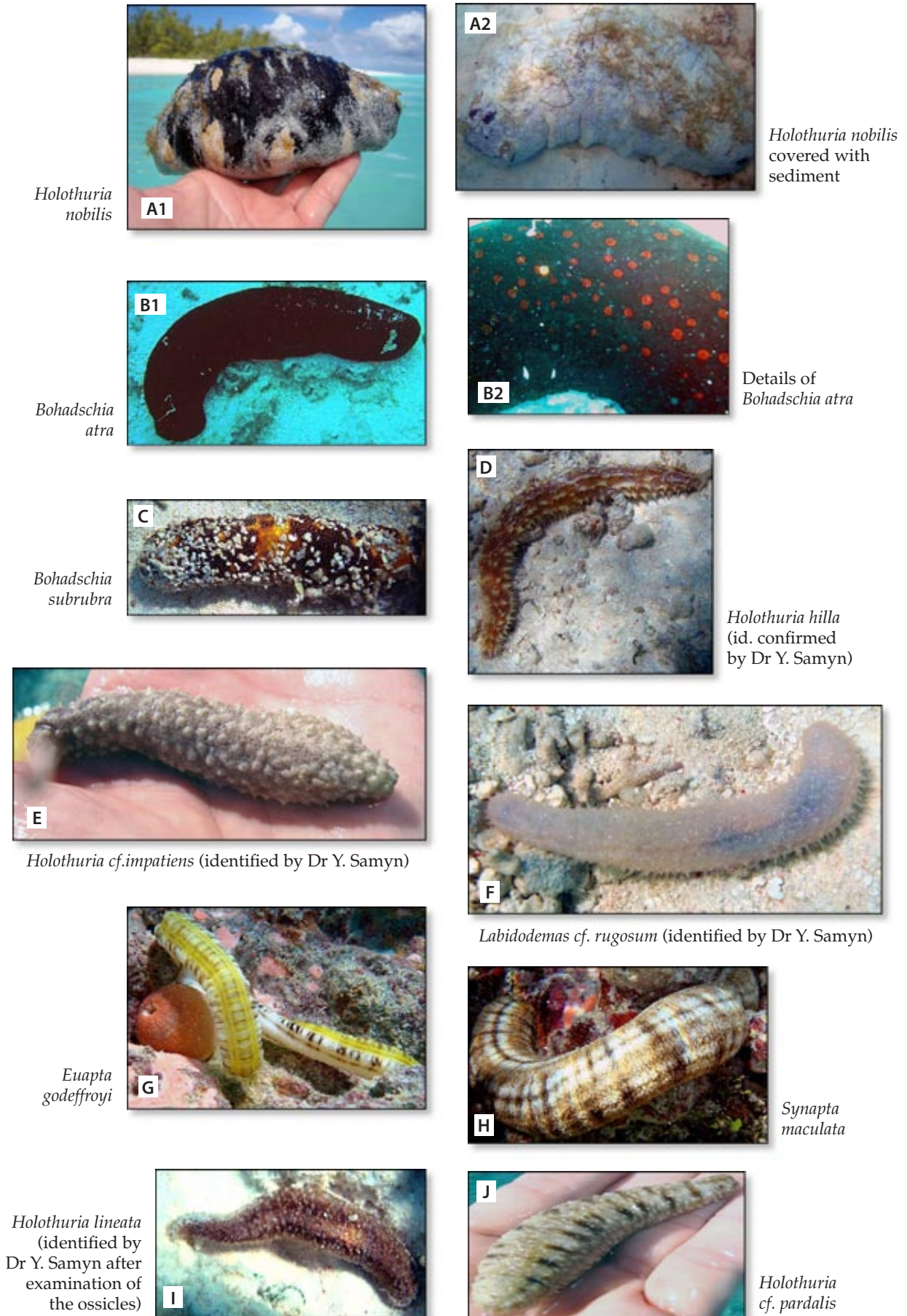


Figure 3. The various species of holothurians sampled on the reef at Grande Glorieuse.

Table 3. Abundance of the various species of ophiuroids sampled by station on Grande Glorieuse over seven hours of diving (1 hour per station), relative abundance (number of specimens of a species/total number of ophiuroids) and frequency of observation (number of stations at which the species was observed/total number of stations).

Station (St)	St 1	St 2 *	St 3 *	St 4 *	St 5	St 6 *	St 7	Relative abundance	Frequency observed
<i>Ophiocoma brevipes</i>	11				7		2	38 %	43 %
<i>Ophiocoma shoeneleini</i>							15	28 %	14 %
<i>Ophiarthrum pictum</i>	3				1		8	23 %	43 %
<i>Ophiocoma erinaceus</i>	2							4 %	14 %
<i>Ophiocoma valenciae</i>							1	2 %	14 %
<i>Ophiarachnella gorgonia</i>							1	2 %	14 %
<i>Macrophiothrix longipeda</i>							1	2 %	14 %
Ophiuroidea							1	2 %	14 %

* Outer slope stations

slopes (Table 3). All these species inhabit the same kind of rubble environment with few living coral colonies, a lot of coral rubble and a lot of sediment. *Ophiocoma brevipes* and *Ophiarthrum pictum* were seen at all the reef flat stations (cf. Fig. 2). Station 7 was the one where the abundance and diversity of ophiuroids were the greatest.

We also observed 3 species of Echinoids represented by 1 specimen of *Eucidaris metularia* at stations 5 and 7; 1 *Echinothrix calamaris* at Station 5 and a number of specimens of *Echinostrephus aciculatus* at stations 2, 3, 4, 6, 7, 8, and 9.

Discussion

Holothurian diversity, as observed in this study, is low (10 species) compared to that recorded at other research sites in the Comoros (Samyn et al. 2005), Mayotte (27 species, Conand et al. 2005) and Reunion Island (Conand and Mangion 2002). However, intensified sampling effort could make it possible to increase specific richness, although Vergonzanne in 1977 also only found 10 species despite extensive surveys, but his work was restricted to the reef flats of Grande Glorieuse.

Holothurian density for the surface area investigated also seems very low in comparison with some areas of other Indian Ocean islands. The data relate mainly to reef flats, like those of the fringing reefs of Reunion Island, where they may reach levels of several hundred specimens per station per hour (pers. comm.). This scarcity could be explained by the lack of favourable biotopes, because the organic matter concentration needed to sustain holothurians could be too low. However, it can be assumed that the Glorieuses Islands reef environment is much less subject to human influences and that the holothurian diversity and abundance noted during the study reflect the circumstances of an oceanic reef as compared to

a reef receiving organic matter deposits from human activities, such as the Reunion Island one.

Holothuria nobilis (Fig. 3A), a species with high commercial value (Conand 1999), occurs abundantly on the reef flats of the Glorieuses Islands in comparison with other nearby sites like the reef flat of the Geysier Bank (Mulochau and Conand 2007), Grande Comore (Samyn et al. 2006) or Mayotte (Pouget 2005). This species is one of the most collected in Mayotte and the Comoros (Pouget 2005; Samyn et al. 2006) and Samyn reports that this very sought-after species no longer occurs in the upper 20 m in the Comoros. In the Glorieuses Islands, a site classified as a Nature Reserve, this species is frequently encountered on the reef flats on coarse sandy bottoms and rubble beds containing occasional coral colonies. We have not observed any preferential distribution patterns on the reef flats.

Bohadschia atra (Fig. 3B), a recently described species (Massin et al. 1999) in the southwestern part of the Indian Ocean, shows relative abundance similar to that observed in Mayotte (Pouget 2005) and, as on that island, also characterises the outer slopes of stations sampled around Grande Glorieuse.

It can also be noted that *Thelenota ananas*, a species quite frequently observed on the Geysier Bank (Mulochau and Conand 2007) situated 135 km southeast of the Glorieuses Islands was not found on this reef.

We sampled a number of species that burrow into the sediment under coral formations or blocks of dead coral, in particular *Holothuria lineata* (Fig. 3I); this species, often confused with *Holothuria pardalis* or *Holothuria verrucosa*, is characteristic of shallow lagoons and has already been observed in Mauritius, Mozambique and the Red Sea (Pearson 1910)

as well as in Australia (Rowe and Gates 1995). The other burrowing species observed are: *Holothuria hilla* (Fig. 3D), *Holothuria cf. impatiens* (Fig. 3E), *Labdodemas cf. rugosum* (Fig. 3F) and *Holothuria cf. pardalis* (Fig. 3J). Only *Holothuria lineata* was identified from examination of its spicules. It would be desirable to observe the spicules of these other species to confirm the identifications. Also, the abundance of these species may be under-estimated because of their behaviour.

Lastly, it can also be noted that the holothurian species *Holothuria pardalis*, the most abundant to be observed by Vergonzanne (1977), was seen only once during our work.

The objective of this project was to sample the holothurians, but we were also able to sample 8 species of ophiuroids. According to Vergonzanne (1977), ophiuroids represent the most abundant and diversified class of echinoderm with 17 species recorded on the reef flats of Grande Glorieuse. The same sampling technique as that used on the reef flat (turning over blocks, searching through sediment, etc.) did not enable us to find any specimens on the outer slopes; in this environment and because of the negative phototropism of ophiuroids (Fell 1966), a night sampling effort might make it possible to observe other species.

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The commercial sea cucumber fishery in Turkey

Mehmet Aydin¹

Introduction

Commercial sea cucumber species in the Aegean Sea, Mediterranean Sea and the Sea of Marmara in Turkey are not consumed domestically but are exported to Asian countries. It is thought that 37 species in the family Holothuriidae are found in the Mediterranean (Fischer et al. 1987). Prior to 2002, there was no regulation regarding the harvesting of commercial sea cucumbers. In 2002, a regulation was established prohibiting sea cucumber fishing during the reproduction period in order to protect sea cucumber stocks (Anonymous 2002). However, there is very little information concerning existing sea cucumber stocks and fishery activities in Turkey. This study examines the potential sea cucumber fishery in Turkey.

Commercial sea cucumber species in Turkey

In the present study, only the commercial sea cucumber species, *Holothuria tubulosa*, *H. sanctori*, *H. polii*, *H. mammata* and *Stichopus regalis* (Figs. 1, 2 and 3), which commonly occur in Turkey's coastal waters, were considered. Data concerning total production and processing methods were collected from the Turkish Statistical Institute (Ankara, Turkey), General Directorate of Protection and Control (Ankara, Turkey) and private companies (Izmir, Turkey).

Production and processing

Recent total sea cucumber production in Turkey is presented in Table 1. Of the five species considered in this study, *H. tubulosa*, *H. polii* and *H. mammata* are

the most commonly exported. These species reproduce especially in nearshore areas during summer in the Mediterranean (July, August and September) (Despalatovic et al. 2004). They live in coastal areas on rocky or soft substrates, between 0 m and 100 m depth. *Posidonia oceanica* meadows are suitable habitats for this species (Fischer et al. 1987).

Stichopus regalis was exported only in 1996 and 1997. This species occurs in the Sea of Marmara and is commonly found in areas deeper than 40 m (Kınacıgil et al. 2003).

Note: 2006–2007 data from DIE. 1996–2005 data from private companies and the General Directorate of Protection and Control.)

Production of sea cucumber fluctuated between 1996 and 2007, and even stopped from 1998–2001. The main reason may have been limited demand during the low production period.

The government allows fishermen to collect sea cucumbers by diving year round, except from 1 August to 15 September. During fishing, a surface-supplied air system is used for divers. One diver can collect approximately 2,000–3,000 sea cucumbers in a day (Fig. 4). *S. regalis* was obtained as bycatch in shrimp beam trawls in the Sea of Marmara.

Collected sea cucumbers are purchased by the piece by processing companies, and are transferred to processing facilities in plastic barrels. Sea cucumbers are first eviscerated and washed with cold water, regardless of processing methods. During process-

Table 1. Total production and processing methods of sea cucumber in Turkey.

Year	Total production (kg)	Processing	Basis of production amount
1996	19,868	Frozen	Fresh
1997	37,665	Frozen	Fresh
2002	172	Flour	Dry
2003	10,843	Dried and flour	Dry
2004	5,421	Dried	Dry
2005	53,293	Dried and frozen	Dry + fresh
2006	24,200	Frozen and dried	Dry + fresh
2007	77,238	Frozen, dried and salted	Dry + fresh

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ing, different techniques are applied (see Table 1). The processing method depends on recipient companies' requests, but sea cucumbers are generally exported in dried and frozen forms (Fig. 5).

