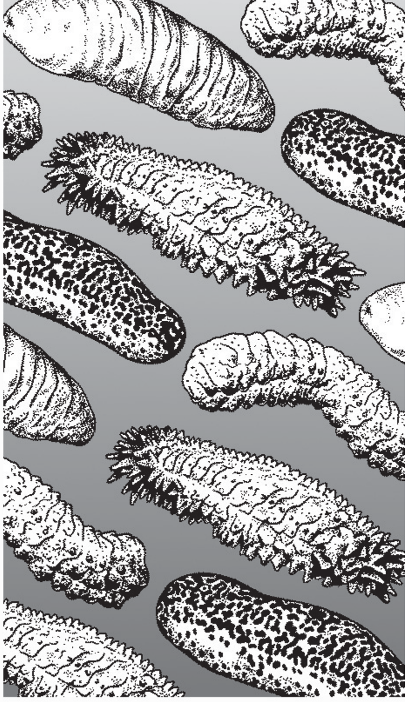

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Inside this issue

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Editorial

This issue of the *Beche-de-mer Information Bulletin* presents eight papers about sea cucumber aquaculture and taxonomy, and about the status of sea cucumber fisheries in various countries. At present, it is obvious that the management of sea cucumber fisheries is taken seriously into consideration in most countries. Many field studies have been undertaken showing that everywhere, and without exception, wild populations of commercial sea cucumbers are depleted. Ecologists have given their recommendations to concerned ministries in all beche-de-mer producing countries. We will see in the next few years whether their recommendations are followed, and if non-invasive harvesting methods such as aquaculture develop sufficiently.

The first paper, by Nyawira Muthiga et al. (p. 3), summarizes the recommendations resulting from a Marine Science for Management (MASMA) grant that provided funding for a regional sea cucumber project led by the Wildlife Conservation Society and the University of La Réunion.

Khalfan M. Al-Rashdi and Michel R. Claereboudt (p. 10) show that there has been a rapid decline in *H. scabra* populations due to overfishing in the Sultanate of Oman, resulting in an increased pressure on other sea cucumber species.

Chamari Dissanayake et al. (p. 14) provide preliminary results on the status of the sea cucumber fishery in Sri Lanka, where 4,000–5,000 families are dependant on sea cucumber fishing activities."

Ravinesh Ram et al. (p. 21) studied the impacts of harvesting and postharvesting processing methods on the quality and value of beche-de-mer in Fiji Islands. This research raised concerns regarding the lack of general awareness and information on improvements in processing techniques at the fisher level, and sea cucumbers' general significance within the overall coastal ecosystem.

Thierry Lavitra et al. (p. 25) investigated the effect of water temperature on the survival and growth of endobenthic juvenile *H. scabra* reared in outdoor ponds in Madagascar. Their study shows that water temperature does not affect the survival of *H. scabra* endobenthic juveniles, but it clearly affects their growth.

Daniel Azari Beni Giraspy and Ivy Grisilda Walsalam (p. 29) present their sea cucumber consultancy company, which offers hands-on training in the aquaculture and commercial production of sea cucumbers.

Yves Samyn et al. (p. 33) explain the basics of zoological nomenclature using examples of sea cucumbers.

Hampus Eriksson et al. studied the biology of *Stichopus herrmanni* at One Tree Reef, on the Great Barrier Reef in Australia (p. 41). *S. herrmanni* can be found in very high densities in this protected area.

We briefly report on three spawning observations from the Indian Ocean on page 46.

Three PhD theses dealing with sea cucumbers have concluded successfully since the last issue. As usual, information and several publications are mentioned in this bulletin (p. 48).

We close the issue with two impressive lists of publications on sea cucumbers by Prof Chantal Conand (p. 55) and Dr Claude Massin (p. 59).

Igor Eeckhaut

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Strengthening capacity to sustainably manage sea cucumber fisheries in the western Indian Ocean

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Background

There has been an active sea cucumber fishery in the western Indian Ocean region (WIO) for about a century. Because sea cucumbers in the WIO are solely harvested for the export market, the fishery generates foreign exchange and constitutes an important means of income generation for local communities. However, the increase in coastal populations, the high demand for beche-de-mer (processed sea cucumber) from Asian countries, the ease of collection in shallow coastal waters, and the introduction of scuba, have all combined to cause overfishing of this valuable resource. Despite the importance of sea cucumbers, information on their biology and ecology — which is crucial for management — is scarce from the WIO.

In October 2005, the Western Indian Ocean Marine Science Association, through the Marine Science for Management (MASMA) grant, provided funding for a regional sea cucumber project led by the Wildlife Conservation Society and the University of Reunion (Conand et al. 2006). A multi-disciplinary team contributed to different aspects of the research, and consisted of scientists from the Universities of Dar-es-Salaam, Reunion and Sweden, the Institute of Fisheries and Marine Science (IHSM) in Madagascar, the Kenya Marine and Fisheries Research Institute, and the Seychelles Fishing Authority.

The project began in 2006 with the production of a comprehensive regional review (Conand and Muthiga 2007), and culminated in a regional workshop that was held in Mombasa, Kenya. The main components of the project included: species inventories and distribution studies; assessing the effectiveness of marine protected areas (MPAs) in managing sea cucumbers; studies on the reproductive biology of key commercial species; studies on the socioeconomics and management of the fishery; and training in the taxonomy and biology of sea cucumbers. Although the project focused mainly in Kenya, Madagascar, Reunion, the Seychelles and Tanzania, the similarities and differences in the biodiversity and fisheries within these countries were expected to generate information that was of relevance to other countries in the region. This paper provides a summary of the deliberations, key research findings, and main recommendations for effectively managing the sea cucumber fishery in the WIO.

Main research findings and management recommendations

Species inventories and the effects of marine protected areas

About 250 species of sea cucumbers are reported in the WIO (Richmond 1997; Samyn and Tallon 2005; Conand and Muthiga 2007) but comprehensive surveys have only been carried out in Kenya, Reunion and the Seychelles (Table 1). As several new species have recently been described (Rowe and Massin 2006; Thandar 2007) and taxonomic studies continue in the region, it is expected that species diversity will increase in the future. Information from historical sources collected during the review and from surveys carried out during the study revealed that at least for the commercial species, densities were very low except in deeper waters, in marine protected areas, and in remote sites, which questions the viability of these populations. More detailed surveys were recommended in each country given the pressure to harvest new stocks of species whose biology and ecology is unknown, such as the case with *Holothuria notabilis* and *Stichopus horrens* in Madagascar (Rasolofonirina 2007).

MPAs promote biodiversity and are used for fisheries management in the WIO region. The project studied the effects of MPAs on sea cucumber population dynamics and reproduction in Kenya and Tanzania. Results indicate that MPAs have a positive impact on species diversity and abundance in the Mombasa Marine Park and reserve in Kenya (Orwa 2007), which validates a previous study in the MPAs and fished sites of Malindi, Watamu, and Kisite-Mpunguti (Muthiga and Ndirangu 2000). In addition, results of the reproductive output of

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Table 1. Sea cucumber diversity in some countries of the western Indian Ocean.

Country	No of species	Main taxonomic references	Comment
Kenya	44 (10 genera)	Humphreys 1981; Muthiga and Ndirangu 2000; Samyn 2003	*Holothuria arenacava*, a new species, has not been reported elsewhere *H. coluber* a new record for Kenya
La Reunion	21 (9 genera)	Conand 2003 Rowe and Massin 2006	*Actinopyga capillata* a new species also reported in Rodrigues
Madagascar	125	Cherbonnier 1988 Massin et al. 1999	*Holothuria naso, H. notabilis* and *Stichopus horrens* are new records
Seychelles	35	Clark 1984	*Holothuria* sp. Pentard still under taxonomic investigation
Tanzania	23 (Pemba Is)	Samyn 2003	Limited taxonomic work has been carried out

Table 2. Breeding seasons of some sea cucumber species in the western Indian Ocean.

Species	Location	Reproductive pattern	Reference
*Actinopyga echinites**	Reunion, (21° S)	Annual, spawning January–February and April–May	Kohler et al. in press
Holothuria arenacava	Mombasa, Kenya (4°S)	Annual, spawning March– May	Muthiga 2006
*H. fuscogilva**	Shimoni, Kenya (4° S)	Annual, spawning December–April	Muthiga and Kawaka in press
H. fuscogilva	Maldives (7° S)	Annual, spawning March– May	Reichenbach 1999
*H. leucospilota**	La Saline, Reunion (21° S)	Annual, two spawning peaks (February & May)	Gaudron et al. 2008
*H. leucospilota**	Mombasa, Kenya (4°S)	Annual, spawning March– May	Kawaka 2008
*H. notabilis**	Toliara, Madagascar (23° S)	Annual, spawning November–December	Rasolofonirina pers. comm.
*H. scabra**	Vanga, Kenya (4° S)	Biannual, spawning major event November–December and minor event May–September	Muthiga et al. 2009
H. scabra	Toliara, Madagascar (23° S)	Annual, spawning November–April	Rasolofonirina et al. 2005
H. scabra	Kunduchi & Buyuni, Tanzania (6° S)	Biannual, spawning August–September and December–January	Kithakeni and Ndaro 2002
*Stichopus horrens**	Toliara, Madagascar (23° S)	Annual, spawning January–March	Rasolofonirina pers. comm.

* = Results from the regional project

the high-value *Holothuria scabra* and the low-value *H. leucospilota* demonstrate the impact of fishing effects. Individuals of *H. leucospilota* were larger, had significantly larger gonads and higher fecundity in the fully protected Mombasa marine park than in the partially protected marine reserve (Kawaka 2009). Studies in Tanzania indicate that seasons (dry and wet) and fishing pressure influence both fecundity and spawning peaks in *H. scabra*, with fishing pressure having a negative effect on body sizes and fecundity (Mmbaga 2009). Area closures and reduced fishing pressure were effective in enhancing reproductive output and potentially increasing densities of sea cucumbers in the region.

Reproductive biology and management implications

Studies were untaken on the reproductive biology of *Actinopyga echinites* and *Holothuria leucospilota* in La Reunion, *H. fuscogilva* and *H. scabra in Kenya, H. notabilis,* and *Stichopus horrens* in Madagascar, and *H. scabra* in Tanzania (Table 2). The research on this project increases the number of studies on the reproductive biology of sea cucumbers in the region from 4 to 11 (Table 2). The main mode of reproduction is sexual, although asexual reproduction through fission has previously been reported in *H. atra* (Conand 2004) and *S. chloronotus* (Conand et al. 2002) in La Reunion. Species closer to the equator (~ 4–7°S) either displayed a biannual pattern with two spawning periods (*H. scabra*) or an annual pattern with a single extended spawning period (*H. arenacava*, *H. leucospilota* and *H. fuscogilva*). Farther from the equator (~21–23°S), species exhibited annual patterns with a single extended spawning period (*H. scabra, H. horrens* and *H. notabilis*) or two short spawning periods (*Actinopyga echinites* and *H. leucospilota*).

Reproductive patterns were not necessarily species specific. For example, *H. scabra* displayed a biannual pattern closer to the equator (Muthiga et al. 2009; Kithakeni and Ndaro 2002) and an annual pattern at higher latitudes (Rasolofonirina et al. 2005). On the other hand, *H. fuscogilva* not only exhibited an annual pattern closer to the equator in this and previous studies (Muthiga and Kawaka in press; Reichenbach 1999; Ramofafia et al. 2000), but has also been reported to have an annual pattern at higher latitudes (Conand 1993). In general, spawning in the studied species coincided with the warmest months of the year in the WIO. However, because the warmest temperatures also coincided with the highest light intensities and highest ocean productivity, experimental studies would have to be carried out to ascertain the main cue for the onset of gametogenesis and spawning in individual species. Studies from the regional project not only contribute to the knowledge of reproductive patterns of the most commercially valuable sea cucumber species in the world (*H. scabra* and *H. fuscogilva*), but also assist in reevaluating the factors that affect reproduction in tropical marine invertebrates.

The project provided information on reproductive parameters that should assist countries in improving the management of their fisheries. For example, information is now available on size at sex maturity and on spawning seasons, which will enable fisheries officers in the WIO to set size limits and seasonal closures (Table 3). Overfishing has reduced population densities. In areas where individuals may be too far apart to successfully reproduce, restocking programmes are recommended for most WIO countries. Mariculture is already being piloted in Madagascar (Rasolofonirina et al. 2004; Eeckhaut et al. 2008), and several other countries in the WIO have shown an interest. Research findings from

Table 3. Possible management interventions based on the reproductive season and size at sexual maturity of commercial species in the western Indian Ocean.

Species	Country	Management interventions
Holothuria scabra	Kenya	Closures November–December, minimum size of 16 cm
H. scabra	Tanzania	Closures December–January, minimum size 16.8 cm
H. scabra	Madagascar	Closures November–April, minimum size 22 cm
H. fuscogilva	Kenya	Closures December–March, minimum size 1167 g or 32 cm
H. notabilis	Madagascar	Closures August–December, minimum size 20 g or 9.5 cm
Actinopyga echinites	Reunion	Closures December–January, minimum size 50 g
Stichopus horrens	Madagascar	Closures November–March, minimum size 170 g, 25 cm

(gutted weight = g; length in cm)
Source: see Table 2 for citations

the project will provide baseline scientific data on reproduction, which is needed for mariculture and restocking programmes.

Fisheries management and legislation

In total 32 sea cucumber species are harvested throughout the WIO (Conand and Muthiga 2007), with Madagascar having the highest number of species harvested (30 species). Five main species — *Holothuria fuscogilva, H. scabra, H. nobilis, Thelonata ananas* and *Actinopyga miliaris* — are harvested in most countries. The sea cucumber fishery is mainly artisanal (except in the Seychelles), contributing to the livelihoods of many households (De la Torre-Castro et al. 2007). Several factors indicate that sea cucumber fisheries are severely stressed:

- catches in most countries have declined between 40% and 80% over recent decades (Conand and Muthiga 2007; Conand 2008);
- abundances of commercial species are low;
- fishers indicate that species of high commercial value have become increasingly scarce;
- the length of fishing trips has increased; and
- sexually immature individuals and species of low commercial value are being harvested.