The drying process is carried out in two ways: sun drying and oven drying. Sun drying is the preferred technique because of its low cost. However, oven drying (50–60°C for 30 min.) is also done, especially during winter.

There are 22–90 sea cucumbers per kilogram of frozen product and 45–270 pieces per kilogram of dried product. Sea cucumber prices range from USD 7–32/kg. Singapore, Korea, Taiwan, Hong Kong and Norway are the main importing countries.

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Figure 1. *Holothuria tubulosa* and *H. mammata*.



Figure 2. *Holothuria sanctori*.

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Figure 3. *Holothuria tubulosa*, *H. mammata* and *H. polii*.



Figure 4. Surface-supplied air system for divers.



Figure 5. Dried *H. tubulosa*.

Diving for holothurians in Vietnam: A human and environmental disaster

Jean Ruffez¹

Abstract

On Ly Son Island in Vietnam, 400 to 500 fishers earn their living from diving. Holothurians are by far the most popular target species for these divers. The diving accident rate is 5% mortality and morbidity. The Francophone Association for Life Science Cooperation and Promotion (AFEPS) is offering to train “rescue divers” who could help prevent and respond to diving-related accidents and also to mitigate the disabling consequences of such accidents. It is clear that an ideal alternative would be to establish holothurian farms around the island and maintain a rational harvest. Unfortunately, AFEPS does not have the financial resources to make such an offer and should avoid doing so because the result would be to push the very people it seeks to help into unemployment.

Introduction

In Vietnam, as in many tropical countries, tens of thousands of fishers dive for a living. These people often belong to the poorest groups in their societies. They offer their services to a “boatmaster” for fishing trips that often take them far away from home. Since 1998, AFEPS has been working with such fisherfolk, in conjunction with Vietnamese doctors who, like us, are inspired by the work of Alexandre Yersin on behalf of the fishers of Central Vietnam. Our Organisation de Solidarité Internationale (OSI – International Solidarity Organisation) is basically medical in nature and its responsibilities are limited to trying to prevent, manage and treat various diving accidents suffered by divers while fishing. AFEPS has already staged training workshops for medical officers responsible for fishers’ health, developed divers’ logsheets suitable for recording their activities, and has spoken out against the human and environmental disaster that this fishing method represents. The Vietnamese government and media have continued to turn a deaf ear to this issue, until recent months. Early in 2007, a major national television channel and some national newspapers heightened community awareness around this shocking state of affairs. In June 2007, an article referred to the sad fate of divers from Ly Son Island. It portrayed diving accidents (mostly decompression incidents) as part of the job, but highlighted their tragic consequences: many dead and paralysed divers. We therefore offered our help to local authorities, who asked us to meet them and suggest some options.

The Union des Blessés de la Face et de la Tête (UBFT – Union of Face and Head Wound Sufferers), which

works on the prevention of neurological and cerebral disorders, has given us its support and has opened a credit line to fund the purchase of emergency and treatment equipment. In February and March 2008, an AFEPS working group travelled to Ly Son to investigate this issue and make some recommendations.

Social organisation and holothurian fishing on Ly Son Island

The Island of Ly Son lies offshore from the town of Quang Nai (the administrative centre for the province of the same name). The island can be reached from the port of Quang Nai, which is 25 km from the town on the estuary of the Tra Khuc River. The island is 20 nautical miles from this port. There are in fact two islands: the “big island” and the “small island”, which are joined together by a strip of coral reef. The big island, also known by its inhabitants as Culoa Re, measures approximately 5.5 km from west to east and 2.7 km from north to south, and about 1 km² in area. The northern coast is more exposed to winds and storms, and so moorings and ports are mostly along the southern coast. The small island lies about 2.5 miles to the north northwest of the big island. The two islands, each having a chief, form a single district, which is administered by a “People’s Committee”. There are approximately 20,000 inhabitants in the district.

The big island has a hospital that mostly does preventative work (e.g. vaccinations, consultations, screening, etc.) and handles medical and surgical emergencies (e.g. caesarean section) and minor sur-

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gery (appendicitis). Schools range from primary to upper secondary. Students who successfully complete secondary education can continue their education on the continent. Young people who want to live on the island and who have no university qualification can work only in agriculture, mostly garlic and onion growing. Some, for prestigious reasons, or because they cannot find jobs on the continent, opt to work as divers. There are between 400 and 500 divers on the island. Diving for sea cucumbers is done from boats 14–15 m in length, on which live a dozen crewmen, including three or four divers. The boat is fitted with a small compressor that is driven by a belt running off the boat's engine. Compressed air is pumped through a small "buffer" tank, which has three or four hoses (60–70 m long) branching off of it. Each branch hose is attached to a weight belt on the diver's waist (Fig. 1). The diver places the end of the hose straight into his mouth, with his mouth serving as a pressure regulator because the air must be delivered at a pressure of seven to eight bars. Divers are given a net to place their harvest in. The island has about 90 such boats, most of which are equipped for holothurian fishing around the Paracel Islands, a two-day trip from Ly Son Island. A few boats stay close to the island and collect shellfish and finfish for local consumption. Young divers get their experience around the island and then, when they feel ready, offer their services to a "boatmaster". A boatmaster prepares the boat for holothurian fishing trips, which usually last about four weeks. Divers remain in the water for 30-minute stretches, three times a day, every day, at depths of 50–55 m. All divers complain of symptoms relating to type 1 decompression accidents (osteoarthritic and muscular), but say that one night of rest is enough and that they

can resume diving the next day. Accidents recorded are not always easy to diagnose: in general, they are type 2 decompression accidents (medullary or cerebral accidents), which rapidly disable them and frequently make them paraplegic (Fig. 2). Excessive intra-lung pressure accidents have also been recorded when hoses break. Divers must return to the surface with no air. Because they have no fins, the 50 m ascent is exhausting and they stop breathing to give themselves a fair chance, but this entails a major risk of excessive pressure in the lungs. Some divers also die on the bottom, probably because of



Figure 1.
An holothurian fisherman ready to dive with the air hose attached to his weight belt.



Figure 2.
Tran Din Loc, ex holothurian fisherman from Ly Son village, tells about the diving accident that left him hemiplegic.
(image: P. Cavenel)

Earning a living at the bottom of the ocean

Tuoi Tre (youth) newspaper, 22/05/2008 (translation from the Vietnamese by Thi Phong Mai)

We were born, live and breathe on land, whereas they, the divers of Ly Son Island, Quang Ngai, have to spend their lives in the sea water. Their food and their life are at the bottom of the sea.

One very dark night, a small boat was “driving” on the sea near the Truong Sa Islands. Le Sen was wearing his diving gear and carrying his torch, then he put the air hose into his mouth and one of his hands was holding his pointed and barbed spear, while the other held a dip net. He took a deep breath and jumped into the sea. Le Sen was a fisherman from the An Hai district and had been diving for 15 years. To begin with, he used the motorised launch or “coffa” to go and harvest shellfish in the areas around the small islands close to the land. But, over these last 10 years, life has become harder and harder and so the fishermen have had to go further and further offshore. Le Sen cannot remember how many times he has been to sea. During the fine weather season, the sea is calm and he goes diving around the Hoang Sa or Truong Sa islands. In the bad season, he fishes around his island.

Le Sen and his friends gather everything that could be classified as seafood. On the boat, the divers are divided into several teams, with each team comprising two to three people. Le Sen’s team works at night. The reason for this is simple: you find more seafood at night than by day.

Under the sea, there is no light and everything seems immense. The light from the divers’ head-lamps attracts fish and squid. The divers’ job is to spear them quickly and accurately and put them in a scoop net. The length of time they spend under water depends on the depth of the sea at each location. The teams work in turn. Each team dives for four hours. On the boat, while they wait their turn, the others rest, and keep an eye on the air hose supplying their friends under the water.

Employment from diving has made it possible to improve living conditions for some of this island’s fishers, especially since the prices for holothurians, the seafood item that the fishers target the most for export, have been very high. After 15 years of diving, Le Sen has managed to build a house for his family and contribute with his brothers to the construction of a 350 hp fishing boat. Another example: Mr Doung Quang Thang of An Vinh district, after some 10 years of diving for holothurians from a powerful boat, has also been able to build a two-storey house. It is courtesy of the sea that the divers have better living conditions on land. But to be a diver is also a very tough profession. Some become disabled because they have to earn a living!

Truong Tuan Nhuan is also a diver, but the life of this 45-year-old fisherman is still extremely hard. He was lucky enough to survive a major storm in 2003, when he was fishing at Trung Sa. The boat’s crew was thrown overboard. Many of his friends on that boat were not as lucky as he and did not come home. Almost every year, the village inhabitants dig new graves for those who have died at sea. Some survive the danger but at the bottom of the sea you cannot predict what will happen. This was the case with Mr Tran Dinh Loc from Con village, in An Vinh district, a 41-year-old diver who now resembles a two-year-old child because he has got to learn to walk again after his diving accident and can no longer look after himself, not even to take a bath. He sighs as he says: “Two years ago when I was diving, I used to see heaps of fish, I was so happy, instead of catching them over two dives with a long break between the two I only took a short break. When I came out of the water, I had the feeling that my bones had been ‘stretched’, I had tingling in my arms and blood was coming out of my ears!” Seeing him in this state, his friends immediately realised that he had had a diving accident and put him back under the water so that he would not experience sudden air pressure variation but this did not improve his state and he was taken home and submerged in a large tank of water and then hospitalised as an emergency case, but in vain. Since then, he has had to give up his job. At present, to feed a family of four children, his wife goes down to the seaside to sell seafood and she also has to cover the costs of daily health care for her husband. Her second, 15-year-old, son has given up school and goes out fishing with his friends. Mr Loc said: “Around here, there were some 10 people in the same state as me: Mr Vui, Mr Quw, Mr Miet, etc.” These are serious diving accidents and, in addition, there are many cases of impaired hearing.

excessive toxic gas content in the air they breathe. Divers from Ly Son seem more aware of the danger than divers from other provinces, and have themselves reduced the number of dives per day from 5 (lasting 30 minutes) a few years ago to 3 (lasting 30 minutes) at present. Clearly this is still too much because they do not make any decompression stops, and the precautionary approach would be to make only two dives per day of 20 minutes duration, each with a decompression stop. It would also be preferable that divers only work six days out of seven in order to decompress. Unfortunately, divers' income would be proportionately reduced and they cannot afford this. It is difficult to know what they earn from four weeks of holothurian diving but it cannot be more than USD 65–80. The mortality and morbidity rate is lower than in the other provinces, but is still approximately 5%. What this means is that half of the divers must be replaced every 10 years. We noted that the island's divers had a higher level of education than the average recorded elsewhere. Eight out of 10 apparently know how to read and write, and many have a secondary level education and some have successfully completed the full secondary school curriculum. They no doubt had to drop out of university subsequently.

What is the future for these young men in the medium and long term?

We are restricted to offering them a rescue diver training course. We will initially be suggesting that some 20 volunteers be trained, if possible with enough schooling to enable them to absorb the contents of the course and especially to subsequently become trainers themselves. We will give them the rudiments of prevention, teach them basic rescue techniques and management of decompression accidents by TRI (therapeutic recompression by immersion) using pure oxygen. In fact, tanks and oxygen are very cheap in Vietnam. We will provide them with the required equipment for handling decompression accidents when they happen far away from a health centre equipped with a recompression chamber. But, in the longer term, holothurians will disappear from the 50 m depth zone, so in the end,

either the divers will need to go deeper to find them and there will be even more accidents, or they will need to give up collecting holothurians to retrain for another kind of diving activity (aquarium fish, groupers stunned by cyanide, lobster, etc.).

We thought about offering them a change of profession for less dangerous jobs, still connected to the sea. Environmentally friendly and community tourism is being introduced in many countries in this region. University teachers are orienting their students towards research of this kind and the first rural guesthouses and home stays are beginning to open. It would be possible for divers to run this kind of accommodation and look after recreational divers to whom they could offer underwater treks or diving on protected sites. We also know that these divers are capable of raising crayfish. We have learned that it is possible to construct holothurian hatcheries and reseed areas around the island and then take a reasonable harvest.

We have suggested these solutions to our Vietnamese colleagues who warned us and raised an essential issue: "To do something for other people without them is to do it against them" (Touareg proverb).

It is true that we have not yet spoken about this with the divers of Ly Son Island and we need to have their opinion. But especially, if unfortunately one or more boatmasters took up the idea of a holothurian hatchery, we would be putting several hundred divers out of work.

We cannot, therefore, suggest anything without talking to the divers themselves, and we especially cannot suggest a change of job even into lobster or holothurian hatcheries without having the financial resources to create a cooperative in which the poorest would also have a share of profits and benefits. We have, therefore, decided to do what we know how to do: provide a rescue diver training school and provide the equipment required for them to perform related tasks. In order to do so, we have funding equivalent to our ambitions thanks to the credit line opened by UBVT.

The influence of commercial diets on growth and survival in the commercially important sea cucumber *Holothuria scabra* var. *versicolor* (Conand, 1986) (Echinodermata: Holothuroidea)

Daniel Azari Beni Giraspy¹ and Grisilda Ivy²

Abstract

There has been enormous commercial interest in culturing tropical sea cucumbers in countries where sea cucumber populations have been overexploited. The production of sea cucumber juveniles in the hatchery requires suitable feeds to maximize survival rates and promote somatic growth. However, so far no research has evaluated the relative efficacy of commercially available feeds for promoting somatic growth and survival for the commercially important sea cucumber *Holothuria scabra* var. *versicolor*. Therefore, several experiments were conducted in the hatchery to evaluate somatic growth of newly settled six-week-old *H. scabra* var. *versicolor* juveniles.

Four commercially available feeds (Algamac 2000, Algamac protein plus, *Spirulina* and *Dunaliella* gold) were used to feed six-week-old juveniles, which averaged 1.7 mm in length at the beginning of the experiments. Juveniles were fed once a day at 3% of their initial body weight. Total body length and survival rates were measured at the end of every week. Significant differences in growth and survival were noticed among juveniles in the four feeding treatments. While Algamac protein plus induced good growth rates in golden sandfish as an individual feed, a mixed feed (Algamac 2000 and Algamac protein plus at 1:1 ratio) produced greater growth rates and survival.

Introduction

Sea cucumbers are harvested worldwide for their body wall (beche-de-mer), with the majority of product being exported to Asia. The rising demand for beche-de-mer product in Asian markets has created mounting harvest pressure on natural populations of sea cucumbers, which has led to severe overfishing throughout the world (Hamel et al. 2001; Conand 2004; Lovatelli et al. 2004; Uthicke 2004). In recent years, there has been a significant decline in natural sea cucumber populations in almost all countries that harvest them (Conand 2004).

Depletion of highly commercial natural stocks has encouraged aquaculture programmes for tropical holothurians (Battaglione et al. 1999; Conand 2004; Lovatelli et al. 2004; Pitt and Duy 2004; Giraspy and Ivy 2005; Ivy and Giraspy 2006; Agudo 2006). Stock enhancement of sea cucumbers, through the release of hatchery reared juveniles, has been suggested as a good solution to restore depleted populations (YSFRI 1991; Yanagisawa 1996; Battaglione and Seymour 1998).

The tropical sea cucumber *Holothuria scabra* var. *versicolor* (market name: golden sandfish) (Fig. 1), a holothurian believed to have aphrodisiac and medical properties, is an economically important species in Asian markets (Conand 1990, 1997; Conand and Byrne 1993). This species has long



Figure 1. *Holothuria scabra* var. *versicolor* – three color morphs (Image: D.A.B. Giraspy)

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been exploited as an important fishery resource in Australia and Pacific nations (Conand 1990, 1997, 2004). High-quality, golden sandfish beche-de-mer fetch more than USD175/kg on the Singapore market.

Economically feasible methods for mass producing *H. scabra* var. *versicolor* have been developed for the first time at Bluefin Sea Cucumber Hatchery (Ivy and Giraspy 2006). Successful production of *H. scabra* var. *versicolor* juveniles during 2005 facilitated the commercial culture of this species in Australia (Ivy and Giraspy 2006).

A major determinant of the viability of sea cucumber grow-out operations in the hatchery is the use of suitable feed for enhancing somatic growth and survival of juveniles in nurseries before releasing them into grow-out ponds or sea ranching. One of the problems encountered in this culture method is that there is no specific diet for small juveniles.

Several studies on nutrition and artificial diets have focused on larvae and juveniles of the temperate species *Stichopus japonicus* (Sui et al. 1986; Sui 1988, 1989). A few studies have also investigated artificial feeds for growing juvenile of other tropical sea cucumbers (Battaglione et al. 1999; Rasolofonirina and Jangoux 2004; Purcell 2005; Asha and Muthiah 2007), but no research has examined the most effective feed to promote growth and survival in *H. scabra* var. *versicolor* juveniles.

As part of commercially growing these golden sandfish juveniles to a size suitable for release into sea ranching areas, several experiments were carried out to promote the growth of settled juveniles. This study is part of an ongoing investigation to promote the somatic growth and survival rates of sea cucumber juveniles using artificial diets, and to identify the specific diet suitable for different species of sea cucumbers cultured in the hatchery. The

present study examined the effect of four different commercial feeds on the growth and survival of juvenile *H. scabra* var. *versicolor*.

Materials and methods

The proximate compositions (i.e. total protein, lipid and carbohydrate) of four commercial feeds used in this study are shown in Table 1.

Experiment 1: Effect of food type on the growth and survival of sea cucumber juveniles

To determine the effect of commercial feeds on the survival and growth of early juveniles, twelve 44-L plastic containers were stocked with randomly selected six-week-old *H. scabra* var. *versicolor* juveniles. Dietary treatment setup consisted of 720 randomly selected juveniles from the same batch divided equally among the 12 containers. Sea cucumber juveniles were fed at 3 % of their initial body weight in triplicate containers. The mean length of juveniles stocked was 1.7 mm at the start of the experiment in each of the containers.

The lengths of a sub-sample of 15 juveniles from each diet treatment were measured at the start of the experiment and at the end of every week during the experiment. The survival rates in different treatments were also determined at the end of each week and the percentage calculated.

Experiment 2: Effect of stocking density on growth and survival of sea cucumber juveniles

The effect of *H. scabra versicolor* juvenile stocking density on survival and growth was determined by stocking randomly selected six-week-old (mean length of 1.7 mm) golden sandfish juveniles at different densities. The three stocking densities used were 60, 90 and 120 juveniles in each 44-L container. The feeding regime was Algamac protein plus and

Table 1. Composition of commercial feeds.

Feed	Ingredient	Composition (%)				
		Protein	Fat	Carbohydrate	Minerals (ash)	Moisture
Algamac 2000	Spray dried cells of Schizochytrium algae	39.0	32.0	13.0	12.0	3.0
Algamac Protein plus	Heterotrophic and phototrophically produced algae, fungi and yeast cells.	42.9	21.0	-	12.4	6.0
<i>Spirulina</i> powder	Highly nutritious blue-green algae	57.0	8.0	24.0	6.2	2.1
<i>Dunaliella</i> gold	Nutrient-dense edible soft wall marine microalgae	7.4	7.0	29.7	49.0	3.0

Algamac 2000 (1:1 ratio) at 3% initial body weight each day. All treatments were made in triplicate and the feeding rate was maintained the same throughout the experiment.

Juvenile rearing conditions

Rearing conditions were similar in all experimental containers and were not artificially controlled. The seawater used in the experiment was one micron filtered and UV sterilized. A 50% water exchange was conducted every day and containers were cleaned weekly with minimal disturbance to the animals. Aeration was provided continuously and the oxygen level was always maintained above 5.5 mg L⁻¹. Seawater temperatures ranged between 24 °C and 27 °C, and salinity fluctuated between 34 ppt to 35.5 ppt during the experiments. The pH value was constant throughout the experiment and the photoperiod was maintained at 14 L:10 D.

Results

Juvenile growth

At the start of the experiments, there were no differences in body lengths of test sea cucumber juveniles among diet treatments (Table 2). However, at the end of the experiments, final body lengths of test animals in different treatments varied considerably (Figs. 2 and 3). Mortality rates of juveniles were high during the first three weeks in all the four treatments.

In single diet treatments, juvenile growth rates were greatest in containers fed with Algamac protein plus, with juveniles reaching a mean length of 46.8 ± 3.6 mm (Fig. 2). Juveniles fed with Algamac 2000 and *Dunaliella* gold reached 34.7 ± 2.6 and

33 ± 4.1, mm respectively. Juveniles fed with *Spirulina* grew to a mean length of 18.6 ± 2.9 mm (Table 2).

Daily growth rates of test sea cucumbers varied with different diet treatments and showed a descending order of diet: Algamac protein plus > Algamac 2000 > *Dunaliella* gold > *Spirulina* powder. Juvenile growth rates on Algamac protein plus was 0.65 mm per day, while it was 0.24 mm per day with *Spirulina*.

Stocking density

The effect of stocking density on the growth and survival of golden sandfish juveniles was quite noticeable in this experiment. Juveniles stocked at a lower density grew to 41.7 mm ± 4.2 in two months time.

This is 12.6 mm more than those juveniles stocked at medium density, and 23.1 mm than those stocked at higher density in eight weeks (Fig. 4). Juveniles stocked at a lower density showed an increase of 0.71 mm per day, while juveniles stocked at medium and high densities grew 0.49 mm and 0.30 mm per day, respectively (Fig. 5)

Table 2. Initial and final growth data for golden sandfish, *H. scabra* var. *versicolor*, early juveniles fed with four different commercial diets.

Feed type	Replicate no.	Total length	
		Start (mean ± s.e)	End (mean ± s.e)
Algamac 2000	3	1.7 ± 0.4	34.7 ± 2.6
Algamac protein plus	3	1.7 ± 0.3	46.8 ± 3.6
<i>Spirulina</i> powder	3	1.7 ± 0.3	18.3 ± 2.9
<i>Dunaliella</i> gold	3	1.7 ± 0.4	33.0 ± 4.1

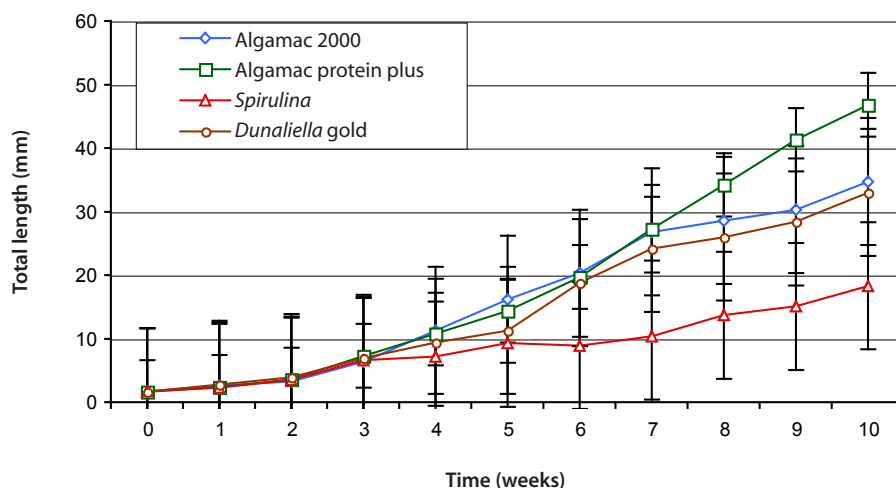


Figure 2. Mean growth of juvenile golden sandfish, *H. scabra* var. *versicolor* fed with commercial feeds.

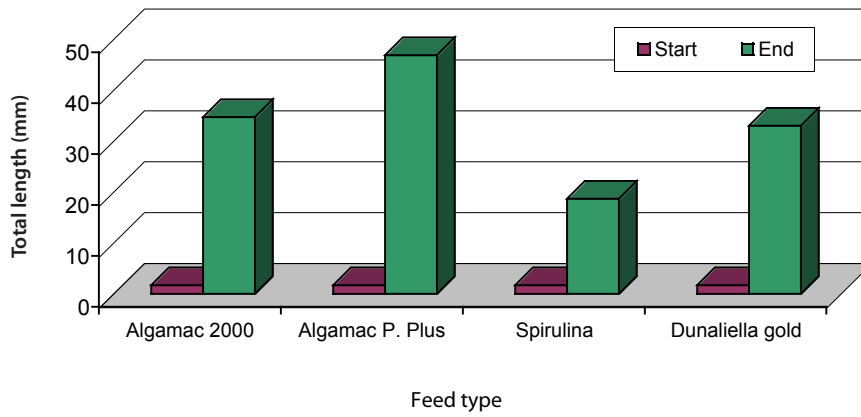


Figure 3. Initial and final body lengths of juvenile golden sandfish *H. scabra versicolor* fed with commercial feeds.