An analysis of legislative and regulatory instruments governing the management of sea cucumber fisheries indicates that most countries (Kenya, Tanzania, La Reunion and the Seychelles), have national fisheries legislations that partly address the sea cucumber fishery (Table 4). The analysis also shows that sea cucumber fishery management plans are lacking everywhere in the WIO except in Madagascar (the largest producer of beche-de-mer in the WIO) and the Seychelles. Fisheries catch monitoring programmes were present in nearly all countries but were often unreliable due to poor collection and storage of catch and export data (Conand and Muthiga 2007). In addition, except in the Seychelles where a system of logbooks was established in 1999, catch statistics are rarely collected at the species level.

Management regulations and interventions include seasonal closures, area closures, size limits, gear restrictions, licensing, restocking, education and extension, and research. At present, most countries have area closures in the form of MPAs that were established for biodiversity conservation and fisheries management. Gear restrictions are also widely used, mainly the prohibition on scuba and the licensing of fishers. To date, no restocking of over-exploited sea cucumber populations is taking place although the first-ever trade company, Madagascar Holothurie SA, has been created in Madagascar, working with non-governmental organisations (NGOs) in a mariculture programme (Eeckhaut et al. 2008; Robinson and Pascal 2009). In most WIO countries, therefore, a lack of targeted management and ineffective or poorly implemented regulations reduces the contribution of this valuable resource to the fisheries sector.

Summary and recommendations

Thirty-three participants from Kenya, Madagascar, Mozambique, Sweden and Tanzania attended the final regional workshop. Participants included managers of fisheries and MPAs, NGO representatives, university lecturers, and scientists with a stake in managing marine resources in the region. The workshop drew on the knowledge gained through the regional sea cucumber project, including the regional review (Conand and Muthiga 2007), several scientific publications produced through the project (see list below), as well as other relevant information from the collective experiences of investigators and participants. The regional workshop served as a forum to enhance awareness among relevant institutions in the WIO about sea cucumbers. Relevant identification and scientific documents were provided to participants, and a field trip served to develop skills in sea cucumber field methods. The workshop also served to enhance networking and coordination among participants, which is crucial to the continued work on sea cucumbers that is needed in the WIO.

Workshop participants acknowledged that sea cucumber fisheries in the WIO are under severe pressure, that national institutions lack capacity, and that poor monitoring systems and enforcement programmes compound the management of this fishery. Participants involved in conservation, fisheries and research resolved to assist their national institutions in developing management programmes (where such programmes currently do not exist), and explore ways to enhance the effective management of this fishery. The following recommendations are relevant (in differing degrees) for each country in the WIO:

1. Develop and implement appropriate stock assessment and monitoring programmes for sea cucumbers. These may use existing structures within fisheries authorities or work in partnerships with local research and educational institutions, NGOs or local communities. Catch and trade statistics should be collected at the species level wherever possible, and management and archiving of data should be improved.
2. Continue research on the biology, fisheries and trade of commercial sea cucumbers in WIO countries. Studies on growth, mortality and recruitment are crucial for fisheries management, and there should be continued efforts to

Table 4. Sea cucumber fisheries management interventions in selected areas of the western Indian Ocean.

	Kenya	Reunion	Tanzania	Seychelles	Madagascar	Mozambique	Zanzibar
Legislation							
Sea cucumber fisheries	present (artisanal)	partly present	partly present	partly present	present	present	present
Policy	partly present	partly present	partly present	present	present	partly present	partly present
Management plans	absent	partly present	absent	proposed	present	absent	absent
Monitoring frameworks	partly present (catch data)	present	partly present	partly present	present but unreliable	partly present	partly present
Socio-economic data collection	partly present	absent	partly present	partly present	present	no information	partly present
Regulations and other interventions							
Seasonal closures	absent	absent	absent	absent	partly present	absent	absent
Area closures (for fisheries and marine organisms)	present	present	present	present	present	present	present
Size limits	absent	absent	present but not enforced	absent	absent	present	present but not enforced
Restocking programme	absent	absent	absent	no information	absent	absent	absent
Stock assessment	absent	partly present	absent	present	present	present	absent
Gear restrictions (scuba)	present	present	present	absent	present	present	absent
Licences (fishing and trading)	present	present	present	present	present	present	present
Education and extension	absent	absent	absent	no information	present	absent	absent
Research	partly present	present	partly present	partly present	present	partly present	absent
Mariculture and other interventions							
Willingness to adopt	absent	absent	absent	absent	present	absent	absent
Marketing	absent	absent	absent	present	absent	absent	absent
Organisation of fishers (collectors, traders)	absent	absent	partly present	absent	absent	absent	absent
Processing (level and quality)	absent	absent	absent	present	absent	absent	absent
Quality assurance	absent	absent	absent	absent	absent	absent	absent

update species inventories and resolve taxonomic challenges.

3. Improve the capacity for management including increasing resources for surveillance, enforcement and training. In particular, capacity is required in the inspection of the trade, data collection and monitoring, and the use of scientific information to implement management interventions.
4. Develop sea cucumber-specific management plans, including specific regulations such as regulations on gear use, size limitations, seasonal and depth closures, and total allowable catches. At present, some high-value species are severely overexploited and total bans may be needed. Management plans should: a) be based on the best available scientific information; b) take into account best practices and the precautionary principle of fisheries management; and c) involve stakeholders during their development and implementation.
5. Train communities in harvesting and processing beche-de-mer in order to improve the quality and reduce the inefficiencies of current systems.
6. Develop mariculture programmes as alternative livelihood options as well as for commercial and restocking purposes.
7. Integrate the use of MPAs within the suit of tools for management of the sea cucumber fishery.

Despite the challenges discussed above, there is increasing interest in improving the management of fisheries in the WIO. Concerns about food security, global climate change and trade, and biodiversity conservation have increased the pressure for governments to better manage coastal and marine resources. Given that the incidence and severity of these challenges vary according to the conditions within each country, the solutions need to be tailored to the specific context within which the challenges occur. The above recommendations are, therefore, generic but if appropriately implemented they should assist in addressing some of the development and management goals of countries in the WIO region.

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Evidence of rapid overfishing of sea cucumbers in the Sultanate of Oman

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Abstract

A small, artisanal sea cucumber export fishery developed in the Sultanate of Oman in 2004. The area covered by the fishery is limited to a single shallow embayment of 320 km^2 in Mahout Bay, and involves approximately 400 fishers, around 50% of whom are women. The fishing season (October to May) in 2005 was the first season to be officially recorded. However, anecdotal evidence suggests low levels of exploitation as early as the 1970s, although catch, effort and export data for this period are unavailable. The total biomass of the stock in 2005 was estimated at 1,500 tonnes (t) (fresh weight). In the following year, at least 14.5 t of processed *Holothuria scabra* were exported to the United Arab Emirates, corresponding to approximately 145 t, or around 10%, of the recorded biomass.

Interviews with fishermen and traders revealed that in 2005, about 100 sea cucumbers per fisher per fishing trip were collected, whereas by 2007, less than 20 sea cucumbers per fisher per fishing trip were collected, indicating that there had been significant pressure on the resource. Over the same timeframe, the value of an average sized *H. scabra* was 0.1 Omani rials (USD 0.25) in 2005, increasing to 1.5 Omani rials (USD 3.75) in 2007, and is still increasing. Concomitantly, fishers began targeting the less valuable *H. atra* in large numbers. This species commands a market price of 0.2 Omani rials (USD 0.5) per specimen. Also, an examination of processed specimens for sale showed a significant number of very small individuals (<6 cm processed, corresponding to around 12 cm live length).

These concurring evidences suggest a rapid decline of *H. scabra* populations in Mahout Bay, with a corresponding increase in pressure on other species such as *H. atra*. Accordingly, the Ministry of Fisheries Wealth of the Sultanate of Oman has initiated a number of projects aimed at monitoring the sea cucumber fishery with the ultimate objective of providing a regulatory framework to ensure the sustainability of the resource. Projects also include an evaluation of enhancement and ranching techniques.

Introduction

Although sea cucumbers (Holothuroidea) have been exploited for at least 1,000 years around India, Indonesia and the Philippines (Conand 2004), their exploitation in the Sultanate of Oman is relatively recent (Al-Rashdi et al. 2007a). Anecdotal reports from older fishermen indicate that a very small-scale *Holothuria scabra* fishery occurred as part of the traditional annual cycle of trade between Oman, India and East Africa, but that the recent increase in *H. scabra* landings only began in 2004 with the establishment of a truly commercial exploitation, involving 400 fishers and a handful of traders and exporters, for export to the United Arab Emirates (Al-Rashdi et al. 2007a). The fishery is restricted to a single embayment in Mahout Bay along the Arabian sea coast of the Sultanate of Oman (Al-Rashdi et al. 2007b). The body walls of sea cucumbers are locally processed and exported in dry form. Because this fishery is quite recent, there are currently no traditional or state-directed management strategies in place (i.e. it is a fully open access fishery) (Charles 2001). Following the report of this fishery, a short study carried out in 2005 to document the status of stocks and the fishery's structure (Al-Rashi et al 2007a,b), suggested that there were already some indications of overfishing in areas easily accessible to fishers.

This paper documents the status of sea cucumber stocks five years after the start of commercial exploitation.

Material and methods

The study area covered Mahout Bay (Ghubbat Hashish Bay; 20°27′ N 58°0′ E), the only known area where the sea cucumber fishery in the Sultanate of Oman takes place (Fig. 1). The semi-sheltered bay covers approximately 320 km^2 and forms the innermost part of the Gulf of Masirah (Fig. 1). It has a maximum depth of about 10 m in the southern part but most of the bay is less than 5 m deep. Tidal ranges

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are 1.8 m during spring tides and less than 1.0 m during neap tides. The bay remains relatively protected from severe storm waves that are generated by monsoonal winds during the summer. A large part of the bay's sandy bottom is covered with sparse to dense sea grass beds dominated by *Halodule uninervis* and *Halophila ovalis* (Al-Rashdi et al. 2007a,b).

Originally, we had planned to revisit all six fishing grounds described in Al-Rashdi et al (2007a,b), but the extremely low population density observed in 2008–2009 did not allow comparisons between sites. During each field survey, we interviewed fishermen about the length (duration) of their fishing trip, the number of fishers involved, and the method and location of the collection. We also recorded the number and species of sea cucumbers collected. On several occasions, we made informal visits to processing areas to document size and species distributions of sea cucumber landings.

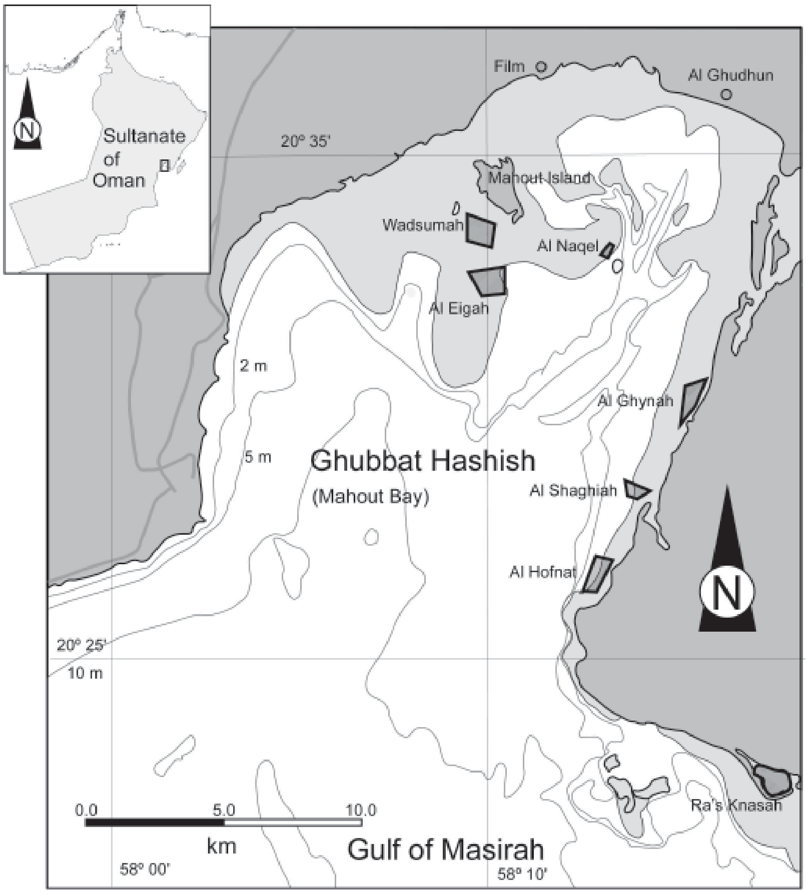

Figure 1. Mahout Bay (Ghubbat Hashish: "bay of grass") in the Sultanate of Oman and the major fishing areas for *Holothuria scabra*.

Since 2007 and following our first survey, fisheries officers were requested to record all exports of processed sea cucumbers (beche-de-mer) at the main office of the Ministry of Fisheries Wealth in Mahout.

Results

Between March 2007 and June 2008, 15.5 t of dried, processed sea cucumbers were officially exported from Mahout Bay. Exports values followed a distinct yearly cycle, with a winter maximum and a summer minimum, ranging from 3.6 t per month in January 2008 to 0.0 t between July and October 2008 (Fig. 2). According to our interviews, prices varied with size and season, but overall, fishers received between 1.5 and 2.0 Omani rials (~USD 3.5–5.5) per sea cucumber in 2007–2008.