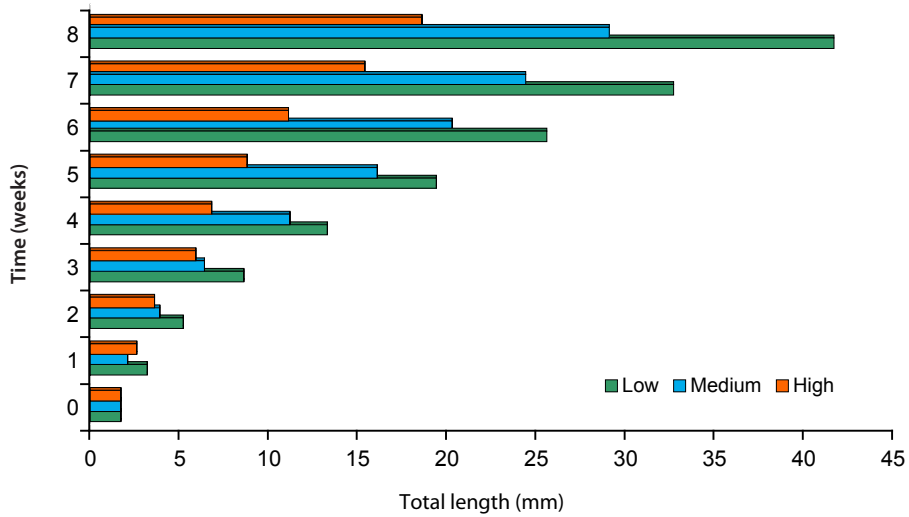


Figure 4. Mean growth of juvenile golden sandfish, *H. scabra var versicolor* maintained at different densities.

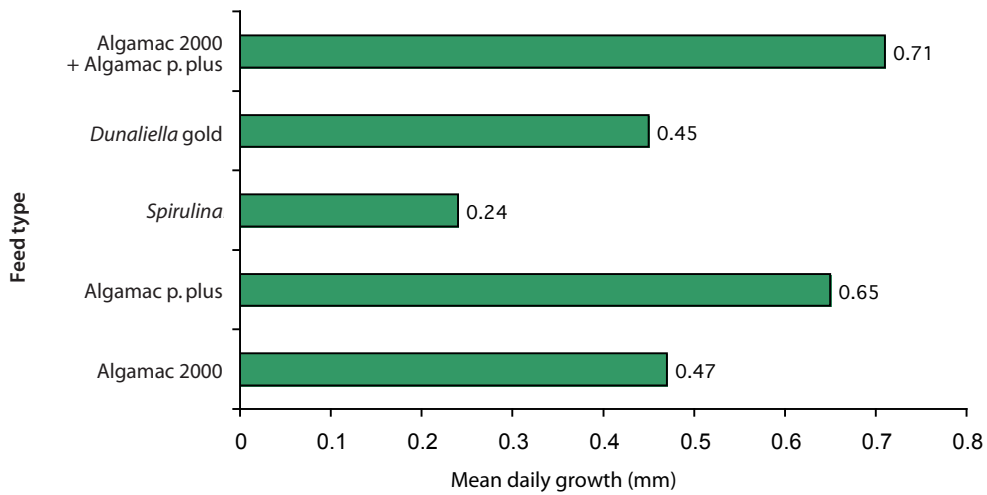


Figure 5. Daily growth rate of juvenile golden sandfish, *H. scabra var. versicolor* fed with five different types of feed.

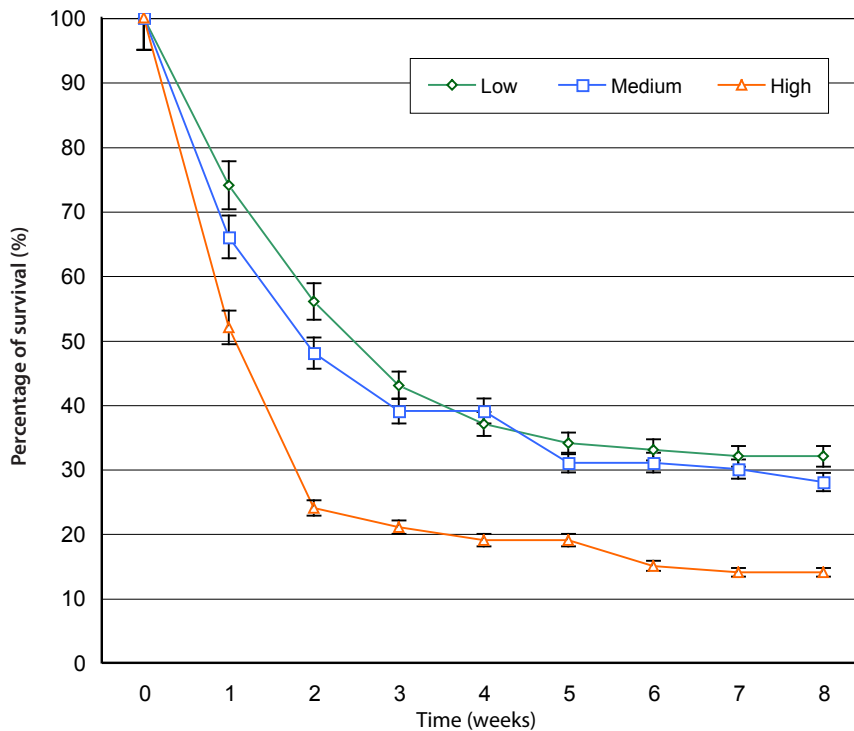


Figure 6. Survival rates (%) of *H. scabra* var. *versicolor* juveniles. Juveniles were reared in three different densities: low, medium and high.

The mean percentage survival of *H. scabra versicolor* juveniles varied greatly at low, medium and high densities (Fig. 6). At the end of the experiment, the percentage of survival at low density was 32%, and was 28% and 18% at medium and high densities, respectively. More than 50% of juvenile mortality occurred during the first three weeks of the experimental period. Juveniles in all treatments showed differential growth, irrespective of the density and feed type (Fig. 7).

Discussion

Early juvenile rearing is fundamentally important to commercial hatcheries that rear sea cucumbers, because juveniles are more susceptible (Ramofafia et al. 1997; Battaglione et al. 1999). Commercially available feeds used in the present investigation showed that certain commercially available microalgal feeds are effective in promoting growth and survival rates in *H. scabra versicolor* in the nursery stage. Artificial feeds investigated in this study were selected on the basis of suitability for nursery rearing based on the commercial availability. Previous usage in the hatchery has shown better growth and survival with *H. scabra*. (Giraspy and Ivy 2005; Ivy and Giraspy 2006)

Size is an important factor in survival when sea cucumber juveniles are transferred between dif-



Figure 7. Differential growth observed in *H. scabra* var. *versicolor* juveniles.

ferent rearing systems, and survival rates of larger juveniles are relatively high compared to smaller individuals (Battaglione et al 1999; Purcell, 2005). In all treatments, mortality was higher during the

first three weeks of the trials compared to the following weeks. The higher mortality rates in the earlier part of the experiment may be due to the smaller size (1.7 mm) of juveniles selected for the study. The survival rate of *Stichopus japonicus* — stocked at a mean length above 4 mm — was more than 60% for over 30 days (Ito 1995). Battaglione et al. (1999) in their studies observed higher mortalities of *H. scabra* juveniles mainly in the first two weeks of the experiment when stocked at a mean length of 1.5 mm.

Since the late 1980s, powdered algae have been used in the hatchery production of sea cucumber juveniles in China, Japan and India (Sui 1988; James et al. 1994; Battaglione et al. 1999). Battaglione et al. (1999) noted that *H. scabra* juveniles fed with Livic grew to a significantly greater length than those fed Algamac after four weeks. However, they did not find any significant differences in survival, total length or weight between diets at the end of the experiment. Most deposit-feeding holothurians have little cellulose activity in their gut and did not appear to assimilate macroalgae before it was decomposed by bacteria and fungi (Yingst 1976).

The present investigation clearly shows the growth differences among juveniles under different treatments. Battaglione et al. (1999) suggested that an addition of powdered algae was beneficial at high densities. Survival rates of newly settled *Stichopus japonicus* are related to stocking density and food availability (Ito 1995; Hatanaka 1996; Yanagisawa 1996; Ito and Kitamura 1997). James et al. (1994) argued that the survival of newly settled *H. scabra* might be improved by reducing competing organisms by filtration and also by providing food by conditioning plates.

The mean percentage survival of golden sandfish juveniles varied considerably in the density trial experiments. Survival rate also improved as they increase in size and age. The sea cucumber *S. japonicus* grew to a mean size of 4.3 mm up to 27.0 mm, depending on initial stocking density and culture conditions and the overall average length was 11 mm after three months (Ito 1995). In the present investigation, *H. scabra versicolor* juveniles grew faster than *S. japonicus*, to a mean length of 46.8 mm in 70 days (Table 2). *H. scabra* juveniles stocked at lower density grew significantly faster than those held at higher density (Battaglione et al. 1999). Higher survival rates (61.1 to 72.8%) were also recorded in *S. japonicus* stocked at mean lengths of 4.3–4.7 mm over 30 days (Ito 1995). Battaglione et al. (1999) found that *H. scabra* juveniles stocked at 20–31 mm in length grew 0.2–0.8 mm day per day with an overall average of 0.5 mm per day. Muliani (1993) recorded growth rates of 0.4 g day for larger *H. scabra* juveniles at initial stocking

densities of 134–186 g m⁻², in enclosures without addition of food.

Conclusion

The present investigation has, for the first time, compared the efficacy of commercial diets in promoting growth and survival for the large-scale application in the hatchery. Results of this study validate the use of suitable commercial feeds as food for *H. scabra* var. *versicolor* juveniles in the nursery phase. Juveniles fed with a mixed diet comprising Algamac 2000 and Algamac protein plus grew more than animals fed with individual diets, indicating that this composition would be better for intensive cultivation of *H. scabra* var. *versicolor* juveniles in the nursery. The use of these artificial feeds, either full or partial (i.e. in conjunction with seagrass or seaweed extract), should be considered in order to reduce commercial production costs and to improve the survival and growth rates of juvenile sea cucumbers.

Acknowledgements

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Poor retention of passive induced transponder (PIT) tags for mark-recapture studies on tropical sea cucumbers

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Abstract

We tested the short-term retention of passive induced transponder (PIT) tags on 20 adult sea cucumbers of both *Holothuria whitmaei* and *Actinopyga miliaris* in New Caledonia. One PIT tag was injected into the coelomic cavity of each individual. One double T-bar tag was inserted into the same hole in the body wall as a means of later identifying the individuals with PIT tags. Only eight days after release in suitable reef habitats, just one-quarter of *H. whitmaei* individuals retained PIT tags and no *A. miliaris* individuals retained them. T-bar tags caused lesions in many *H. whitmaei* and we concur with previous studies that these tags are unsuitable for biological studies on most tropical sea cucumber species. In view of the poor retention of PIT tags, we encourage the development of novel tags for tropical sea cucumbers that are individual, biologically benign, cheap and can be identified in the field.

Introduction

Fishery managers need better information on the growth and movement of commercially valuable sea cucumbers. Reliable estimates of sea cucumber growth rates in natural habitats provide a better understanding of how quickly the animals can attain harvestable size from juvenile stages. These estimates are important, for example, in assigning the periodicity of rotational fishing closures or time frames for temporary closures. Information on displacements of sea cucumbers over medium and long time intervals (e.g. 1–5 years) can inform managers about how far different species are likely to disperse and, therefore, how large no-take reserves need to be to protect breeding populations.

The estimation of growth rate and displacement of marine animals in the field is usually achieved through mark-recapture studies. A number of individuals need to be tagged with tags that are individually identifiable and can be identified rapidly in the field. Tags need to be generally retained for long periods and need to be benign in their effects on the animals' growth and movement.

Previously, we studied the retention and detection of various tag types on the sandfish *Holothuria scabra* (Purcell et al. 2006). That study indicated that coded wire tags and elastomer implants could not be used to identify individuals easily and that T-bar tags were stressful to the animals and expelled quickly in juveniles. We therefore proposed to try the use of passive induced transponder (PIT) tags, inserted

into the coelomic cavity of sea cucumbers, as the new tagging method for the present study. The PIT tags (also called microchips) are the same as those used in livestock and pets. They are commonly 12 mm long and return a signal to a decoder to show the individual tag number. Success in the retention and benign effects of PIT tags has been documented for fish (Ombredane et al. 1998; Skov et al. 2005; Woods 2005), crustaceans (Bubb et al. 2002) and sea urchins (Woods and James 2005) but no studies had been published on their use in sea cucumbers.