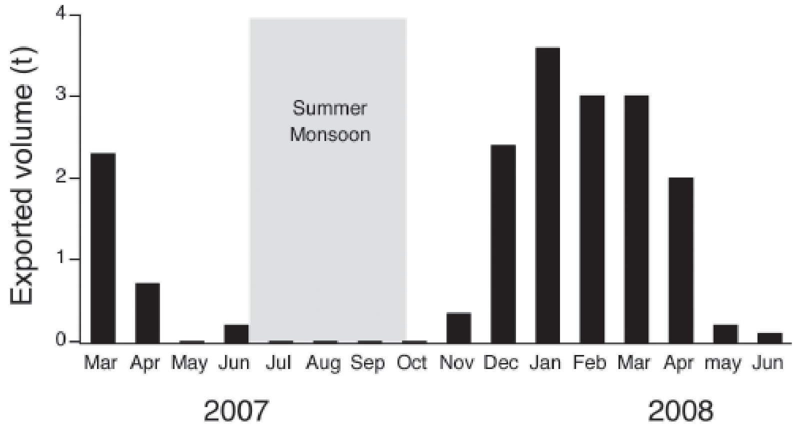

Figure 2. Volume of dried *Holothuria scabra* exported from Oman to Dubai in 2007–2008. The grey area covering June-September corresponds to the period of the southwest monsoon (Khareef), during which most fishermen leave the area.

We observed a definite decline in sea cucumber abundance. In 2008, on all exploratory dives at the six fishing grounds used in the 2004–2005 survey (Fig.1) (Al-Rashdi et al. 2007a), only one or two sea cucumbers were observed during the 30-minute dives, precluding any use of quantitative population density or biomass estimates. Similarly, shallow water quadrats in the same locations as that of the previous survey (Al-Naqel, Wadsumah, Al-Eigah, Al-Shagnhiah, Al-Hofnat and Ra's-Knasah) showed that abundances were very much reduced: in Ra's-Knasah, we collected 3 individuals per 200 m^2 and only one individual in Al-Naqel. In the other four sites, no sea cucumbers were recorded. In terms of catch per unit of effort, fishers and traders reported that in 2005, about 100 sea cucumbers per fisher were collected during a single fishing trip (3–4 hours of wading at low tide), whereas in 2007, less than 20 sea cucumbers per fisher were collected (Table 1). We also observed a shift in fishing methods used by fishermen. In 2005 (Al-Rashdi et al. 2007b), all fishing took place at spring low tide on foot, but in 2007–2008, 30% of fishermen reported using snorkeling and skin-diving gear to collect their catch. Furthermore, in 2005, about 50% of the fishers were women and children; this ratio dropped to less than 10% in 2007–2008 (Table 1).

The shift in collection methods also allowed fishers to access deeper fishing sites. One additional fishing ground was exploited in 2007–2008 in Mahout Bay (Al-Ghynah: Fig. 1), and fishermen reported that some populations of *H. scabra* near Masirah Strait were also newly exploited.

Our observations at the processing sites revealed that in addition to *H. scabra* (*feik al-bahar*, literally "sea jaw", probably in relation to the U-shape this species tends to adopt in collection buckets), a significant proportion of processed sea cucumbers were *H. atra* (*abu ar-Reyf*, "father of Reyf") and *H. leucospilota* (*abu ar-Reyf naqly*, "fake *abu ar-Reyf*"). We also witnessed large numbers of very small *H. scabra* (<12 cm fresh, <6 cm processed) being processed (Fig 3).

Discussion

The rapid decline in population densities observed between 2005 and 2008 in Mahout Bay is not exceptional. Most exploited sea cucumber populations around the world experience similar declines at the onset of commercial exploitation (Conand 1997; Uthicke and Conand 2005). The abundance of *H. scabra* observed originally in 2005 was similar to

Figure 3. Small, processed juvenile *Holothuria scabra* on Mahout Island, October 2008. The 50 baisa coin is 23 mm in diameter.

Table 1. Changes in sea cucumber fishery indicators between 2004–2005 and 2007–2008 in Mahout Bay, Sultanate of Oman.

Indicator	2004–2005	2007–2008
Holothuria scabra population density	1000 ind. ha^{-1}	<1 ind. ha^{-1}
Targeted size	> 20 cm	All sizes (including <15 cm)
CPUE (ind. h^{-1})*	25 ind. h^{-1}	<5 ind. h^{-1}
Price to fishers (Omani rials)	0.1–1.0	1.5–2.0
Targeted species	*H. scabra*	*H. scabra* *H. atra* *H. leucospilota*
Fishing grounds	6 recorded grounds in Mahout Bay	7 recorded grounds in Mahout Bay + 2 in Masirah Strait
Fishers involved in the fishery	450	150
% of women and children	50%	15
Fishing methods	Low tide collection by hand	Low tide collection by hand (70%) Skin-diving (30%)

* Based on a four-hour fishing trip at low tide.

that of unexploited stocks of the same species in the Red Sea (Hasan 2005), and is likely the result of a highly productive ecosystem and a nearly unexploited sea cucumber population. The decrease in targeted size classes observed between 2005 and 2008 is an indicator of stressed (or overexploited) populations. Fishermen now collect almost any size of animal, including individuals well below the size at first maturity estimated for this species (i.e. 160–180 mm) (Conand 1989; Hasan 2005; Kithakeni and Ndaro 2002). This strategy was developed by fishermen to maintain a constant income from the fishery. However, because smaller size individuals fetch a much lower price than larger ones, more sea cucumbers needed to be caught. This in turn led to the collection of immature individuals (Richmond 1996). The recent addition of low-value species (*H. atra* and *H. leucospilota*) to catches indicates the poor status of the fishery in Mahout Bay (Friedman et al. 2008). Overall, all six indicators listed by Friedman et al. (2008) suggested that the *H. scabra* fishery was in poor "health" and that an annual exploitation of >10% of the stock was unsustainable (although export and landing data are likely to be strongly underestimated).

Following these observations, the Ministry of Fisheries Wealth gathered a team of experts to develop a management strategy for the Oman's sea cucumber fishery. Future regulation will include a minimum size at capture of 20 cm, as well as a seasonal closure (February–August). Despite these soon-to-be implemented regulations, several closure experiments in the Indo-Pacific have shown that overfished sea cucumber stocks were slow to recover (D'Silva 2001). This is partially because holothurians are broadcast spawners, whose fertilization rate drops rapidly at low population densities.

Modelling experiments indicate that individuals separated by only a few meters do not contribute practically to larval production because of the dilution of sperm in the water column (Claereboudt 1999). The reduction in population density due to fishing may render the remaining individuals nearly incapable of successful reproduction (Allee effect). In addition, the population in Mahout Bay appears to be nearly isolated from other populations of the same species, and most likely self-recruits, further increasing the likelihood of recruitment failure in the future.

In addition to these fisheries management efforts, the Ministry of Fisheries Wealth has also invested in sea cucumber aquaculture research to replace or supplement the income of fishermen involved in the sea cucumber fishery near Mahout, as well as to develop a large-scale sustainable production of beche-de-mer.

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Present status of the sea cucumber fishery in Sri Lanka

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Abstract

This paper provides preliminary results on the present status of the sea cucumber fishery in Sri Lanka. At present, the fishery is restricted to the northwestern and eastern parts of the country. Sea cucumber fishing activities are greatly influenced by the monsoon. About 4,000–5,000 families are dependant on sea cucumber fishing activities. The major sea cucumber processing procedures include grading and cleaning, evisceration, boiling, store in salt or burying, boiling (second time) and drying. The entire annual production is currently exported to Singapore, Hong Kong and China. The fishery is open access, and there are no regulations or precautionary approaches used, except for issuing licenses for diving and transportation. After realizing the needs of implementing suitable management plans for the sustainable use of sea cucumber resources in Sri Lanka, the National Aquatic Resources Research Development Agency began a project under the technical assistance of the Food and Agriculture Organization of the United Nations.

Introduction

Sri Lanka is a small tropical island in the Indian Ocean southeast of the Indian sub-continent, situated at 5°55′–9°55′ N and 72°42′–81°52′ E. Sri Lanka's coastline is about 1,770 km long and contains several bays and shallow inlets. Since the declaration of a 200-mile exclusive economic zone in 1978, Sri Lanka has had sovereign rights over about 500,000 km^2 of the ocean. Fishing takes place all around the coast, but primarily within the continental shelf, which rarely extends more than 40 km and averages 25 km, with a total area of about 30,000 km^2.

As with many coastal fisheries, Sri Lanka's sea cucumber fishery is primarily artisanal and contributes to the livelihoods of fishermen in the coastal region. The sea cucumber industry in Sri Lanka is quite old, having been introduced by the Chinese. Hornell (1917) stated that processed sea cucumbers appear to be one of the commodities taken to China during the last thousand years when trade existed between southern India, Sri Lanka and China. However, there are no records on local consumption of sea cucumbers in Sri Lanka. Beche–de–mer is the major commodity produced in Sri Lanka, and the entire annual production is currently exported (Dissanayake and Wijeyaratne 2007).

Materials and methods

The reports presented here have been mainly gathered during 2008. Identification was done using the key prepared by Conand (1998) and available literature (James 2001). The length and weight of some commercial sea cucumbers were measured. At landing sites, sea cucumbers were grouped according to species, and the total length of each individual was measured to the nearest 0.1 cm using a measuring board. At the time of measurement, these sea cucumbers were alive. Before taking length measurements, a slight pressure was applied to their bodies until they fully straightened out. The total length was then measured. The total weight of each individual was also measured using a field balance. The weight of each individual was taken before evisceration.

Results

Present status of the sea cucumber fishery and fishing season

Although there was a well-established sea cucumber fishery around Sri Lanka in the past (Adithiya 1969; Moiyadeen 1993), at present it is restricted to the northwestern (Puttlam to Mannar) and eastern (Trincomalee to Kalmunaei) parts of the country (Fig. 1). The rapid development of the sea cucumber fishery in Sri Lanka occurred during the last few years due to the high demand for beche-de-mer on the international market and the attractive prices offered. This has changed the previously unimportant and unregulated fishery into a commercially important one in which fishers invest considerable effort. Now, however, sea cucumber populations are showing some signs of depletion (Dissanayake and Wijerathne 2007).

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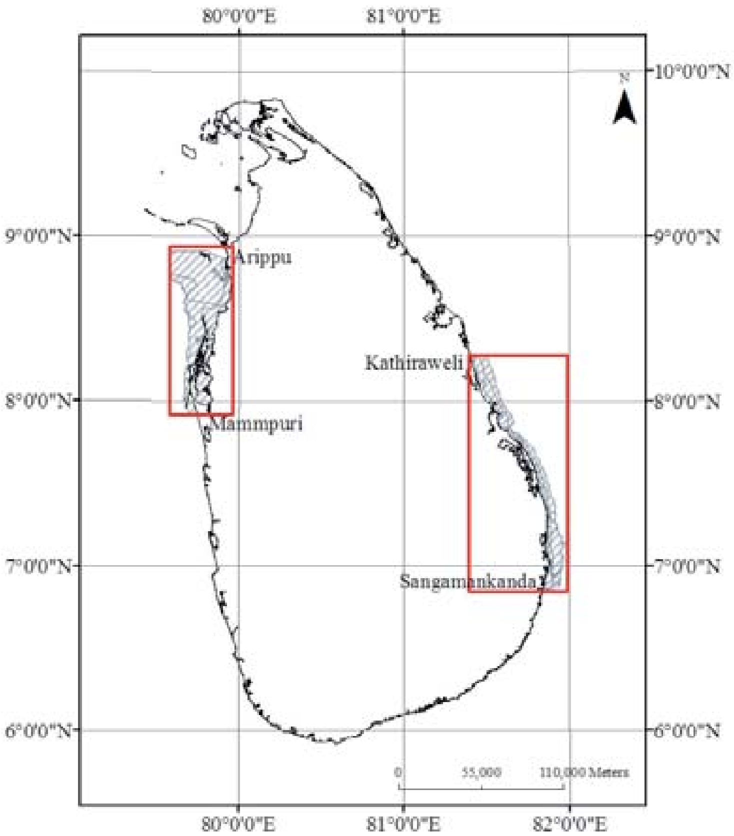

Figure 1. Sri Lanka and the major sea cucumber fishing areas on the northwestern and eastern coasts.

Sri Lanka's sea cucumber fishery is greatly influenced by monsoonal winds during the time of the southwest and northeast monsoons, which bring much wave action and currents in the sea, thereby increasing the turbidity of water and making it difficult to spot animals. Moreover, the inter-monsoonal rains also discharge water from river mouths to coastal areas making the water more turbid.

Off the northwestern coast, from Puttlam to Mannar, harvesting occurs intensively during the northeast monsoon (October to April), when the southwest monsoon (May to September) has subsided, the inter-monsoonal rains have ceased, and the water becomes clear. On the east coast, fishing occurs during the southwest monsoon (April to October). The industry, however, does not completely end during the "off season".

Work force and harvesting practices

No special gear or net is used to catch sea cucumbers, which are mainly harvested by hand, through scuba diving or skin diving. Scuba diving is carried out at all major landing sites. Fiberglass reinforced plastic boats with 15–25 hp outboard motors are the main craft used for this fishery (Fig. 2).

On a daytime fishing trip, two to three divers and a boat operator leave at 7.30–8.0 am and return at 14.30–15.30. On a night-time fishing trip, fishers leave at 18.00 and come back in the early morning hours (i.e. 02.00–03.00) the following day. The true fishing time varies from 2–3 hours for both day and night diving.

About 4,000–5,000 families are dependant on sea cucumber fishing. Around 500–600 families engage in the beche-de-mer fishery on the northwest coast, and they have permanent settlements on islands and coastal areas of Puttalam lagoon. The rest of the families are settled on the east coast while some migrate between the areas during the season to dive for fresh sea cucumbers. These families either join local divers on a contract basis or work for a dealer or processor.

Sea cucumber species in commercial catches

The sea cucumber species found in commercial catches are listed in Table 1, and are illustrated in Figure 3. Catches include three *Actinopyga* species, seven *Bohadschia*, nine *Holothuria*, two *Stichopus*, two *Thelenota* and a species identified as *Acaudina molpadioides*,and include *Holothuria scabra*, *H. nobilis* and *H. fuscogilva* as well as a species already described from the Seychelles, named "pentard".

Figure 2. Some of the boats used in the sea cucumber fishery.

Table 1. Sea cucumber species found in commercial catches around Sri Lanka.

No	Scientific name	English name	Local name
1	*Actinopyga echinites**	Deep water redfish	Goma attaya
2	*Actinopyga miliaris***	Blackfish	Kalu attaya
3	*Actinopyga mauritiana***	Surf redfish	Gal attaya
4	*Bohadschia argus***	Leopardfish	Koti attaya
5	*Bohadschia atra***	Tigerfish	Nari nool attaya
6	*Bohadschia marmorata***	Chalkyfish	Duburu Nool attaya
7	*Bohadschia similis***	Brownspotted sandfish	Line nool attaya
8	*Bohadschia* unidentified sp. 1**		Sudu nool attaya
9	*Bohadschia* unidentified sp. 2**		Kiri nool attaya
10	*Bohadschia* unidentified sp. 3**		Kiri nool attaya
11	*Holothuria atra*	Lollyfish	Narri attaya
12	*Holothuria edulis*	Pinkfish	Rathu attaya
13	*Holothuria fuscogilva**	White teatfish	Preema attaya
14	*Holothuria hilla*		
15	*Holothuria leucospilota*		
16	*Holothuria nobilis**	Black teatfish	Polanga attaya
17	*Holothuria scabra**	Sandfish	Jaffna attaya
18	*Holoturia spinifera*	Brown sandfish	Disco attaya
19	*Holothuria* sp. (pentard)*		Preema bathik attaya
20	*Stichopus chloronotus***	Greenfish	Dabalaya
21	*Stichopus herrmanni**	Curryfish	Sani attaya
22	*Thelenota ananas*	Prickly redfish	Annasi attaya
23	*Thelenota anax**	Amberfish	Poona attaya
24	*Acaudina molpadioides***		Uru attaya

* The scientific names of these species were confirmed by Dr Chantal Conand and Dr Sven Uthicke.
** The scientific names of these species need to be confirmed.

Table 2. Lengths and weights (mean values and ranges) of commercially exploited sea cucumbers.

No	Scientific name	Length (cm)	Mean length (cm)	Weight (g)	Mean weight (g)
1	*Actinopyga echinites*	13.5–30.7	22.6	374–1,325	669
2	*Actinopyga miliaris*	17.2–41.3	27.6	220–4,000	675
3	*Bohadschia marmorata*	19.6–56.1	33.8	150–3,125	1,148
4	*Bohadschia similis*	14.3–36.7	23.7	180–569	418
5	*Bohadschia* unidentified sp. 1	18.3–40.5	28.6	232–1,700	730
6	*Holothuria atra*	20.5–35.4	27.3	350–1,100	595
7	*Holothuria edulis*	15.9–28.5	18.3	275–450	285
8	*Holothuria fuscogilva*	25.2–46.2	35.8	1,000–3,200	1,892
9	*Holothuria nobilis*	23.8–41.7	34.8	985–2,500	1,719
10	*Holothuria scabra*	11.1–29.5	18.5	107–720	471
11	*Holoturia spinifera*	10.2–32.5	18.6	147–298	238
12	*Holothuria sp(pentard)*	26.8–39.7	33.8	965–2,775	1,365
13	*Stichopus chloronotus*	25.2–38.7	31.3	285–950	565
14	*Stichopus hermanni*	30.5–48.2	37.5	855–2,100	1,350
15	*Thelenota ananas*	30.3–50.9	39.8	1,050–2,900	1,725
16	*Thelenota anax*	19.3–38.5	27.4	125–495	378

The weight of each sea cucumber species is summarised in Table 2. The heaviest species include *H. fuscogilva*, *H. nobilis*, "pentard", *B. marmorata*, *S. herrmanni* and *T. ananas*, which reach an average weight of more than 1.3 kg per individual. The mean weight for *H. scabra* is 471 g.

Sea cucumber processing

Divers use either net bags or plastic barrels to transport live sea cucumbers to the shore. Different sea cucumber species are processed in different ways. Although there are some modifications from species

Figure 3. Dominant sea cucumber species in commercial catches.

to species, the major processing procedures involve the following steps.

1. Grading and cleaning
   After sea cucumbers are brought to the landing site, they are graded and cleaned in seawater to remove dried slime, sand and other extraneous particles (Fig. 4a). While cleaning, the animals are squeezed to remove the water absorbed during storage.
2. Evisceration
   The internal organs (intestines, gonads and respiratory track) are then removed by making a small slit near the posterior end with a sharp knife (Fig. 4b).
3. Boiling (first time)
   After evisceration, sea cucumbers are boiled in a clean 1,000-litre barrel. Sea cucumbers are stirred during boiling (Fig. 4c). Boiling time depends on the species, and a wire mesh is used to remove the boiled product from the barrel.
4. Storage in salt or burying
   The boiled product (Fig. 4d) is either stored in salt or buried in moist sand to activate bacterial decomposition. Storage time depends on the species.
5. Boiling (second time)
   All species are boiled once again to destroy any bacteria, which could damage the outer layer.
6. Drying
   Drying is one of the most important operations in the processing of sea cucumbers. Sun drying is considered to be better than smoking. Sun drying is quite common and boiled sea cucumbers are transferred to drying platforms or mats for sun drying (Fig. 4e, 4f)

4a. Grading sea cucumbers

4b. Removing internal organs

4c. Boiling sea cucumbers

4d. Boiled sea cucumbers

4e. Readying for sun drying

4f. Sun drying on gummy mats

Figure 4. Major steps in processing sea cucumbers.

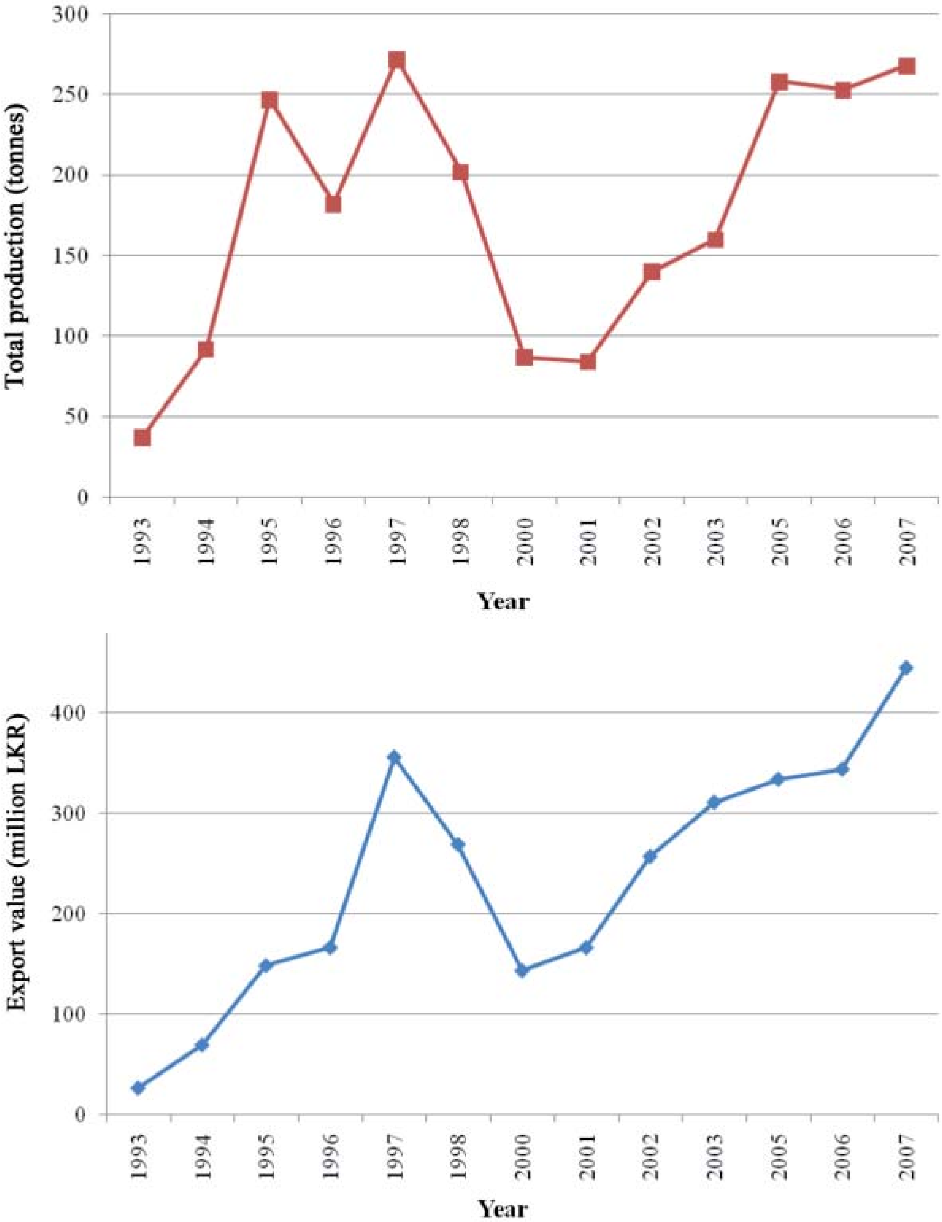

Figure 5. Annual sea cucumber production (in tonnes) and export value (million LKR).
LKR = Sri Lankan rupees. Source: Fisheries statistics 2007, Department of Fisheries

Sea cucumber trade and export

There are no records of local consumption of sea cucumbers within Sri Lanka. Beche–de–mer is the major marine commodity exported from Sri Lanka (in tonnage), and the entire annual production is currently exported to Singapore, Hong Kong and China. Because there are import and re-export mechanisms, as well as a shortage of continuous information regarding annual exports and a lack of statistical databases for catch and effort monitoring, it is difficult to give a precise estimate of sea cucumber production. Using available data, Figure 5 summarises the annual sea cucumber production (in tonnes) and foreign exchange earnings. Annual sea cucumber production increased gradually from 1993 to 1997, when it reached a peak, then declined from 1997 to 2001, and increased again from 2001 to 2007. Export earnings ranged from 100 to 400 million Sri Lankan rupees (LKR) from 1993 to 2007,[3] following the same trend as production. Because there is no proper data collection procedure in place for sea cucumbers, it is impossible to differentiate species in the total annual production.

3. In 2007, LKR 400 million were approximately equivalent to USD 3,640,000.00

Management practices

The fishery is open access, and no regulations or precautionary approach is used for management, except issuing licenses for diving and transportation, and forbidding the export of product if it exceeds 200 pieces per kg (to avoid the exploitation of undersized specimens). Hence, the fishery is almost totally unregulated. Recently there are some signs of population depletion, including lower volumes of high-value species and fishers having to travel farther, and concerns were raised regarding the sustainability of the fishery.

In Sri Lanka, research on holothurians or any other echinoderm species is at a very preliminary level. Intensive research needs to be undertaken the reproductive biology and ecology of sea cucumbers, as well as determining stocks, in order to prepare and implement a management plan for the sustainable use of this resource.

Recognizing the need to implement suitable management plans for the sustainable use of sea cucumber resources in Sri Lanka, the National Aquatic Resources Research Development Agency (NARA) has started a project on sea cucumbers under the technical assistance of the Food and Agriculture Organization of the United Nations (FAO). The project is financially supported by the Canadian International Development Agency (CIDA) and the International Fund for Agricultural Development (IFAD), and is expected to continue for three years (starting from 2008). The project aims to implement the following activities.

- Carry out both fishery dependant and fishery independent surveys in the major sea cucumber fishing areas to determine the stock status of sea cucumbers.
- Implement suitable management plans (based on survey results) to ensure the sustainable use of sea cucumber resources through the active participation of communities that are directly involved in fishing activities.
- Provide sufficient training to NARA research staff in order to enable them to carry out and supervise sea cucumber surveys in other parts of Sri Lanka.

The first phase of the independent survey was completed on the northwestern and eastern coasts of Sri Lanka, and the second phase began in late May 2009. The dependent survey activities were also implemented in 2008 and are ongoing. Survey activities were designed by NARA research staff under the guidance of Dr Brian Long, an international survey biologist recruited under the project.

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Impacts of harvesting and post-harvesting processing methods on the quality and value of beche-de-mer in Fiji Islands

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Abstract

At least 18 commercial species of beche-de-mer are harvested in Fiji. The main target species are *Holothuria fuscogilva*, *H. whitmaei* and *H. scabra*, although *H. scabra* is currently banned from export in Fiji. This study examined the impacts of processing methods on the quality and value of beche-de-mer in Fiji Islands. The findings revealed that poor processing methods contributed significantly to the loss in value of dry beche-de-mer product. The knowledge and poor understanding of processing techniques by fishermen is a key factor linked to this loss in value. First boiling after harvest, improper cutting and/or gutting, smoke curing and harvesting of undersized species were identified as the main problem areas in processing leading to revenue losses. *H. fuscogilva*, *Stichopus herrmanni* and *S. chloronotus* were found to be the more difficult species to handle during post-capture and processing. Poor quality products traded by fishermen resulted in fishermen receiving 20–30% less than the maximum price offered for well-processed products. Knowledge of the reproductive biology of commercial sea cucumber species and their effective management is essential for future sustainability of beche-de-mer production in Fiji Islands.

Introduction

The beche-de-mer fishery is an important source of income for coastal communities in the Pacific (Polon 2001). In Fiji, the beche-de-mer fishery and its trade began when the sandalwood trade declined (Ward 1972). Sea cucumbers are generally consumed by Asian communities, as a delicacy and for their medicinal properties, and the dried form is called beche-de -mer (*iriko* in Japanese, *hai–som* in Chinese or *trepang* in Indonesian) (Bumrasarinpai 2006; Lo 2004).