The short-term study was conducted to trial the PIT tags in two species, *Holothuria whitmaei* and *Actinopyga miliaris*. These species were chosen because they are commercially important, belong to different genera, and were relatively abundant at the study site. We aimed to determine if the retention of PIT tags was high enough over one month to give confidence in their use for long-term mark-recapture studies. Animals were also tagged with double T-bar tags. The body wall of *Holothuria whitmaei* is 12 mm, whereas it is 6 mm thick in *Actinopyga miliaris* (SPC 2004). Single T-bar tags were used on seven sea cucumber species by Conand (1991), who found that retention was generally poor but could be nearly two years in some individuals. However, she concluded that "the tagging generates a stress" because some tagged individuals eviscerated, individuals of most species shrank after tagging, and tags were often expelled by the animals. We therefore only employed the use of T-bar tags as a means of later distinguishing the tagged animals from wild conspecifics, not as a proposed method for biological studies.

Methods

The study commenced on 25 April 2007 at Ilot Maître, New Caledonia. The large reef surrounding the island was declared a provincial marine reserve in 1990. We collected 20 individuals of two species with different body morphology and size: *Holothuria whitmaei* (black teatfish) and *Actinopyga miliaris* (hairy blackfish). All *H. whitmaei* individuals were collected from the reef base on the northwest side of the main reef, and all *A. miliaris* individuals were collected in shallow lagoon seagrass beds just to the north of the island.

The animals were placed in bins of seawater on a boat, and were drained for about 1 minute on deck before being measured (length and width on the ventral surface, to ± 0.5 cm) and weighed (to ± 5 g, with an electronic balance). The body weights of *H. whitmaei* individuals averaged 2,440 g, while those of *A. miliaris* averaged 532 g.

Immediately after being weighed, one PIT tag was injected into the coelomic cavity on the dorsal surface, about one-third of a body length from the anus. A double T-bar tag was then inserted through the body wall, in the hole from the PIT tag injection, such that one anchor was on the medial surface of the body wall and one anchor was outside the animal. The functioning and individual number of each PIT tag was then verified with a hand-held reader (Fig. 1).

The animals were held briefly in bins with fresh seawater before being placed on the reef in two groups. All of the 20 *H. whitmaei* were placed within an area of about 20 m² on sand-covered pavement in the lagoon next to large rocks where they could find shelter. This is a habitat in which we find *H. whitmaei* on other reefs and in which we have found this species at Ilot Maître. The 20 *A. miliaris* were placed in a separate group in shallow seagrass beds, in an area of about 20 m² near where they were collected. We also removed untagged *A. miliaris* from that area. The functioning of the PIT tags underwater was verified using the decoders, through a plastic bag, on several occasions.

Eight days after tagging and releasing the sea cucumbers, we returned to the field sites where the two groups had been placed. All 20 individuals of both species were relocated visually. We then recorded whether the animals had retained the T-bar tag, and noted the tag number (Fig. 2). The presence of a PIT tag was checked thoroughly using the decoders, as practiced in the previous week. Because few PIT tags were detected (discussed below) we also

dissected a couple individuals, which verified that there were no PIT tags retained in the body cavity.

Results and discussion

Eight days after tagging, only 5 out of the 20 tagged *H. whitmaei* had retained PIT tags, and only 10 out of the 20 individuals had retained the T-bar tags. Additionally, we observed that about half of the individuals with T-bar tags had infected lesions (white growth and exposed tissue) around the insertion point of the tags. A T-test showed that animals retaining PIT tags were not significantly heavier than those that lost them ($t_{18}=0.53$, $p = 0.60$). Although *H. whitmaei* individuals that retained T-bar tags were heavier (2,641 g) than those that had expelled them (2,240 g), the difference was not significant ($t_{18}=1.54$, $p = 0.14$).

None of the *A. miliaris* had retained PIT tags, but 12 out of the 20 individuals had retained T-bar tags. Notably, only a couple of the animals with T-bar

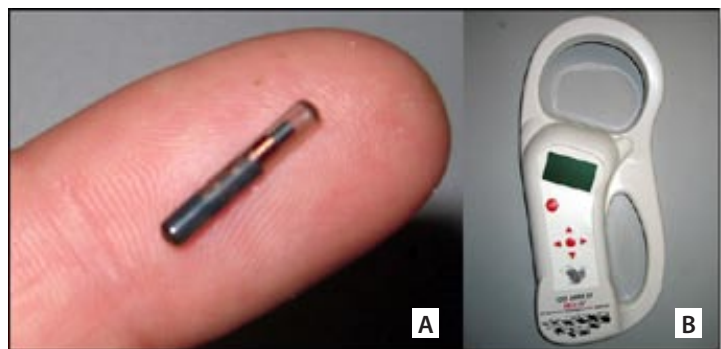


Figure 1 . A) PIT tag. B) Hand-held PIT tag decoder (Loligo Systems ApS, Denmark).



Figure 2. A black teatfish, *Holothuria whitmaei*, on the lagoon reef platform, showing an orange T-bar tag (circled) retained in the body wall, eight days after tagging.

tags had lesions near the tag insertion points. *A. miliaris* individuals that retained T-bar tags were heavier, on average (566 g), than those that lost them (481 g), but the difference was marginally non-significant ($t_{18}=2.07, p = 0.053$).

In view of low tag retention rates after only eight days in both species, we concluded that PIT tags were unsuitable for these species, and probably for other related species too. Also, the lesions seen with T-bar tags, and the relatively high loss rate of about half the tags in eight days, suggested that they were also unsuitable for studies on growth and behaviour. In both species, we found an indication that larger individuals retain T-bar tags better than smaller ones. Similarly, Conand (1990) found that small *A. echinites* lost T-bar tags more readily than large ones and caused “necrosis of the body wall, sometimes leading to death”. Deleterious effects were a general conclusion of Conand (1991) using single T-bar tags on five of seven sea cucumber species. Her findings on movement of tagged *A. mauritiana* and *A. echinites* are valuable, as few results of this nature exist, but whether the movement rates were affected (higher or lower) by the tags cannot be discounted. A key result of Conand (1991) was that the utility of T-bar tags differs among species. Based on findings on the two species in the present study, we believe T-bars have limited use in biological studies (e.g. growth, movement, mortality) on most tropical sea cucumbers. Further improvements to minimise deleterious effects of external tags on sea cucumbers could prove resolve this problem.

Conclusions

T-bar tags can cause lesions in sea cucumbers, and we argue that external tags of this nature may confound results from studies on growth and movement due to deleterious effects on animal health. PIT microchips were mostly rejected and, unfortunately, do not appear to be suitable tags for sea cucumbers.

Genetic fingerprinting remains a useful “tagging” method for mark-recapture studies on sea cucumbers (Uthicke and Benzie 2002, Uthicke et al. 2003). However, it requires much analytical competence, detection is relatively costly, and tagged and untagged animals are indistinguishable in the field. Fluorochrome marking (Purcell et al. 2006) is cheap but is mostly a batch-marking technique that could only be applied in the field to small isolated groups of individuals, which again, are distinguishable only after examination of tissue samples in the laboratory. We therefore encourage the development of novel tagging methods for sea cucumbers that are cheap, allow animals to be individually distinguished in the wild, and are benign in terms of their affect on animal health.

Acknowledgements

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Abstracts & new publications...

Sea cucumbers fisheries: a manager's toolbox

Friedman K., Purcell S., Bell J. and Hair C. 2008. Sea cucumber fisheries: a manager's toolbox. ACIAR Monograph No. 135. Australian Centre for International Agricultural Research, Canberra. 32 p.

The Australian Centre for International Agricultural Research (ACIAR) is pleased to announce the publication of "Sea cucumber fisheries: a manager's toolbox".

Sea cucumber fisheries are an important source of cash income to isolated coastal communities throughout the Pacific islands region.

This valuable reference tool for managers and fishers provides indicators for assessing the health of sea cucumber fisheries, "best practice" management, and the measures needed to rebuild severely depleted stocks.

Copies will be sent free to key Pacific island fisheries organisations. Visit ACIAR's website to order hard copies online (AUD 9.00 incl. GST). Free electronic download will also be possible from ACIAR's website in late November.

<http://www.aciar.gov.au>



Abstracts from the 11th International Coral Reef Symposium, Ft. Lauderdale, Florida, USA (July 2008), communicated by Dr D. Taddei

New insights into the biodiversity and evolution of aspidochirotid holothurians

François Michonneau, Kris Netchy, John Starmer, Alexander Kerr, Gustav Paulay

Understanding and management of coral reefs depend fundamentally on our ability to distinguish and identify species, in conjunction with knowledge on their origin, distribution and biological characteristics. Yet available information on reef biota remains often inadequate and difficult to access. Aspidochirotid sea cucumbers are a case in point: they include the largest and most conspicuous motile invertebrates on reefs, and are often severely overfished because of their economical value. Identification of some harvested species, even though common, is problematic. We are undertaking a revision of these organisms. Here we

present results from a molecular phylogeny on 200+ taxa, based on 2 mitochondrial gene regions. Results provide insight into macroevolutionary transitions, diversification, and species limits. Holothurians show substantial niche conservatism in latitudinal distribution, depth range, and feeding mode. Heavy reliance on ossicles has led to a confused taxonomy: in some groups ossicles evolve rapidly, possibly in response to variation in carbonate saturation levels, in others they are conserved and mask substantial cryptic diversity. The latter is exemplified by the circumtropical “species” *Holothuria impatiens*. This species complex revealed to consist of at least a dozen reciprocally monophyletic, well-defined, evolutionary significant units (ESUs). Each major tropical region has at least one endemic ESU, the East Pacific and Indo-West Pacific (IWP) host multiple taxa. The latter include peripheral, archipelagic endemics as well as ESUs that range across the entire IWP. Broad overlap in the range of some in combination with recent divergence indicate the rapid evolution of reproductive isolation barriers among these ESUs. Morphological distinctiveness of ESUs vary: some show differences in ossicle morphology, others in live coloration, yet others show no morphological differences that we have been able to discern to date. These results are leading to a better understanding of the varied diversity and diversification mechanisms of reef organisms.

Natural feeding of coral reef holothurian, *Holothuria atra* on microalgae and meiofauna from seagrass beds in Chuuk, FSM

Do-Hyung Kang, Md Abu Affan, Hyun Soo Rho, Sang-Gyu Paik, Heung-Sik Park

The coral reef holothurian, *Holothuria atra* (Jäger, 1833) has an important role in nutrient recycling as a sediment-feeder in coral reef ecosystems. This recycling of nutrients contributes to the high productivity in coral reefs. Limited information is available on the main food sources of *H. atra*, despite their importance on the reefs. This study investigates the food items (i.e. microalgae and meiofauna) consumed by the sediment feeding holothurian, *H. atra*. Sediment samples in front of the mouth, faeces at the posterior and the intestines of the sea cucumbers were taken from each individual. The different sediment samples were fixed in 10% formalin for later qualitative and quantitative analysis of microalgae and meiofauna. Taxonomical determination of microalgae was performed with an inverted microscope. Extraction of the meiofauna was performed using Ludox HS 40 and the species were identified to the class level. Total number of microalgae and meiofauna was identified to 25 species and 10 classes in three different samples, respectively. Microalgae and meiofauna in before feeding sediment were recorded 349 ind ml⁻¹ and 12.2 ind ml⁻¹ with the major groups of Bacillariophyceae and Polychaeta, respectively. After feeding, the microalgae and meiofauna were ingested up to 85.6% and 79.1% by the holothurians. In the intestine contents, the abundance of Bacillariophyceae without chlorophyll was higher than other groups while the abundance of Polychaeta was lower than other groups. This data demonstrated that Bacillariophyceae and Polychaeta were main ingested food items of *H. atra*.