From a total of 1,200 species known today, approximately 24–35 species are commercially exploited (Jun 2002; McElroy 1990; Conand 1989; Nair 2003). Of these exploited species, Asian markets target species from the generas *Holothuria* (Jun 2002), *Actinopyga*, *Bohadschia*, *Stichopus* and *Thelenota*. Holothurian species such as *H. scabra* (sandfish), *H. fuscogilva* (white teatfish) and *H. whitmaei* (black teatfish) are among the highest value species (Holland 1994), demanding high prices in Asian markets. Well-dried product of "A" grade receives a value of USD 70–190 per kilogram, depending on size and quality (McCormack 2005).

Beche-de-mer processing entails an uncomplicated sequence of actions to turn wet live sea cucumbers into a dry non–perishable commodity. Post-harvest steps incorporate a first boiling, slitting and gutting, second boiling, smoking, and ultimately sun drying (SPC 1994; Sachithananthan et al. 1985; Seeto 1994). Although these steps are uncomplicated, they require continuous attention to obtain a standard dry product that has a good shape, texture and form. If the steps are not properly followed, the ultimate grade of the product will be negatively affected, thus significantly lowering the value of the final product (SPC 1994).

Studies carried out in the Verata region of Fiji Islands revealed that there was a need for enhanced beche-de-mer processing techniques (Chamberlain 2002). Chinese marine product agents purchasing products from this part of Fiji expressed a desire for improving beche-de-mer processing techniques in this and other areas of Fiji because considerable value was lost through merchandising substandard product. Correspondingly, findings by (Jun 2002) in the Philippines revealed that products that were wet, ill-shaped or half cooked subsequent to

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Figure 1. Sites visited in Fiji for data collection.

processing were rejected or considered to be class "B" thus earning local fishers 40% of the maximum price offered by marine product agents for a well-processed product.

Materials and methods

Study site

The study was conducted in Fiji Islands (Fig. 1) between August 2006 and July 2007.

Twenty-one sites were chosen from eastern and western Viti Levu, northern and southern Vanua Levu and two islands from the outer Lau group (Vanua Balavu and Lakeba Island). These two islands have two main buyers who are engaged in buying products from other islands in the Lau group. Therefore, data from the two islands represent the data for the Lau Group. Catch analysis and interviews with fishers was done at the time when the fishers visited the marine product agents on the two islands to sell their products, either in raw or dry form. However, the fishers based on the main islands of Fiji were visited directly in their villages, and data on harvesting and processing were collected.

Data collection

Data pertaining to Fiji's sea cucumber fishery was gathered through library and internet research, while information on key issues such as processing was acquired through formal and informal interviews and questionnaires given to fishermen at various sites (n = 21) around Fiji, the fisheries officers at the Ministry of Fisheries and Forests, and the main exporters of beche-de-mer. Data that were gathered from fishers and marine product agents included the following:

- Location of harvest
- Number of hours fished
- Time and/or season of harvest
- Species commonly harvested
- Storage method in the sea
- Sea cucumber processing methods
- Difficult steps in processing
- Species that are difficult to process or handle

Questionnaires were prepared and given to the target population. The key population targeted for interviews and catch analysis were artisanal beche-de-mer fishermen (n = 86), middlemen (n = 8) and the main exporters of beche-de-mer (n = 5), but for study purposes, only one exporter (Star Dragon Co Ltd located in Suva, Fiji) was involved in the entire study. An identification card and sea cucumber pictures were shown to fishers and buyers during data collection for sea cucumber identification.

Results and discussion

Beche-de-mer is produced through a series of steps that convert perishable sea cucumbers into a dried product. These steps include a first boiling, cutting and gutting, salting, a second boiling, smoke drying, a third boiling, and finally sun drying. Fishers use an alternative and shorter processing method in order to gain income more quickly, but skip fundamental steps that are crucial to producing a good quality beche-de-mer product. Fishers reported that *Stichopus herrmanni* (curryfish), *S. chloronotus* (greenfish) and *H. fuscogilva* (white teatfish) were some of the more difficult species to process. Maintaining the quality of the high-value *H. fuscogilva* was particularly a problem, and *S. herrmanni* and *S. chloronotus* were also difficult to process due to their fragile skin and flesh. During the first boiling, the flesh of these two species disintegrates. Fishers, therefore, have minimised the collection of greenfish and curryfish. Skipping important processing steps has also affected the quality (Fig. 2) as well as the value of the dried products on the international markets. Problems with poorly processed beche-de-mer include:

- Undersized individuals belonging to all species.
- Products not cut and gutted properly (i.e. gut contents are still intact with dried product).
- Products when dried do not have proper cylindrical shape and appearance is a major grade determiner.
- Burned products.
- Products are contaminated with sand and dust when packed at the marine product agents' warehouse.

Our findings revealed that greater percentages of products belonging to low to medium value species (e.g. brown sandfish, curryfish, amberfish, tigerfish, lollyfish and deepwater redfish) had quality issues due to inappropriate processing. Inappropriate post-harvest handling techniques resulted in 10–45% loss in value for all species processed. The percentages varied in different parts of Fiji Islands depending on the processing technique used. One of the major causes of value loss was that fishers skipped fundamental processing steps (e.g. first boiling, cutting and gutting, and drying).

High-value species that can potentially bring more revenue into the country are actually being valued less due to their low quality, and so are ranked as grade B instead of grade A by international markets. The price obtained by marine product agents in Fiji also affects the price distributed to local beche-de-mer fishers. There is often a difference of 10–20% on the product price received internationally, and 20–30% of the maximum price by the fishers.

Conclusion

Beche-de-mer harvesting and processing in Fiji Islands will continue to face quality problems unless beche-de-mer legislations are properly enforced. In order to make money quickly, fishers speed up processing and skip essential steps, thus affecting the quality and value of the final product. Fishers find both smoke drying and first boiling to be difficult processing steps that eventually result in poor quality products being produced from Fiji Islands.

These poor processing methods also resulted in a final product with a poor appearance (i.e. distorted or twisted), and one that contained particulate matter (i.e. sand was present in the gut cavities) and was spoiled due to improper storage. This reduced the grade of the product from "A" grade to "B", "C" or "D" grade. Further research needs to be done on the impacts of processing methods on beche-de-mer quality in Fiji Islands.

Ways to add value to beche-de-mer products exported from Fiji Islands should be investigated. The reduced grade in the final product has also prompted immediate awareness by and education for fishermen to improve processing methods and quality of beche-de-mer in Fiji Islands.

Figure 2. Poorly processed sea cucumbers for export from Fiji Islands.

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Effect of water temperature on the survival and growth of endobenthic *Holothuria scabra* (Echinodermata: Holothuroidea) juveniles reared in outdoor ponds

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Abstract

The present work analyzes data from Madagascar Holothurie Société Anonyme to determine the effect of water temperature on the survival and growth of *Holothuria scabra* juveniles in ponds, and tests a system for heating pond water during the cold season (April–August). Our study shows that while water temperature does not affect the survival of endobenthic juveniles of *H. scabra* it greatly affects their growth. We strongly recommend using a system to shade farming ponds during the hot season (September–March), and a water heating system such as greenhouses during the cold season.

Introduction

At the Madagascar Holothurie Société Anonyme (MHSA) farm in Belaza (Eeckhaut et al. 2008), juvenile *Holothuria scabra* 0.8 cm long (0.03 g) were transferred from the hatchery to outdoor ponds filled with a thin layer of sediment collected from the natural environment (i.e. sea grass bed). Juveniles were reared in ponds for about two months until they reached an average size of 7 cm (15 g), and were then transferred into fenced in areas containing sea grass for mariculture.

In the ponds, several factors influenced the growth of *H. scabra* juveniles:

- food quality, which can be "artificially added" (Rasolofonirina 2004; James 1994,1999);
- photoperiod (Pitt and Duy 2004);
- season (Lavitra 2008);
- sediment quality (James 1994; Lavitra 2008); and
- rearing densities (Battaglene 1999; Pitt and Duy 2004; Lavitra 2008).

Water temperature also plays a fundamental role in the biological activities of sea cucumbers (Wolkenhauer 2008; Battaglene et al. 1999; Mercier et al. 1999; Purcell and Kirby, 2005).

This paper analyzes the data recorded at MHSA (from December 2008 to October 2009) in order to determine the effect of water temperature on the survival and growth of *H. scabra* juveniles, and presents an adequate water heating system for the farming ponds during the cold season.

Material and methods

Pre-growth of H. scabra *at MHSA*

Juveniles were transferred from the hatchery to the outdoor ponds in Belaza (23 km south of Toliara) when they were two to three months old (larval stage included), 0.8 cm in length, and 0.03 g in weight. The ponds were concrete and measured 8 m long by 4 m wide (32 m^2). Each pond was filled with a thin layer of sediment collected from the sea grass bed. The water was changed weekly while the sediments were retained throughout the two-month farming period (i.e. they were not discarded). Parameters potentially affecting the survival and growth of *H. scabra* juveniles were monitored from December 2008 to October 2009 in the farming ponds. These parameters were surveyed daily (at 3:00 pm) and the monthly average calculated.

Effect of water temperature on the survival and growth of H. scabra *juveniles*

In order to survey the effect of water temperature on the survival and growth of *H. scabra* juveniles, only trials with the same farming conditions were considered for the analysis:

- water salinity: 33 ± 0.6‰
- initial rearing density: 700 individuals $pond^{-1}$ (22 individuals m^{-2})
- sediment volume : 0.6 m^2 (covering 2 cm depth)

In total, 16 trials (from 5 December 2008 to 5 October 2009) were analyzed and were regrouped within

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three temperature levels: T1 (28 ± 0.6°C: 5 trials), T2 (30 ± 0.2°C: 3 trials) and T3 (31 ± 0.3°C: 8 trials). Towards the end of the first farming cycle (one month), the number of juveniles in each pond was counted, their average weight calculated, and the yields obtained for each temperature level were compared.

Heating water systems during the cold season

During the cold season, a greenhouse system made from a plastic sheath made and stretched with a frame (Fig. 1) was installed in each pond. In order to determine the effects on the production yield, two ponds were used (with and without greenhouse). Water temperature was surveyed daily and the yield obtained after the farming period compared. This experiment lasted 39 days (from 15 June 2009 to 23 May 2009).

Results

Temperature and salinity in the farming ponds

The water temperature in the farming ponds was generally high (more than 26°C) during the whole year (Fig. 2A). From September to March (hot season), the water temperature was above 30°C and remained below 30°C from April to August (the cold season). Salinity remained stable and averaged 34‰ (Fig. 2B), except in March 2009 (32‰) when it was lower due to a cyclone and associated rains.

Effect of water temperature on the survival and growth of H. scabra juveniles

The results show that water temperature did not effect the survival of *H. scabra* endobenthic juveniles ($p = 0.156$). After one month of farming, survival rates were 94, 97 and 92, respectively, for the water temperatures 28°C, 30°C and 31°C. However, juvenile growth rates were highly influenced by water temperature. A significant difference was observed between 28°C and 31°C ($p = 0.005$). Growth rates were 0.09 ± 0.05 g d^{-1}, 0.193 ± 0.053 g d^{-1} et 0.379 ± 0.168 g d^{-1}, respectively, for 28 °C, 30 °C and 31°C (Fig. 3). The growth of *H. scabra* juveniles is exponentially related to water temperature and is statistically significant ($p < 0.001$). The higher the temperature, the greater the growth (Fig. 4).

Figure 1. Outdoor ponds with greenhouse.

Effect of the greenhouse

Water temperature in the pond with a greenhouse reached 30.8 ± 1°C (3.1°C of increase; $p = 0.0001$), and was 27.7 ± 0.7°C in the pond without a greenhouse. At the beginning, *H. scabra* juveniles weighed 0.03 g. After 39 days of farming, the average weight of juveniles was 9.9 ± 6.5 g in ponds with a greenhouse, and 3.7 ± 1.6 g in ponds without a greenhouse (Table 1).

Discussion

Our study shows that water temperature does not affect the survival of endobenthic juveniles of *H. scabra*. However, it has a predominant effect on their growth. In general, high temperatures (above 30°C) favor greater growth. Nevertheless, the growth and the biological activities of holothurians might decrease under excessive temperatures (Renbo and Yuan 2004; Xiyin et al. 2004). An experiment conducted at MHSA in December 2008 showed that juvenile *H. scabra* survived at 39°C water temperature, above which they became weak, and die at 41°C (unpublished data). Thus, during the hot season, it is strongly recommended to shade farming ponds (Renbo and Yuan 2004; Xyin et al. 2004; Lavitra 2008) and to use a heating system in the cold season (present work). This knowledge of the effect of water temperature on the survival and growth of *H. scabra* juveniles is very important in order to

Table 1. Water temperature, growth and survival rates of farmed juvenile *Holothuria scabra*.

Ponds	Average temperature (°C)	Initial weight (g)	Final weight (g)	Growth rate (g d^{-1})	Initial number	Final number	Survival rate (%)
With greenhouse	30.82 ± 1.04	0.03	9.94 ± 6.51	0.254	700	629	89.43
Without greenhouse	27.67 ± 0.75	0.03	3.74 ± 1.64	0.095	700	654	93.43

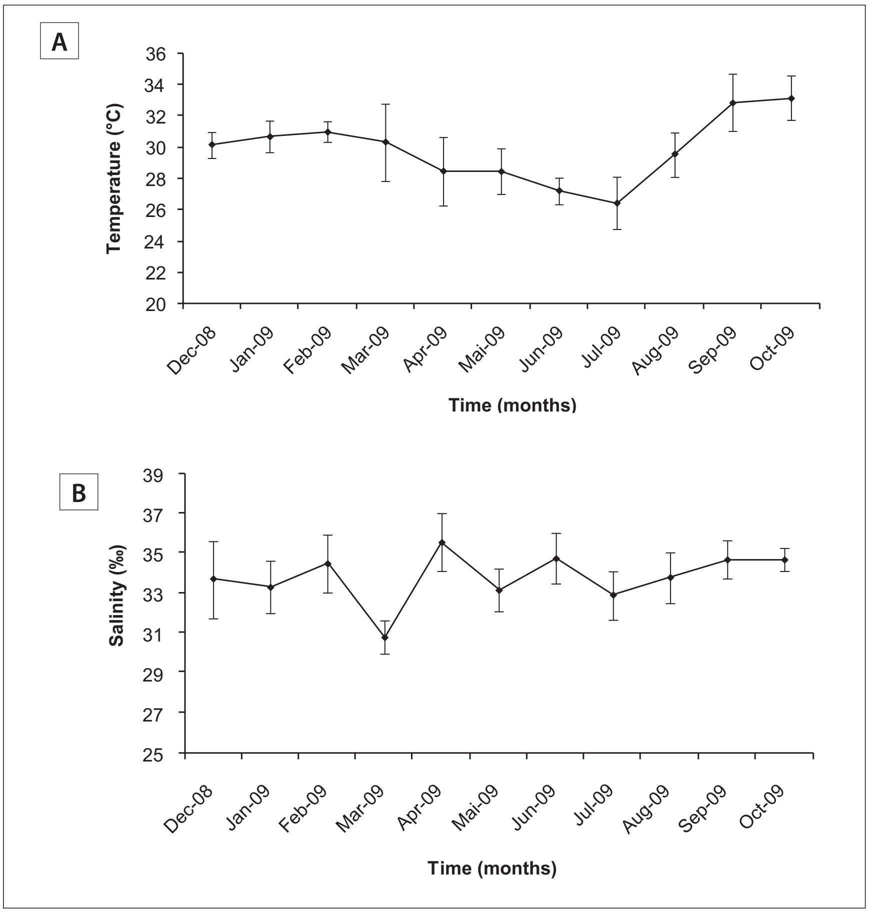

Figure 2.
Monthly variations of water temperature (A) and salinity (B) in the outdoor ponds at Belaza. Vertical lines represent standard deviations.

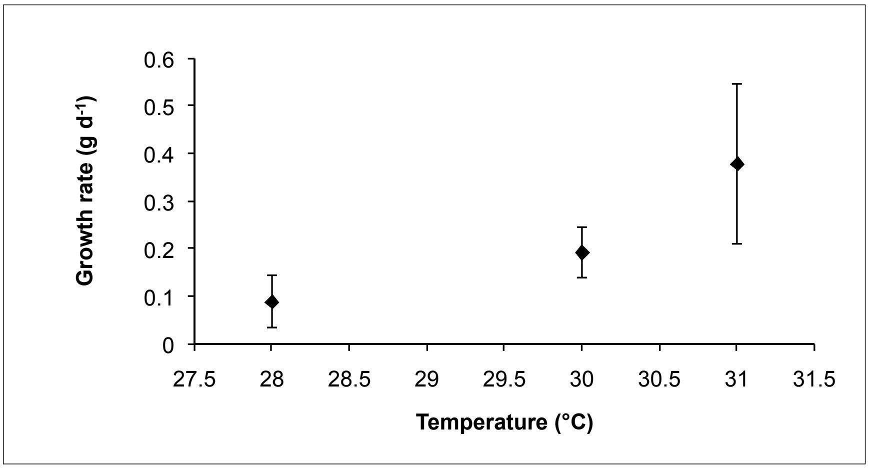

Figure 3.
Growth rate of *H. scabra* endobenthic juveniles according to water temperature. Vertical lines represent standard deviations.

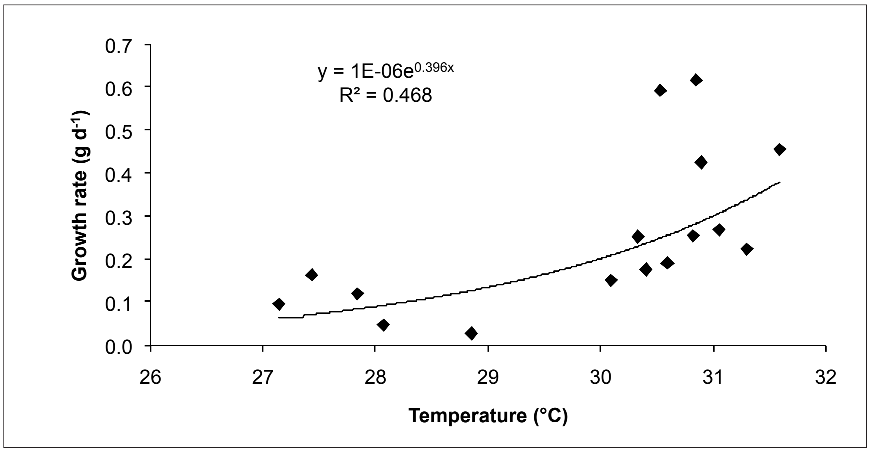

Figure 4.
Relationship between temperature and growth rate of endobenthic juveniles of *H. scabra*.

develop mariculture in other regions or countries in the future.

The effect of water temperature on the growth of *H. scabra* juveniles may be related to the animal's feeding behavior. When the water temperature was increased to more than 30°C, *H. scabra* changed their usual burying cycle and remained on the surface (Mercier et al. 2000). When water temperature was reduced, sea cucumbers buried into the sediment for long periods (Purcell and Kirby 2005), which reduced the animal's time spent feeding (Wolkenhauer 2008). The effect of water temperature on feeding behavior has been observed in sea cucumbers in general (Li 1990), and in some echinoderm species (Thompson and Riddle 2005). Besides feeding behavior, the rapid growth of *H. scabra* juveniles at high temperatures might also be explained by the abundance of phytobenthos in the farming ponds during this period, as they constitute their main food (Uthicke 1999; Uthicke 2001; Pitt and Duy 2004; Taddei 2006).

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Aquaculture potential of the tropical sea cucumbers *Holothuria scabra* and *H. lessoni* in the Indo-Pacific region

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Introduction

On the Asian dried seafood market, the sea cucumbers *Holothuria scabra* (sandfish) and *H. lessoni* (golden sandfish) fetch higher prices than any other tropical sea cucumbers. The premium price for processed sea cucumbers has resulted in increased fishing pressure on wild populations of these vulnerable species (Conand 2004). Because of this, in recent years several nations have taken strong management actions to protect the declining sea cucumber fishery (Bell et al. 2008; Friedman et al. 2008).

The attractive price for processed sea cucumbers (called beche-de-mer) and the declining wild fishery has led to considerable interest among private and government agencies in developing alternative methods of producing beche-de-mer, especially through aquaculture (Pitt and Duy 2004; Purcell 2005; Giraspy and Ivy 2005; Eeckhaut et. al. 2008). Sea cucumber aquaculture would provide a permanent solution, making it possible to both enhance declining wild sea cucumber populations through restocking, and provide sufficient beche-de-mer product to satisfy the increasing Asian market demand.

Prospects for farming the tropical *Holothuria scabra* (sandfish) and *H. lessoni*(golden sandfish)

The tropical sea cucumber *H. scabra* makes up some of the largest sea cucumber catches worldwide, and the premium quality beche-de-mer of both *H. scabra* and *H. lessoni* command high prices. This decade has seen significant interest focused on the culture of *H scabra* (Battaglene et. al. 1999; Mercier et. al. 2000; Giraspy and Ivy 2005; Eeckhaut et al. 2008) and *H. lessoni* (Ivy and Giraspy 2006).

Both sandfish and golden sandfish are considered to have the best potential for aquaculture because they have many attributes that make them suitable for hatchery production.

Factors favouring sea cucumber farming in tropical countries

- Well established market acceptance in Asia
- Very high market value and declining wild fisheries
- Availability of suitable species
- Low disease risks
- Availability of commercial technology
- Range of culture systems developed

Suitability of sandfish and golden sandfish for farming

- Wide availability of sandfish species
- Relatively hardy species, adaptable to a range of environments
- Suitable coastal environments
- High water quality (low nutrient content)
- Relatively warm water temperatures
- Large number of potential land-based sites for hatchery
- Potential sea-based sites for grow-out
- High priority industry for public sector research and development staff
- Current and new investment possibilities in hatchery facilities
- Reduced risk through experience gained with commercial production

Commercial technology

Despite the rapid increase in tropical sea cucumber aquaculture research and development activities, commercial expansion has been very slow due to various impediments. One of these impediments is the lack of optimal hatchery management practices for the successful mass production of juveniles in the hatchery.

Hatchery production of sandfish has been carried out at an experimental scale in the Pacific region (Purcell 2004, 2005; Pitt and Duy 2004), with the production of thousands of juveniles. Based on

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these works, a manual for sandfish production was published recently (Agudo 2006).

However, the commercial production of sandfish has only been carried out recently in a few countries such as Australia, Maldives (Giraspy and Ivy 2005) and Madagascar (Eeckhaut et al. 2008). The hatchery technology for the golden sandfish *H. lessoni* was developed by Sea Cucumber Consultancy, Australia (Ivy and Giraspy 2006).

In commercial hatcheries, barriers to mass production of tropical sea cucumbers (e.g. high mortality rates in larval settlement and early juvenile stages) have hampered large-scale production. However, continuous research on effective diets and settlement cues has made significant advances to overcome these barriers and Sea Cucumber Consultancy has been consistently able to produce millions of sea cucumber juveniles in recent years.

Stages in the commercial production of sandfish

1. **Broodstock collection and management**:
   Sea cucumbers are collected by fishers who dive during spawning season, when the gonad index is over seven. Nearly 5 individuals m^{-2} are placed in a flow-through seawater system with dissolved oxygen over 5.5 mg L^{-1} and a feeding rate of 5–7% of body weight.
2. **Spawning stimulation and fertilisation**:
   Spawning inducement is by thermal shock (i.e. temperature raised by 3–5°C). Males spawn first followed by the females (Fig. 1). The diameter of the fertilised egg is around 180 microns (µ). Fertilised eggs hatch into auricularia larvae after 48 hours of fertilisation and start feeding on microalgae.
3. **Larval rearing and feeding**:
   Larvae are reared in 1,000-L fibreglass tanks at a density of 0.5 ml^{-1}. During the larval rearing period the temperature was maintained between 25°C and 27°C, salinity ranged between 37.5‰ and 38‰, while pH remained at 8.2. Larval diet consisted of *Rhodomonas salina*, *Chaetoceros calcitrans*, *C. mulleri*, *Isochrysis galbana* and *Pavlova lutheri* in different combinations and at different stages. The feeding regime depends on the developmental stage, and from the early auricularia to late auricularia stage, microalgal density is gradually increased from 15,000 cells ml^{-1} to 35,000 cells ml^{-1}.
4. **Larval development and settlement**:
   The auricularia larvae develop into 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 in nursery tanks. The corrugated plates with settlement cues facilitate pentacula attachment and juvenile growth.
5. **Nursery phase**:
   The settled juveniles spend three to four months in nursery tanks, and several kinds of feeds are used for the growing juveniles. Juveniles that are 5–7 cm (Fig. 2) are ready to sea ranch or grow out in ponds.
6. **Sea ranching and pond grow-out**:
   The keys to successful sea ranching are site selection and routine management. Sea cucumber juveniles are sea ranched in sheltered bays with sea grass. Areas with few predators, such as sea stars and crabs, are preferred for successful sea ranching.

Juveniles that are 5–7 cm can be grown successfully in ponds with required water exchange. Monitoring water quality parameters and growth characteristics are essential during the grow-out phase. Sea cucumbers in grow-out areas are ready to harvest 12 months after release (Fig. 3).

Technical service

The Sea cucumber Consultancy Company (registered in Queensland, Australia), offers dedicated consultancy and management service on all aspects of sandfish commercial production. Sea Cucumber Consultancy is first of its kind and has the technology to produce millions of tropical sea cucumber juveniles in a season. This technology has developed as a result of significant research during the last 15 years mainly in the fields of spawning inducement, larval culture and settlement and juvenile grow out. The commercialisation of sea cucumber aquaculture in the Maldives and Australia has taken a significant step forward with the Sea Cucumber Consultancy's efforts.

Sea Cucumber Consultancy provides hands-on training for the mass production technology transfer in following stages of sea cucumber aquaculture project development.

Prefeasibility study

This is the preliminary stage for the development of sea cucumber aquaculture project. A prefeasibility study is carried out to determine the scope of success for a potential sea cucumber business in a specific area. During the study, the suitability of natural resources such as water, land, climate and other parameters of the proposed project sites are analysed

Feasibility study

If the prefeasibility study is favourable for sea cucumber aquaculture, then a full feasibility study is required. In this step, an appropriate and site-specific aquaculture system is developed and production target is forecasted. An estimate for constructing and operating an aquaculture facility are also determined.

Sea cucumber farm design and engineering

The actual design for the commercial sea cucumber aquaculture facility starts at this stage. Simultaneously with the feasibility study and detailed topographic study of the selected site, the design of the facility (plans of the hatchery, nursery, live feed production unit, water treatment systems, buildings, layouts of water and air distribution system) are defined. The final project cost is determined at this stage.

Aquaculture facility construction

The technical follow-up during construction determine the quality and good execution of technical works. In addition, the selection of the technical personnel suitable for the work begins.

Technology transfer

In order to safeguard the smooth operation of the facilities, technical protocols are compiled and training for hatchery, nursery and farm management staff are provided in different stages during the first production cycle. Technical support continues until the first harvest.

Management

Besides the design and construction of a sea cucumber hatchery and farm, the management of hatchery and farm and grow out are provided on an *ad hoc* basis.

Technical advice and training

Technical advice is based on assessments of the technical and management aspects of hatchery and farming operations, to improve the production protocols and management procedures.

Figure 1. Female *Holothuria scabra* releasing eggs.