The effects of temperature and light on the gametogenesis and spawning of four sea urchin and five sea cucumber species on coral reefs in Kenya And La Reunion

Nyawira Muthiga, Chantal Conand, Joan Kawaka, Sophie Kohler

This paper reviews studies of the reproductive cycles of 4 species of sea urchins (*Echinometra mathaei*, *Diadema savignyi*, *D. setosum*, *Tripneustes gratilla*) and 5 species of sea cucumbers (*Actinopyga echinites*, *Holothuria atra*, *H. leucospilota*, *H. scabra* and *Stichopus chloronatus*). Measurements of gonad index and macro and microscopic observations of gonads were used to evaluate changes during gametogenesis in individuals collected on Kenyan and Reunion reefs. The effects of temperature, light and lunar period were also assessed. *Echinometra mathaei*, *H. arenacava*, *H. leucospilota* in Kenya and *H. atra* in Reunion showed an annual pattern while *A. echinites*, *H. leucospilota* and *S. chloronatus* in Reunion and *H. scabra* in Kenya showed a biannual pattern of reproduction. A particularly pronounced seasonal pattern occurred in *E. mathaei*, *H. arenacava* and *H. leucospilota* on Kenyan reefs where gametogenesis started in July when temperatures and light were at their lowest and spawning peaked between March-April just after peak levels of temperature and light. These species showed higher correlations between light and gonad index than between temperature and gonad index indicating that light had a stronger influence than temperature on the onset of gametogenesis on these species on the Kenyan coast. In the species without pronounced annual reproductive patterns, gonad indices were high during one (*D. setosum*, *D. savignyi*, *T. gratilla* in Kenya) or two (*A. echinites*, *H. leucospilota* and *S. chloronatus* in Reunion and *H. scabra* in Kenya) periods of 1–2 and up to 6 months but the reproductive season often coincided with periods of high temperature and light. Only three of the sea urchin species (*D. savignyi*, *D. setosum* and *T. gratilla*) showed lunar periodicity.

Cryptic diversity of sea cucumbers: the nocturnal monsters, *Bohadschia* (Holothuroidea: Holothuriidae)

Sun Kim, Alexander Kerr, Gustav Paulay

Sea cucumbers are among the most poorly studied macrobiota on coral reefs. For example, the genus *Bohadschia* (Holothuroidea: Holothuriidae) is often considered one of the most taxonomically controversial groups. In this study, we investigated the systematics of this group using field and molecular methods. Initial findings include that the morphologically and ecologically distinct *B. argus* is derived within the taxonomically muddled *marmorata*-complex. Also, a clade, *B. bivittata* in part, has tiny lines over its dorsum, a character that was not previously considered taxonomically important. In addition, several species, including *B. koellikeri* appear to be hybrids. Finally, we have a lot more to learn about their systematics on reefs worldwide, as we are discovering many new *Bohadschia* species.

Multiple ecological radiations of sea cucumbers onto coral reefs

Alexander Kerr, Ronald Clouse, Mark O'Loughlin, Tim O'hara, Daniel Janies

Aspidochirotida is a large order of sea cucumbers (ca. 25% of extant diversity) consisting of three families: Synallactidae, Stichopodidae and Holothuriidae. Most members are either found on coral reefs or at great depth. We present a phylogeny of 45 species of aspidochirote holothuroids (13% of ordinal-level diversity) based on PCR-amplified partial 16S, 12S, 28S, 18S and H3 gene sequences. Estimated maximum likelihood and maximum parsimony topologies, the latter estimated via POY direct optimisations, indicated that Synallactidae is polyphyletic and renders Stichopodidae paraphyletic. This jumble suggests that members of the former family experienced at least two parallel losses of planktotrophic larvae and complicates interpretations of the bathymetric diversification within the aspidochirotes. The third family, Holothuriidae, appears monophyletic and consists of two large basal subclades. Surprisingly, several previously unconsidered gross anatomical and ecological characters define these groups. The first subclade, "Holothuriinae," is primarily of cylindrical, diurnally cryptic to burrowing forms, while the second subclade "Bohadschiinae," consists mostly of large, diurnal and epibenthic species with flattened ventrums. Further, bohadschiines often release a fluorescent green exudate when first placed in alcohol. These obvious characters permit straightforward diagnosis of two large clades in a family with a tumultuous nomenclatural history.

Rapid speciation, allopatric differentiation, and simple morphology confound true diversity of some of the largest mobile reef invertebrates (*Actinopyga*, Holothuroidea, Echinodermata) [poster]

Kris Netchy, Gustav Paulay, Alexander M. Kerr

As Asian economies grow, so too does the demand for beche-de-mer. In this multimillion-dollar industry, large holothuroids (sea cucumbers) are harvested and sold as food in Asian markets, and overharvesting is an imminent threat throughout the tropics. Holothuroids are among the most poorly known macrobiota on coral reefs, and their systematics is in a poor state worldwide, hampering research and resource management. The systematics of sea cucumbers in the genus *Actinopyga* has been especially neglected. This is primarily because they are among the most morphologically simple and conserved animals, making species differentiation difficult. In this study, two mitochondrial genes, one nuclear gene, and several morphological characters were examined in order to systematically characterize the *Actinopyga*. The data revealed exceptionally fast rates of evolution, clearly structured populations in wide-ranging species, and several examples of cryptic diversity. Understanding the species-level relationships and noting higher levels of diversity than previously thought will allow for better management of beche-de-mer fisheries.

Abstracts from the “Fifth North American Echinoderm Conference, Florida Institute of Technology, Melbourne, Florida, USA, 20–25 July 2008” communicated by A. Kerr

Sea-cucumbers (Holothuroidea: Echinodermata) in western literature from antiquity to Linnæus [talk]

Alexander M. Kerr

The starting point of modern zoological nomenclature is ostensibly the tenth edition of Linnæus' *Systema Naturæ* published in 1758. However, terms likely referable to our totem beasts, the holothuroids, occur sporadically in Western literature as far back as Classical times. In this presentation, I trace holothuroid nomina from a dubious first mention circa 450 BC by the comic poet Epicharmus to the lively series of emendations in disposition within the twelve editions of *Systema* that included as congeners hydrozoans, tunicates and a priapulid worm. The etymology of the term holothuroid itself is likewise uncertain. Indeed, what Aristotle referred to as was doubtless not a sea cucumber at all, but the name, nevertheless, came to designate the class, probably via a mis-ascription in 1554 by Rondelet in his well illustrated *Libri de piscibus marinis*. Nevertheless, the name *Holothuria*, and thus Holothuroidea, was not certain until the ICZN stepped in and finally settled the long-running row over its proper ascription in 1924.

The Holothurian PEET Project and the Aspidochirotid Working Group: Integrative taxonomy on a large scale.

C. Campbell, M. Honey, L. Kenyon, A. M. Kerr, S. Kim, C. Massin, S. McPherson, K. Mezali, F. Michonneau, K. Netchy, M. O'Loughlin, G. Paulay, D. Pawson, F. Rowe, Y. Samyn, S. Smiley, F. Solis-Marin, J. Starmer, A. Thandar, D. VandenSpiegel, T. Werner

We are undertaking a major revision of holothurians, focused on the Aspidochirotida, with support from the NSF PEET program, additional funding from our institutions, governments, and other sources. The project includes reviews of nomina, literature, type specimens, field surveys, DNA sequencing, and revisionary taxonomy. For nomina we are upgrading and databasing Smiley & Pawson's (1990's) manuscript on holothurian names. This is resulting in a comprehensive database of the >2500 available holothurian nomina, with relevant information checked, verified, and captured. Scans of original descriptions of aspidochirotid nomina are being posted on the PEET-cuke web site (<http://67.98.162.85/marinelab/peetcukes/>), together with ca. 4000 references dealing with holothurians. Major repositories with holothurian type material are being surveyed, aspidochirotid type material identified, and fresh ossicle preparations made from relevant tissues of these. Collections in Hamburg, Berlin, Moscow, Paris, London, and our home institutions have now been studied. Many type specimens once considered lost, especially from Semper's work, have been rediscovered. Field surveys have focused primarily on shallow, tropical waters and to date have resulted in large, new collections from the Comoros, Mascarene, Philippine, Vanuatu, Fiji, Mariana, Caroline, Marshall, Cook, Society, Line, and Hawaiian Islands, Australia, Panama, Mexico, Mediterranean basin, Florida, and Washington. Several new species as well as fresh tissue samples from many species were obtained on these trips. DNA has been extracted from >1600 specimens and sequenced from >1100 to date, representing >350 species, focused on aspidochirotids, but covering other available, appropriately-preserved holothurian species. Sequence data, field appearance (including photo-documentation for recently collected material), ossicle complements, and internal anatomy are being integrated to redefine taxa, with many species complex challenges getting sorted out. Student theses and projects are focused on partial to comprehensive revisions of: *Stichopus*, *Actinopyga*, *Bohadschia*, *Holothuria* (*Thymiosycia*), *Holothuria* (*Selenkothuria*), *Holothuria* (*Halo-deima*), and *Synapta*, with other projects in the works.

Other abstracts from various sources

The influence of population density on fission and growth of *Holothuria atra* in natural mesocosms

Jessica Lee, Maria Byrne and Sven Uthicke

Source: Abstract of a paper accepted by the Journal of Experimental Marine Biology and Ecology (2008).

Investigation of the population dynamics, asexual reproduction (fission) and growth of holothuroids has been impeded by the difficulty of tagging individuals. We conducted the first tests on the interactions between population density, fission and growth of holothuroids in experimental populations placed in natural mesocosms (microatolls) at One Tree Reef (OTR), Great Barrier Reef. Similarly sized *Holothuria atra* were translocated to the microatolls in low (LDT) and high (HDT) density treatments. We hypothesised that holothuroids in lower density treatments would have more resources per individual and that this would promote higher frequencies of asexual reproduction and smaller individuals. The seasonal pattern of fission was similar in natural (unmanipulated) and experimental populations, with the maximum number of fission products occurring in winter and spring. The overall density of the LDT (0.19 ind. m⁻²) and HDT (0.59 ind. m⁻²) did not vary over time. This 'steady state' suggested that some fission products died and that asexual reproduction compensated for overall mortality and emigration. There was no difference in sediment chlorophyll pigments between treatments indicating that the different densities of *H. atra* did not affect benthic microalgal biomass. The percentage of fission products was greater in the LDT than the HDT but this difference was not statistically significant, providing some support for the hypothesis that *H. atra* in the LDT exhibit a higher fission rates. At the end of the experiment *H. atra* in LDT were significantly longer and heavier than in HDT. *H. atra* surpassed their initial deployment weight and length after 13 months in the LDT by 115.2% and 45.2% respectively and in the HDT 86.9% and 24.6% respectively, changing from the small to the large phenotype known for this species. This differential growth may be linked to habitat stability and high benthic productivity and demonstrates the phenotypic plasticity of holothuroids and potential to achieve 'Optimum Individual Size' with respect to environmental conditions. Our results will assist in fine tuning conceptual models on asexual reproduction and future experimental studies on the phenomena of fission and plastic growth in holothuroids.

Phenotypic plasticity of gut structure and function during periods of inactivity in *Apostichopus japonicus*

Fei Gaoa, Hongsheng Yang, Qiang Xua, Fangyu Wang, Guangbin Liua and Donovan P. Germanc

Source: Comparative Biochemistry and Physiology Part B: Biochemistry and Molecular Biology Volume 150, Issue 3, July 2008, 255–262.

Apostichopus japonicus is a common sea cucumber that undergoes seasonal inactivity phases and ceases feeding during the summer months. We used this sea cucumber species as a model in which to examine phenotypic plasticity of the digestive tract in response to food deprivation. We measured the body mass, gross gut morphology and digestive enzyme activities of *A. japonicus* before, during, and after the period of inactivity to examine the effects of food deprivation on the gut structure and function of this animal. Individuals were sampled semi-monthly from June to November (10 sampling intervals over 178 days) across temperature changes of more than 18°C. On 5 September, which represented the peak of inactivity and lack of feeding, *A. japonicus* decreased its body mass, gut mass and gut length by 50%, 85%, and 70%, respectively, in comparison to values for these parameters preceding the inactive period. The activities of amylase, cellulase and lipase decreased by 77%, 98%, and 35% respectively, in comparison to mean values for these enzymes in June, whereas pepsin activity increased two-fold during the inactive phase. Alginase and trypsin activities were variable and did not change significantly across the 178-day experiment. With the exception of amylase and cellulase, all body size indices and digestive enzyme activities recovered and even surpassed the mean values preceding the inactive phase during the latter part of the experiment (October–November). Principal Component Analysis (PCA) utilizing the digestive enzyme activity and body size index data divided the physiological state of this cucumber into four phases: an active stage, prophase of inactivity, peak inactivity, and a reversion phase. These phases are all consistent with previously suggested life stages for this species, but our data provide more defined characteristics of each phase. *A. japonicus* clearly exhibits phenotypic plasticity (or life-cycle staging) of the digestive tract during its annual inactive period.