Figure 2. Twelve-week-old sea cucumber juveniles ready for grow out.

Figure 3. Twelve-month-old adult sea cucumbers ready for harvesting.

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Using sea cucumbers to illustrate the basics of zoological nomenclature

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Abstract

In addition to a brief account of the need to have unique and unambiguous scientific names for taxa, this paper, annotated with examples of sea cucumbers, explains the basics of zoological nomenclature. In doing so it aims to reduce the confusion that exists among various breeds of end-users of taxonomists who may not fully understand the seemingly arbitrary and often volatile nature of scientific names. This paper also aims to provide teachers and students with a comprehensible account of the basic principles of zoological nomenclature.

Introduction

We, a group of profoundly enthusiastic sea cucumber taxonomists, were recently given the opportunity by the National Science Foundation Partnerships for Enhancing Expertise in Taxonomy program[12] to undertake an integrative taxonomic revision of aspidochirotid sea cucumbers, with the main focus on the commercially important families: the Holothuriidae and the Stichopodidae. In order to drive this daunting project to success, several interlinked lines of research are currently being undertaken: literature is compiled, scientific names extracted and judged, types are tracked down and their taxonomic status assessed, finally field surveys are carried out to generate novel systematic and biogeographical knowledge. Each of these tasks demands specific expertise and skill.

In the present paper we succinctly explain the basic rules for establishing scientific names and their standards of reference: their so-called types.

Why do we need scientific names?

When Shakespeare had Juliet say the famous words "What's in a name? That which we call a rose by any other name would smell as sweet", he meant that a name is an arbitrary construct, that if replaced by any other name, will not change the identity of the name-bearer. This concept might work for common names used by romantic authors, but it does not apply to the scientific names of taxa. A taxon[13] is a named or unnamed group of real organisms that can be recognized as a formal entity at any level of a hierarchical classification. But what is a scientific name?

A scientific name is the unique identifier of a taxon. Such names are necessary to avoid a nomenclatural Tower of Babel where different names are used for the same taxonomic unit by different authors, as this would obstruct efficient communication. Despite the existence of a rigorous set of rules governing scientific names, all too often multiple names have been given to the same taxon (synonyms, see below) or, conversely, multiple taxa have been endowed with the same name (homonyms, see below). The universally accepted rules for assigning names are known as the codes of nomenclature. In zoological nomenclature, the code used today is published in the fourth edition of the International Code of Zoological Nomenclature (ICZN 1999, the "Code").

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12. http://www.guammarinelab.com/peetcukes 2009
13. Taxa= plural, taxon= singular

In addition to a scientific name, species may also have one or more vernacular names. These names are non-unique and not universally understood. They are used for general, non-scientific purposes and are not further discussed here.

Figure 1. Fishermen use vernacular names such as "golden sandfish" in English or "le mouton" in French for *Holothuria lessoni* (Massin et al. 2009). (photo credit: S. Purcell)

What is in a scientific name?

The Code specifies that scientific names are spelled in the 26 letters of the (ISO basic) Latin alphabet, and that numbers, diacritical and other marks such as apostrophes or hyphens may not be employed. If such marks have been used in the original spelling, subsequent taxonomists correct them in their publications, in accordance with the rules expressed in the Code. Such corrections do however not affect the nomenclatural value of the name.

Example 1 The genus name *Mülleria* was corrected to *Muelleria* because the Code stipulates that the umlaut is to be deleted from a vowel and the letter "e" inserted after that vowel.

Example 2 *Holothuria fusco-rubra* was corrected to *Holothuria fuscorubra* to unite component words (i.e. *fuscorubra*, meaning dark red) without a hyphen.

The number of words in a scientific name depends on the taxonomic rank; that is, the level of the taxon in the taxonomic hierarchy (e.g. species, genus, family) of the named taxon. Above the species rank, a scientific name is composed of only a single word (a uninomen) and always begins with an upper-case letter. Family-group names are derived from the stem of the genus type, with the addition of a suffix: **–oidea** for a superfamily, **-idae** for a family, **-inae** for a subfamily, **-ini** for a tribe, and **–ina** for a subtribe. Higher and lower ranks have no regulated suffixes. To determine the stem in a generic name, one must delete the case ending of the genitive singular of the type genus.

Example *Cucumaria* (genitive Cucumariae; stem Cucumari-) gives the family name Cucumariidae.

The scientific name of a species is binominal (i.e. two names); the first name is the generic or genus name and the second the specific name. The generic name *always* commences with an upper-case letter; while the specific name *never* has an upper-case letter, regardless of the original spelling or regardless whether or not that name was derived from a person's or a locality name.

Figure 2. In 1886, Théel corrected *Labidodemas Selenkianum* Semper, 1868 to *Labidodemas selenkianum* Semper, 1868 — a species generally considered to be a junior subjective synonym (see below) of *Labidodemas semperianum* Selenka, 1867 (originally spelled as *Labidodemas Semperianum* Selenka, 1867). (photo credit: B. Van Bogaert)

Example In 1883, Ludwig established a new species from the Strait of Magellan: *Holothuria Magellani* Ludwig, 1883. Even though the specific name refers to a geographical locality, it cannot take an upper-case letter. This species is now thought to belong to the genus *Mesothuria* and hence its valid scientific name is *Mesothuria magellani* (Ludwig, 1883).

When used, the scientific name of a subgenus is interpolated in parentheses between the generic and the specific names. Like the generic name, it is capitalized. Addition of a subgeneric name does not make the name a trinomen.

Figure 3. Rowe (1969) decided that the species *Holothuria difficilis* Semper, 1868, *Muelleria parvula* Selenka, 1867 and *Holothuria sanctori* Delle Chiaje, 1823 formed an evolutionary unit within the genus *Holothuria* Linnaeus, 1767. To accommodate these species in a natural group, he erected the subgenus *Platyperona* Rowe, 1969. The complete binominal name of *H. difficilis* thus became: *Holothuria (Platyperona) difficilis* Semper, 1868. (photo credit: Y. Samyn)

At the subspecies rank names become trinominal (three names), and subspecies names, like species names, begin with a lower-case letter. The Code does not recognize names below the subspecies level, except that "varieties" established before 1961, are automatically regarded as subspecific names.

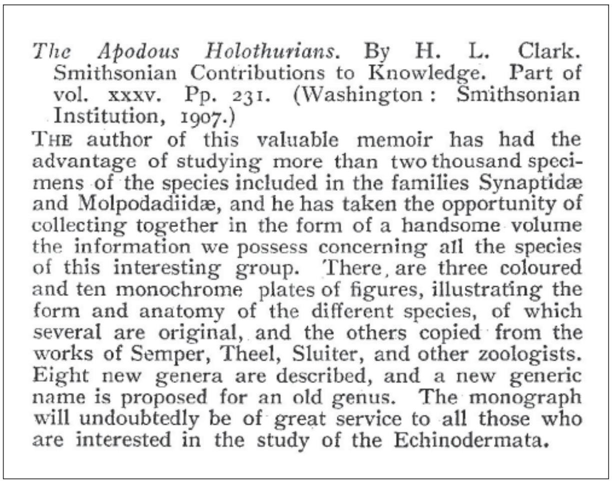
Figure 4. In 1921 and 1938, H.L. Clark recognized and named four different color varieties in addition to the typical form in *Holothuria impatiens* (Forsskål, 1775). Because these varietal names were given before 1961, they are now regarded to have subspecific rank. As such, the correct scientific name given to, for instance, *Holothuria impatiens* var. *pulchra* H.L. Clark, 1921 (cf. picture) is *Holothuria impatiens pulchra* H.L. Clark, 1921, a trinomen. When one adds the subgenus — *Holothuria (Thymiosycia) impatiens pulchra* H.L. Clark, 1921 — the name is still considered a trinomen. (scan of Fig. 3 in Plate 19 in H.L. Clark, 1921)

Whose name? And since when?

The author of the scientific name of a taxon is placed without intervening mark or punctuation after the name, except when a species name is combined with a different generic name than what was originally designated. In this case the author's name is placed in parentheses. The year of publication of the name may also be appended after the author's name, separated by a comma, and included within parentheses when the author's name is so delineated. The author and year do not form part of the taxon name *per se*, but citing them once in a paper is recommended because this allows detection of homonyms (see below) and facilitates access to other relevant scientific literature.

Figure 5. In 1775 Forsskål described the species *Fistularia impatiens*, hence the binomen *Fistularia impatiens* Forsskål, 1775. However, as the genus name *Fistularia* was used (i.e. was pre-occupied) by Linnaeus, 1767, for a genus of fish, it had to be abandoned for the species recognized by Forsskål. Currently, the species is assigned to *Holothuria* Linnaeus, 1767, resulting in the new combination *Holothuria impatiens* (Forsskål, 1775). (photo credit: D. VandenSpiegel)

In some cases, obtaining the correct date of a publication can be problematic. For instance, when the date of actual publication is not in agreement with the date printed on the work itself, or when a work was separately published in parts over a given period of time.



The Apodous Holothurians. By H. L. Clark. Smithsonian Contributions to Knowledge. Part of vol. xxxv. Pp. 231. (Washington: Smithsonian Institution, 1907.)

THE author of this valuable memoir has had the advantage of studying more than two thousand specimens of the species included in the families Synaptidæ and Molpodadiidæ, and he has taken the opportunity of collecting together in the form of a handsome volume the information we possess concerning all the species of this interesting group. There are three coloured and ten monochrome plates of figures, illustrating the form and anatomy of the different species, of which several are original, and the others copied from the works of Semper, Theel, Sluiter, and other zoologists. Eight new genera are described, and a new generic name is proposed for an old genus. The monograph will undoubtedly be of great service to all those who are interested in the study of the Echinodermata.

Figure 6. H.L. Clark's important monograph, "The Apodous Holothurians", is cited alternatively with two publication dates (1907 and 1908; see Pawson et al. 2001). According to the Code the date printed on the publication should be accepted unless there is evidence to the contrary. H.L. Clark (1921) himself indicated that, even though 1907 is the publication date on the title page, the work actually appeared in 1908. Accordingly, new taxa introduced in that work all date from 1908 (e.g. *Acaudina* Clark, 1908) (screenshot taken from the book review that appeared in volume 78 of the journal *Nature*)

Example The exact dates of publication of Semper's *Reisen im Archipel der Philippinen. Wissenschaftlige Resultate Holothurien* are difficult to assess as this work was published in several parts. Johnson (1969), having the complete and original work at his disposition, showed that pages 1–70 and plates 1–15 were published in 1867, whereas pages 71–228 and plates 16–40 were published in 1868. As a consequence all names introduced in the first part are dated 1867, whereas those from page 71 onwards are dated 1868 (e.g. *Colochirus cylindricus* Semper, 1867 (p. 56), but *Colochirus peruanus* Semper, 1868 [p. 233]).

Generic, subgeneric, specific and subspecific names are to be placed in *italics*, or underlined, in text. The name of the author and date of publication are in normal type face.

What is the status of a scientific name?

To be used, a scientific name needs to be *available* and *valid*, as defined by the Code.

To be *available*, a scientific name:

- must have been proposed during or after 1758 (the start of zoological nomenclature defined by the publication of the tenth edition of Linnaeus' *Systema naturae* and Clerck's *Aranei Svecici*);
- must appear in a work that consistently applied the Principle of Binominal Nomenclature;
- must be accompanied by a taxonomic description or reference (e.g. a previous work that describes, but does not validly name, the species) to such a description;
- may have to satisfy additional criteria. For example, descriptions of species published after 1999 have to include designation of a type specimen(s) (see below).

Example *Holothuria fisheri* Domantay, 1953 and *Holothuria mortenseni* Domantay, 1953 are two names that appeared in a checklist without descriptions. As a result, the species concepts *Holothuria fisheri* and *Holothuria mortenseni* as proposed by Domantay in 1953 are not available. In fact, the same names could be validly used for other species in the future, and if so used would take their authorship and date of publication from that usage.

To be *valid*, a scientific name:

- must be the oldest available name for the taxon (i.e. be the senior synonym). The same taxon may have been described subsequently, if so, these names are considered junior synonyms. Junior synonyms, although they may be available, are not valid.

  Synonyms can be based on different types (see also below) in which case they are considered *subjective* synonyms.

Figure 7. *Holothuria vagabunda* Selenka, 1867 is considered to be the junior subjective synonym of *H. leucospilota* (Brandt, 1835). The name *Holothuria vagabunda* is available but is not valid in the opinion of the specialist who treated it as a junior subjective synonym of *H. leucospilota*. Another specialist can remove *H. vagabunda* from synonymy with *H. leucospilota*, and thus treat *H. vagabunda* as a valid name. (photo credit: A. Kerr)

Synonyms can also be based on the same type(s) in which case they are considered *objective* synonyms.

Figure 8. The subgenus *Ludwigothuria* Deichmann, 1958 is the junior synonym of *Halodeima* Pearson, 1914. *Ludwigothuria* and *Halodeima* are objective synonyms because they are based on the same type species, namely *Holothuria atra* Jaeger, 1833, species here depicted from the Comores. (photo credit: D. VandenSpiegel)

Figure 9. Cherbonnier introduced *Bohadschia cousteaui* twice: once in 1954 and once in 1955. But both descriptions were based on the same syntypes. *Bohadschia cousteaui* Cherbonnier, 1955 is thus the junior objective synonym of *B. cousteaui* Cherbonnier, 1954. (photo credit: Y. Samyn)

- It cannot have been *suppressed*. A scientific name can be made invalid by the Commission on Zoological Nomenclature when its usage threatens the stability and universality of well-established names or may cause confusion. Suppressed names are placed on the "Official Lists and Indexes of Names in Zoology" (available at: http://www.iczn.org 2009), together with a reference to the ruling of the Commission published in the *Bulletin of Zoological Nomenclature*.