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 1,170 and 4,000 ind ha⁻¹ and biomass ranged between 393 and 2903 kg ha⁻¹. 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 $W (g) = 0.033 \text{ Length (mm)}^2 \cdot 178$.

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

Ahmed 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, mostly dendrochirotid species. Altogether eight 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 these were lacking. The new species are *Sclerothyone unicolor*, *Pentacta rowei*, *Cladodactyla brunspicula*, *Panningia trispicula*, *Paracucumaria massini*, *Psolidium pulcherrimum*, *P. pseudopulcherrimum* and *Synallactes samyni* whereas the new records for the region are *Pawsonellus africanus* Thandar and *Pannychia moseleyi* Théel for South Africa and *Pseudoaslia tetracentriophora* Hedding for Namibia.

A new dendrochirotid sea cucumber from the west coast of South Africa (Echinodermata: Holothuroidea: Cucumariidae)

Mageshnee Natasen Moodley

Source: African Zoology (2008), 43(1):61–65

Five specimens of a small cucumariid holothuroid collected between 18 and 32 m, from off St. Helena Bay on the west coast of Western Cape Province, South Africa, are new to science and here described. The presence of une qual tentacles, naked interambulacra, smooth prolonged handle of somebody wall plates and the form of the tentacle and introvert deposits, in combination, sets the new species strongly apart from its congeners.

Reproduction of the sea cucumber *Holothuria leucospilota* in the Western Indian Ocean: biological and ecological aspects

S.M. Gaudron, S.A. Kohler and C. Conand

Source: Invertebrate Reproduction and Development, 51:1 (2008) 19–31 19

Reproduction of *Holothuria leucospilota* was investigated for the first time in the Western Indian Ocean in 2005–2006 in the reef of La Réunion. Two spawning events occurred revealed by gonad index (GI) and histology. Gametogenesis of *H. leucospilota* was divided into five stages of maturity: *resting*, *immature*, *growing*, *maturation* and *post-spawning*. It was synchronous within the population and initiated in July when solar radiation increased. From July to December, the *growing* stage was dominant, followed by a majority of specimen in *maturation* in January. The first spawning event occurred in February whereas the second one

occurred in May. Breeding season of *H. leucospilota* takes place during Austral summer when temperature and tropical rainfall reach their maximal. Between March and June, only 22% of specimens were found with a completely resorbed gonad in *resting* stage. 'Atresia' appeared more frequently in females in an advanced stage of maturity. In male gonad 'atresia' was only observed in the *post-spawning* stage.

Sexual dimorphism was significantly measured in body weight, gonad weight, tubule diameter being all greater in females. An unbalanced sex ratio was skewed (17:191) towards females. Weight at the first maturity was defined for a total weight above 180 g. All of these biological aspects are relevant for the conservation of *H. leucospilota* species in the Western Indian Ocean that is under fishing pressure.

Restoring small-scale fisheries for tropical sea cucumbers

Johann D. Bell, Steven W. Purcell, Warwick J. Nash

Source: Ocean & Coastal Management 51 (2008) 589–593

Overfishing threatens to extinguish local fisheries for valuable tropical sea cucumbers by reducing population densities to the point where reproductive success trails behind natural mortality (known as depensation or the 'Allee effect'). Once this happens, conventional management measures alone, such as closed seasons/areas, size limits and gear restrictions, will usually fail to repair the damage. A different suite of active management interventions must be considered to restore the spawning biomass of severely over-exploited populations. These include: (1) restocking no-take zones with hatchery-reared juveniles; (2) aggregating remnant wild individuals in no-take zones; and (3) development of small enterprises to rear wild-caught sea cucumbers in simple sea pens, or dedicated sublittoral areas, to the size above sexual maturity that optimises earnings. The first intervention is currently limited to a few species of tropical sea cucumbers, whereas the second and third interventions can be applied to many species. The third intervention is particularly attractive – it allows fishers to add value to their catch, reverses the effects of fishing from damaging to improving the potential for replenishment by overcoming the Allee effect, and creates multiple groups of spawners to supply recruits throughout the range of the population(s) supporting a fishery.

Captive breeding and sea ranching of commercially important tropical sea cucumbers in Australia

Dr Daniel Azari Beni Giraspy

Source: Abstract of a paper presented at the "Australasian Aquaculture Conference" held in Brisbane, Australia, 3–6 August 2008

Overfishing of holothurians is affecting sea cucumber population worldwide, and aquaculture and restocking programs are needed to meet the demand and also to bring back the depleted fisheries to sustainable level. The demand for *beche de mer* is significantly increasing in Asia, making the sea cucumbers more vulnerable for exploitation. Among the 1,250 known species of sea cucumbers, about 20 species have commercial value. The sea cucumbers Sandfish (*Holothuria scabra*) and the Golden Sandfish (*H. versicolor*) are considered to be the most valued of the tropical edible species with highest prices on the international export market.

Bluefin Seafoods Pty. Ltd., Hervey Bay, Queensland has received an innovation grant from the Federal Government of Australia to develop and perfect the hatchery technology for mass production of sea cucumbers for restocking programmes. Under this programme, the techniques for the mass production of *H. scabra* (sandfish) and *H. versicolor* (golden sandfish) have been developed and millions of sea cucumber juveniles have been routinely sea ranching during the past few years. The operation includes; Broodstock Collection: sea cucumbers are collected by diving during spring season, when the gonad index is over seven. 2 to 5 ind m⁻² are placed in flow through sea water system with dissolved oxygen over 5.5 mg L⁻¹ and feeding rate between 5 and 7% of body weight. Spawning stimulation and fertilisation: spawning inducement is by thermal shock (temperature raised by 3–5°C). Males spawn first followed by the females. The diameter of the fertilised egg is around 180 µm. Fertilised eggs hatch into auricularia larva within 48 hrs of fertilisation and starts feeding on microalgae Larval rearing and Feeding: larvae are reared in 1000-L fiberglass tanks at a density of 0.5 ml⁻¹. During the larval rearing period the temperature was maintained between 25 and 27°C, salinity ranged between 37.5 and 38 ppt, while pH remained at 8.2. Larval diet consisted of *Rhodomonas salina*, *Chaetoceros calcitrans*, *C. mulleri*, *Isochrysis galbana* and *Pavlova lutheri* in different combinations at different larval stages. Feeding regime depends on the developmental

stage and from early auricularia to late auricularia stage, microalgal density is gradually increased from 15,000 cells ml⁻¹ to 35,000 cells ml⁻¹. Larval development and settlement: the auricularia larvae develop in to doliolaria and pentacula stages before they metamorphose into juveniles. The non-feeding doliolaria larvae are transferred to tanks with settlement cues and the flow-through system is maintained. Early juveniles attach on the settlement substrates on the nursery tanks. The corrugated plates with settlement cues facilitate pentacula attachment and juvenile growth. Nursery phase: the settled juveniles spend three months in the nursery tanks and artificial feeds are used to feed the growing juveniles. 3 to 5 cm size juveniles are ready to sea ranch. Sea ranching: The keys to successful sea ranching are site selection and routine management. Sea cucumber juveniles are sea ranched in sheltered bays with sea grass. The areas with fewer predators such as sea stars and crabs are preferred for successful sea ranching. Mass production of sandfish and golden sandfish are quite feasible with our hatchery technology. This technology can be used for aquaculture production as well as for the restoration of depleted wild populations to allow sustainable fishery. The hatchery technology for other commercially important sea cucumbers is under-way to refine technology for the better settlement and higher survival rates.

Characterization, control and optimization of the processes involved in the postmetamorphic development of the edible holothuroid *Holothuria scabra* (Jaeger, 1833) (Holothuroidea: Echinodermata)

Thierry Lavitra

Source: PhD Abstract – University of Mons-Hainaut – Septembre 2008

Studies on characterization, control and optimization of the processes involved in the postmetamorphic development of the edible sea cucumber *Holothuria scabra* (Jaeger, 1833) were carried out between 2004 and 2008, for one part in Toliara (south-west of Madagascar) and for another part at the University of Mons-Hainaut. Holothuriculture is a mariculture in full expansion. Natural populations of various species of sea cucumbers are in decline due to the ever increasing demand of Asian populations; particularly of China who consider these animals as delicacy food. The present work was performed under the PIC project "Tropical holothuriculture" which aims at putting in place, in Madagascar, the first hatchery and farm of holothuroids in the south-ouest of Indian-Ocean. The researches aimed firstly to determine the effect of food quality and of the rearing density on survival and growth of *H. scabra*. The nutritional activity of *H. scabra* was also analyzed by integrating data on the nycthemeral cycle of individuals and other data regarding the sediments composition, the excrements and the food bowl. This work also aimed to present the problems encountered during the farming period, to characterize their impact on the holothurian production and to propose solutions allowing to avoid them or to limit their impact. It also allowed to identify the methods used in Toliara region for trepang (dried and exported holothurians) processing, particularly for *H. scabra*, to analyze the morphometric parameters linked to the transformation process and to update the information on holothurian commercialization from the collect until their delivery to the exporters.

To optimize survival and growth rates of epibenthic juveniles of *H. scabra*, the experiments suggested the use of brown algae *Sargassum latifolium* (Turner, 1809) as their food and a rearing density of 450 ind. m⁻². When they reach the size of 15 mm (8 weeks), epibenthic juveniles become endobenthic (*i.e.*, they burrow into the muddy sand from sun rise to sun set). They are transferred into pounds covered with sediments collected from the sea grass bed. The rearing density should not exceed 20 ind m⁻². The mixed farming with the fish *Térapon jarbua* (Forskall, 1775) is suggested in order to avoid invasion of isopods parasites (crustaceans) encountered during warm season. When they reach the average weight of 15 g (6 cm long; 6 to 8 weeks), juveniles are placed into enclosures at sea, at a rate of 2 ind m⁻². Before the transfer, strict controls of the sites in the natural environment must be achieved in order to avoid predators. The most redoubtable predators in Toliara region are the crabs *Thalamita crenata* Rüpell, 1830.

H. scabra are detritivores, ingest sediment where they live. They came out of the sediment where they burrow, at the beginning of the afternoon to feed; they burrow again before the sunrise. A *H. scabra* adult ingests on average 101 g of sediment (dry weight) day⁻¹, which is 29% of their fresh weight. They select particles less than 2 cm of diameter, and extract the organic matter where they feed bacteria. The bacteria in sediments and in the excrements highlighted by FISH method (*In Situ* Fluorescent Hybridation) belong to the group of *Cytophaga-Flexibacter-Bacteroides*, of δ -Protéobactéria and of γ -Protéobactéria.

Several processing methods are employed by the fishers in littoral villages in Toliara region. As a general, *H. scabra* are eviscerated, boiled, treated with papaya leaves in order to remove the chalky spicules and sun

dried. In general, whatever their initial sizes, individuals lose 91 % and 52 % of their weight and length respectively after the processing. The actors of the commercial chain are beyond the fishers, the middlemen, the collectors and the exporters. Trepanng of the first category may be sold presently between USD 33 to 50 kg⁻¹ to the exporters.

Impact of removal - A case study on the ecological role of the commercially important sea cucumber *Holothuria scabra* (Echinodermata: Holothuroidea) in Moreton Bay, Australia

Svea Mara Wolkenhauer

Source: PhD abstract, University of Rostock, 2008

The ecology of holothurians, their ecological role in marine ecosystems, and the potential impacts of their removal (through over-fishing) was the subject of this study. This was investigated by focusing on important aspects of holothurian behavioural dynamics, such as burying and feeding, as well as assessing their impact on important habitat variables such as sediment mixing, and seagrass and algae biomass and productivity.

Certain species of holothurians have been harvested for the human food consumption for centuries. The dry products of the body wall (also called 'bêche-de-mer' or 'trepanng') of these animals are considered as a delicacy to the Asian (particularly Chinese) food industry. Currently, there are more than 20 holothurian species that are commercially used around the world. *Holothuria scabra* is one of those most targeted species due to their thick body wall and large size. Since most commercial species inhabit shallow waters and are easily harvested by hand at low tide, high value species such as *H. scabra* are easily over-exploited. *H. scabra* are already over-exploited or extinct in many locations such as Solomon Islands, some places along the Indian coast and in many places along the South-East Asian coastline.

The main objectives of this study were to: (a) document the difference in the productivity and biomass of seagrass and benthic microalgae (BMA) with and without *H. scabra* by means of *in situ* exclusion cages, (b) quantify the rate and extent of vertical sediment transport associated with feeding and burying of *H. scabra* using luminophores as tracers in aquaria, and (c) investigate the relationship between burying and feeding behaviour and temperature (within a seasonal context) by means of continuous long-term monitoring of *H. scabra* behaviour in mesocosms.

Exclusion experiments were conducted in shallow seagrass habitat to investigate the impact of holothurians on seagrass biomass and productivity. In addition, sediment samples were taken to measure BMA biomass and organic matter (OM). Holothurians appear to be beneficial for seagrass, with significantly higher seagrass productivity (12%, ANOVA, $p = 0.008$) and slightly higher seagrass biomass (18%, ANOVA, $p = 0.348$) under natural holothurian densities compared to exclusion areas. Conversely, the presence of holothurians appeared to reduce BMA biomass and OM, as suggested by higher BMA biomass (ANOVA, $p = 0.089$) and OM content (ANOVA, $p = 0.110$) in exclusion cages. Combining all major response variables in a Principal Component Analysis (PCA) suggested that the exclusion of holothurians caused marginally significant differences in those variables compared to natural densities (MANOVA, $p = 0.074$).

The results of bioturbation experiments demonstrated that *H. scabra* caused mixing of the surface sediment layers during their feeding and burying activities. Instantaneous sediment mixing rates (IMR) of 0.016% d⁻¹ were calculated for the top 2 cm for *H. scabra* at natural densities (0.48 ind m⁻²). Moreover, the holothurians did not influence sediment deeper than 6 cm and their pattern of bioturbation created a relatively smooth sediment surface with the formation of a shallow anoxic layer (3–6 cm). A new mode of bioturbation for these animals is suggested, categorising holothurians as "conveyor diffusors".

Overall findings of the behaviour study showed that differences in burying and feeding behaviour of adult *H. scabra* were strongly related to water temperature, thus resulting in drastic seasonal changes in behaviour. Austral winter (Jun-Aug) was a time of very low activity with most animals being buried for whole or part of the day, feeding only a few hours each day and displaying very little to no searching activity. Austral summer (Nov-Feb) was a time of high activity with short periods of being buried (early morning), frequent feeding and searching (morning, afternoon and late evening) and some spawning activity occurring (late afternoon). The behavioural pattern during shoulder seasons (Mar-May and Sep-Oct) was similar to that observed during summer. The exception was searching activity, which occurred more frequently during the shoulder seasons, due to higher food requirements (e.g. preparation for spawning). Hence, the ecosystem function of holothurians was altered dependent on seasons and needed to be taken into account when establishing an ecological role of those animals within their habitat.

Results of this study demonstrated a potential mechanism by which fisheries for holothurians may impact their surrounding habitats and result in indirect cascading ecological consequences for the animal's ecosystem function. Furthermore, given that seagrass habitat is a known nursery for other important fishery species (e.g. prawns), there is the potential for an impact in one fishery (holothurians) to be linked to another. Over-fishing of holothurians might alter the overall habitat structure in unpredictable ways and could thus have consequences for the ecology of tropical seagrass beds in the long term. Furthermore, findings in this study have implications for population surveys for *H. scabra* when relying mainly on visually counting animals along transects. Surveys should be conducted at consistent diel and seasonal timing if results are to be compared with previous data. Based on burying data presented in this study, it is suggested that the most suitable time to conduct population surveys on *H. scabra* would be during austral summer (Nov.–Feb.) from midday to late afternoon.

Most of the findings in this study were based on individual *H. scabra* and their ecological role as ecosystem engineers. However, one of the most important aspects of this research was the ability to use the acquired results and draw conclusions as to the wider population of *H. scabra* within Moreton Bay. By using models of activity dynamics in combination with sediment transport rates, this study estimated the overall impacts *H. scabra* population had on their associated habitat in Moreton Bay.

The reproductive biology of sandfish *Holothuria scabra*, tigerfish *Bohadschia argus*, and asexual reproduction mode of Warty Selenka's sea cucumber *Stichopus horrens* and prospective management option for sea cucumbers fisheries in Tongan coastal waters

Source: BSc supervised by Dr Mike Barker, University: Otago University, Dunedin, New Zealand (Sep. 2007).

Holothurians (sea cucumbers) are one of the five extent classes of echinoderms which exploited commercially in the Indo-Pacific including Tonga. The rising demand for sea cucumbers in international markets has caused declines in many holothurian populations worldwide. The Tonga government banned commercial fishing of sea cucumbers in late 90s based on stock assessments carried out by the South Pacific Community, and the fishery hasn't been opened since then.

The sandfish *Holothurians scabra* is one of the most valuable sea cucumber species exploited commercially in the Indo-Pacific whereas the tigerfish *Bohadschia argus* had lower commercial value. The Selenka's sea cucumber *Stichopus horrens* is one of the most important subsistence fisheries in Tonga and in other South Pacific Islands. Typically the viscera of the live animal are collected and the sea cucumber is then released back on the reef. Folklore has it that the internal organs are regenerated in a few days.

The objectives of the present study were to determine the reproduction pattern of *H. scabra* and *B. argus* during summer periods in Tongan coastal waters. For *S. horrens* the study was focused on the process of organ regeneration, particularly how long it takes for the internal organs to be replaced.

To study the reproductive biology of the above sea cucumbers species, 20 individuals of *H. scabra* and *B. argus* were collected from November 2005 to April 2006 and the gonad index (GI), gonad tubules sizes, gonad maturity stages (stages 1 to stage 5), were determined and compared with other studies. For *S. horrens*, 4 replicates and 2 controls cages were set up at the most common fishing ground for this species with a back up experiment at the Ministry of Fisheries aquaculture facilities. Animals were cut open and the internal organ (intestine and gonads) removed. Undamaged animals were used as controls (20 animals for each cages).

The GI for *H. scabra* and *B. argus* were not significantly different between sexes ($P = 0.383$ for *H. scabra*, $P = 0.380$ for *B. argus*) but variable across months. The maximum GIs were recorded in December 2005 and February 2006 for *H. scabra* but high indices for *B. argus* also occurred in March 2006. Both species had similar patterns of maturity stages revealed by histological analysis. Mature stages (stage 3) were present in the ovaries throughout the sampling periods for both species. The testes were dominated by pre-spawned stages (stage 4). Oocytes sizes varied between months for both the study species. The tubule length and diameter were significant difference between sexes for both *H. scabra* and *B. argus* ($P = 0.000$).

The body tissue of *S. horrens* only took 2 to 5 days to repair however internal organ were regenerated over 30 days

The overall results for the reproductive biology of *H. scabra* and *B. argus* in Tonga indicated that the spawning activities occur during the summer season, a similar reproductive pattern to that found in New Caledonia

and the Great Barrier Reef (Australia) coastal waters. However, this study does not allow the full reproductive cycle for these species to be determined for Tonga, due to limits of the length of the sampling period that were possible (NZ AID regulations on student travel). In *S. horrens* the period taken for regeneration was similar to the length of time found for other sea cucumber species. Also *S. horrens* was found to undergo asexual reproduction.

The management of sea cucumber fisheries in Tonga has been consistently focused on size limits. The future options for managing the sea cucumber fisheries in Tonga are discussed also.

Bio-écologie et exploitation de deux espèces d'holothuries aspidochirotés, *Holothuria notabilis* et *Stichopus horrens* dans la baie de Toliara (Sud-ouest de Madagascar)

Razafimandimby Yacinthe

Source: Mémoire de DEA Océanologie, Université de Tuléar, IH-SM (2008).

The study on “the bio-ecology and the exploitation of the sea cucumber species *Holothuria notabilis* and *Stichopus horrens* in Toliara bay” make available the bio-ecological characteristics of these species for which it is the first study at the world scale. The density of the population of *H. notabilis* from the sea grass beds is on average 200 individuals per hectare or 31% of the total sea cucumber density in these environments. It is a small size species. It reaches the first sexual maturity at a total weight of 63 g.

The population of *S. horrens* has a density of 50 individuals per hectare and also accounts for 31% of the sea cucumber density from the reef-flat of the Mareana islet which is lower in sea cucumbers. The weight at first sexual maturity is 254 g. It is a species of average size.

The two studied species are characterized by an annual cycle of reproduction. Globally, the reproductive periods take place during warming of sea water.

The analyses of the exploitation of sea cucumbers in Ankilibe village showed that the annual production is estimated at 5 tons of trepang (dried weight) including 63% of *H. notabilis* and 13% of *S. horrens*. All the categories of villagers take part to the fishery and they even collect some juveniles.

These bio-ecological and socio-economic data could contribute to management measures for rational and durable management of the sea cucumber fishery in the South-west region of Madagascar or even for the whole Island.

Étude de l'évolution de l'exploitation d'holothuries au cours des 10 dernières années (1996–2006) dans la région sud-ouest de Madagascar Zone Nord

Rakotomahefa Solofondraibé

Source: Mémoire de fin d'études MaST/ML. Université de Tuléar, IH-SM. 40 p. + annexes. (2008).

Étude de l'évolution de l'exploitation d'holothuries au cours des 10 dernières années (1996–2006) dans la région sud-ouest de Madagascar Zone Sud

Andriatsimalona Sitrako Jo-Martin

Source: Mémoire de fin d'études MaST/ML. Université de Tuléar, IH-SM. 43 p. + annexes. (2008).

Communications...

From Chris Mah.

Chris Mah has started a new echinoderm-related blog where he posts discussion topics, reports on field work, various articles, news and other educational and popular items.

Web page: <http://www.echinoblog.blogspot.com/>

From Steve Purcell.

http://www.lnc.nc/articles/article_70329_223659.htm is a link to an article (in French) that attests to the fact that in New Caledonia sea cucumber fishers travel long distances from their ports and jurisdiction of fishing to collect sea cucumbers on remote reefs. Fishers from other regions are causing conflicts with locals over fishing rights, customary reserves, and respect over resources. The article notes that the customary leaders on Ouvea put in a formal complaint about the fishing at Beautemps-Beaupré Atoll.

From Igor Eeckhaut.

A new method involving a natural molecule has been developed to induce oocyte maturation in holothuroids. Oocyte maturation in sea cucumbers is stopped during the meiosis at prophase I. Maturation naturally concludes just before spawning, leading to mature oocytes ready to be fertilized. Although thermal shocks applied on mature individuals can induce spawning, it was not possible until now to perform reliably *in vitro* fertilization of sea cucumber oocytes. The method and molecule are patented under the number WO 2008/003691 (patent title: "oocyte maturation method"; patent authors: "Richard Rasolofonirina, Aline Léonet, Michel Jangoux and Igor Eeckhaut"). The method induces maturation and fertilization of more than 90% of oocytes while other oocyte maturation inducers [1-Methyladenine, dithiothreitol (DTT), dimercaptopropanol (BAL) and L-cysteine] induce 28 to 90% of maturation. Moreover, the use of later OMIs results in fertilization rates that never exceed 40%, the obtained larvae always present developmental abnormalities. The new method is used in routine in the new trade company, Madagascar Holothurie SA. It is efficient throughout the whole year on *Holothuria scabra*.

From Mark O'Loughlin.

Recent (since 2000) Asteroidea and Holothuroidea papers by Mark O'Loughlin et al. on the Internet published in "Memoirs of Museum Victoria", and available free at:

<http://museumvictoria.com.au/About/Books-and-Journals/Journals/Memoirs-of-Museum-Victoria/>

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Congress announcements

The International Echinoderm Conference “Echinoderms in a Changing World” will be held at the University of Tasmania in Hobart, Tasmania, Australia from 5–9 January 2009.
Webpage: <http://www.cdesign.com.au/echinoderm2009/>

The 7th European Conference on Echinoderms will be held in Goettingen, Germany from 1–8 October 2010. The homepage will be available in August or September 2008, at the latest.

The 4th “Arbeitstreffen deutschsprachiger Echinodermenforscher” will be held from 24–26 October 2008 in Vienna, Austria at the Natural History Museum. The conference website is already online at:
http://www.nhm.wien.ac.at/Content.Node/forschung/geologie/echino_treffen.html
First circular (English), available at:
http://www.nhm-wien.ac.at/Content.Node/forschung/geologie/mitarbeiter/pdfs/Zirkular1_EN.pdf

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