Figure 10. *Holothuria guamensis* Quoy and Gaimard, 1833 was suppressed by the Commission because it was judged that there was confusion about how the name was applied in the absence of both type specimens and an adequate description. Even though the specimen shown here corresponds remarkably well with the description of *H. guamensis*, that name cannot be validly used for it (photo credit: G. Paulay)

- must have the oldest use of that name for that taxon. Sometimes the same name is applied to two different organisms by different authors, because the authors are not aware of each other's work. In such cases the younger name — junior homonym — is considered invalid unless that name is protected (*nomen protectum*) by a decision of ICZN.

Example 1 In 1889, Sluiter introduced the name *Holothuria lamperti*. Sluiter (1889) was however not aware that Ludwig, in 1886, had introduced exactly the same species name for another species. *Holothuria lamperti* Sluiter, 1889 is the junior primary homonym of *Holothuria lamperti* Ludwig, 1886 and is thus invalid. Ludwig (1891) set aside *Holothuria lamperti* Sluiter, 1886 and introduced the replacement name *Holothuria kurti* Ludwig, 1891.

Example 2 *Holothuria maculata* Lesueur, 1824, *H. maculata* Brandt, 1835 and *H. maculata* Kuhl and van Hasselt, 1869 are all three junior primary homonyms of *H. maculata* Chamisso & Eysenhardt, 1821 and thus are invalid. If such happens, the species concepts behind each of these names established after 1821, automatically take the name of their oldest other available name. For instance *Holothuria maculata* Brandt, 1835 was replaced by its valid junior subjective synonym *Holothuria (Microthele) nobilis* (Selenka, 1867).

- cannot be a so-called *nomen dubium*: a scientific name given to a particular species that has an unidentifiable name-bearing type. It will be up to the taxonomist to decide how to treat such a name; either stabilization through re-description of material from (roughly) the same type locality or by replacement where an unidentifiable name-bearing type is replaced by a neotype (see below). The latter option requires approval from the ICZN.

Example *Ananus holothuroides* Sluiter, 1881 of which Théel (1886) thought that the name represents probably a deformed *Holothuria pyxis* Selenka, 1867 or some other species, is a *nomen dubium*.

Type(s) as permanent and objective standards of reference to scientific names

Each scientific name recognized by the Code is (or should be) objectively defined by a name-bearing type. This applies from the family-group down to the species-group. Thus:

- each family-group taxon (including subfamilies and tribes) has a type genus;
- each genus-group taxon (including subgenera) has a type species;
- each species-group taxon (including subspecies) has one or several type specimens.

Figure 11. *Stichopus* is the type genus of the Stichopodidae; *Stichopus chloronotus* Brandt, 1835 is the type species of *Stichopus*; *Stichopus moebii* Semper, 1868 is one of the species in the genus *Stichopus*, its holotype (cf. picture) is deposited in the *Zoologisches Museum zu Universität Hamburg* under the acquisition number ZMH E. 2702. (photo credit: Y. Samyn)

Types can be designated by the original author (original designation) or by a later author (subsequent designation). However, a nominal species is only eligible to be fixed as the type species of a nominal genus (or subgenus) if it was originally included in the nominal genus when that genus was named.

Example In 1958, Deichmann designated *Holothuria sanctori* Delle Chiaje, 1823 as type species of *Microthele* Brandt, 1835. This, as Clark & Rowe (1967) noted, is inadmissible because *H. sanctori* was not originally listed by Brandt in *Microthele*. The species *H. (Microthele) maculata* Brandt, 1835 was subsequently (by Clark & Rowe, 1967; not by Brandt, 1835) designated as type-species. Clark and Rowe's (1967) typification stabilized the original concept of *Microthele*. *H. sanctori* (cf. picture) was later referred to a new subgenus: *Platyperona* Rowe, 1969.

The identities of species-group taxa are established by the designation of type specimens. To eliminate the potential for conflict among multiple specimens thought to represent a species, which may turn out to represent more than one species, only a single type specimen, the primary type, has relevance in establishing the identity of a species.

All species described after 1999 have to be accompanied by the designation of a primary type, but older descriptions were not required to and often lacked any type designation. This creates a problem when either no types were designated by the author, or when multiple types (= syntypes) were established. For the former, subsequent revisers of that species can search for and attempt to establish what specimen(s) were studied by the describing author(s) and treat such specimens, if found, as syntypes (if several) or as holotype (if clearly only a single specimen was used to establish the species concept). For the latter (i.e. *w*hen an author did not establish a specimen as the primary type, either because he designated a series of specimens, or it is clear that he has studied multiple specimens, then these specimens are considered to constitute a type series, and they are referred to as syntypes). Subsequent authors may then select a single specimen from this type series and designate it as the primary type. That action makes the selected specimen a lectotype (i.e. subsequently designated primary type), and at the same time renders all other specimens in the type series to be paralectotypes (i.e. subsequently designated secondary types). If it is found later that the designated lectotype was not a syntype, it loses its status as lectotype.

If no specimens can be identified to remain from the author's study, then a reviser may establish a neotype to solidify the concept of that species and as such stabilize its name. Neotype designation is however not to be taken lightly and the Code stipulates a number of conditions that must be met. Most important is that a neotype is not to be designated as a curatorial routine but as way to clarify the taxonomic status or type locality of a species. Authors must also prove that the remaining name-bearing types (holotype, lectototype, all syntypes or earlier established neotype) is lost or destroyed.

Figure 12. In 2009, Massin et al. stabilized the identity of the commercial species *Holothuria scabra* Jaeger, 1833. Such designation was needed because the taxonomic identity of the species was unclear (photo credit: S. Purcell).

Acknowledgements

It gives us great pleasure to thank Dr J. Van Goethem of the Royal Belgian Institute of Natural Sciences for critical revision of an early draft of this paper. We also express our profound gratitude to Dr S. Stöhr from the Swedish Natural History Museum for providing us with a very comprehensive clarification on the correct spelling of the name "Forsskål", and to Dr M. Reich of Göttingen University to clarify the status of *Holothuria lamperti* Sluiter, 1889. We also thank the National Science Foundation of the United States for financial support to PEET project DEB-05297924. The logistic and financial support of the Belgian GTI National Focal Point is also fully acknowledged.

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Biology of a high-density population of *Stichopus herrmanni* at One Tree Reef, Great Barrier Reef, Australia

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Abstract

The population biology of *Stichopus herrmanni* on a back reef habitat at One Tree Reef, southern Great Barrier Reef, Australia was investigated. A density of 736 animals per hectare was recorded, and is one of the highest known for this species. Individuals were found in 67% of all transects. The population's size-frequency distribution approximated a normal distribution with a mean length of 344 mm. There was no evidence of small or juvenile specimens. The mean distance between individuals was 221 cm. Reproductive success is likely to be enhanced by the high density, large size and short distance between individuals. This population will be monitored to provide baseline data on the population biology of *S. herrmanni* from an unfished reef as a potential reference site for the Great Barrier Reef fishery of this species.

Introduction

Australian waters have historically been fishing grounds for sea cucumbers (MacKnight 1976; Uthicke 2004). There are presently a number of beche-de-mer fisheries operating in Australian waters, including the East Coast Queensland Fishery (located along the Great Barrier Reef), the Northern Territory Fishery, Torres Strait Fishery, Western Australia Fishery and a developmental fishery in Moreton Bay, South Queensland (Kinch et al. 2008a). In addition, there is an area in Australian waters off of Broome where Indonesian fishermen harvest reef resources (includes Ashmore Reef, South and North Scott Reef) (Skewes et al. 1999). The East Coast Queensland fishery along the Great Barrier Reef (GBR) has been operating since 1997 (Kinch et al. 2008a). From 1997–2001 this fishery focussed on teatfish (*Holoturia whitmaei*, *H. fuscogilva*) and to some extent sandfish (*H. scabra*) (QDPIF 2007). In recent years, this fishery has concentrated on blackfish and burrowing blackfish (*Actinopyga spinea*, *A. miliaris*), harvesting *Actinopyga spinea* in waters deeper than 30 m (QDPIF 2007). This fishery also focuses on shallow-water species in the curryfish group (*Stichopus herrmanni*, *S. ocellatus*, *S. vastus*). The Queensland fishery is managed by a rotational zoning system (Lowden 2005). Stocks of *S. herrmanni* are particularly conspicuous in the shallow waters of the southern GBR in the Bunker Capricorn Group where they inhabit shallow back reef areas and lagoons. *S. herrmanni* is also included in other beche-de-mer fisheries, such as in the western Indian Ocean (Conand 2008), and in many Pacific Islands (Kinch et al 2008a). It is also part of a domestic market in some areas (Lambeth 2000).

Current beche-de-mer management and fishing practices throughout the Indo-Pacific region are resulting in overfishing (Bell et al. 2008; Friedman et al. 2008). This makes it imperative to adopt an adaptive and precautionary management approach to the development of new fisheries. There is also a need to understand how removing commercial sea cucumbers, often the largest benthic species in coral reef communities, affects ecosystem resilience (Wolkenhauer et al. 2009). Tropical holothurians serve an important role in nutrient recycling, which improves benthic productivity (Uthicke 1999; Uthicke and Klummp 1998). With these aspects in mind, the relatively recent focus on the curryfish species group in eastern Australia provides the impetus to establish rigorous local and benchmarked knowledge of the biology of this species in the region, a current gap in the published literature. This information is necessary in order to inform management decisions regarding the fishery.

S. herrmanni is currently listed as a low to medium value beche-de-mer species (Lambeth 2000; Choo 2008; Conand 2008). Processing the body wall of this and other species in the curryfish group can be difficult because it tends to fall apart during boiling, thereby reducing its commercial value (Lambeth 2000). This is due to the mutable properties of the body wall. In the East Coast Queensland Fishery, processing and

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marketing of curryfish as frozen ready-to-eat product avoids this problem, thus enhancing the value of the product (QDPIF 2007). The trend of switching to frozen product at the expense of the traditional dried product is expected to continue from the Queensland fishery (QDPIF 2007).

The lagoon system at One Tree Reef supports a diverse and abundant assemblage of sea cucumber species. This reef has been a "no-take" scientific research zone for decades. The local and long-term high abundance of *S. herrmanni* at One Tree Reef provides an opportunity to investigate the population biology of this species from an unfished reef. A similar approach has been adopted for black teatfish surveys in no-take and special sanctuary zones in the far northern GBR Marine Park (Byrne et al. 2004; Uthicke et al. 2004). This study will contribute to the generation of a time series dataset for populations of *S. herrmanni* excluded from harvesting. This provides an important baseline data for the GBR fishery and also for comparison with other populations of *S. herrmanni*, especially in areas subject to harvesting.

Methods

The survey was undertaken at One Tree Reef (23°30'S, 152°05'E) in the Capricorn Bunker Group of the southern GBR. This is a platform reef with a lagoon enclosed by a continuous reef. The resident population of *S. herrmanni* was surveyed from 4–8 May 2009 at "Shark Alley", a back reef area just southwest of One Tree Island. Depending on the tide, the depth at this site ranged from 0.5–4.0 m. Shark Alley is subject to wave action over the reef flat at high tide. However, at low tide, the back reef area has low energy areas that are high in nutrients as seen by the prominent cover of benthic microalgae over fine sediment.

The population of *S. herrmanni* was surveyed using 40 m x 1 m transects and employing the protocol of the Reef Fisheries Observatory (Secretariat of the Pacific Community) used elsewhere in the Pacific Islands region (Kim Friedman pers. comm.). This approach allows for a thorough investigation of an area with high replication due to the short time required to process each transect. Transects (n = 36) were laid out in back reef areas along the reef edge. The data were used to estimate a per hectare (ha^{-1}) density.

As an indication of aggregation, nearest neighbour measurements (i.e. animal-to-animal proximity) were randomly collected for *S. herrmanni* individuals that were encountered during snorkelling in Shark Alley. Data were collected for the sizes of two neighbours and their distance from one another, thus providing a rough estimate of proximity within sampled populations. The length of the animals encountered in the nearest neighbour survey was measured to establish a length-frequency distribution for *S. herrmanni* at One Tree Reef.

Results

The mean density of *S. herrmanni* along the back reef site was 736 animals ha^{-1} (SE = 172, n = 36). This species was found in 67% of transects (n = 36) and was most common in areas close to main reef feature or reef outcrops (Fig 1a, b). *S. herrmanni* were located on sand, rubble and nestled among live coral. The length-frequency distribution resembled

Figure 1. *Stichopus herrmanni* is common near and on reef features in Shark Alley at One Tree Reef, Great Barrier Reef, Australia.

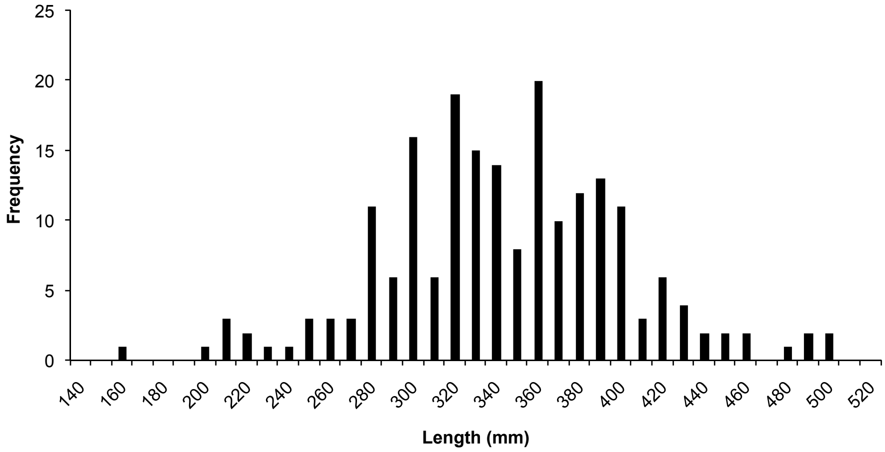

Figure 2. Length–frequency diagram for *S. herrmanni* at One Tree Reef. n = 203.

a normal distribution (Fig. 2) with a mean length of 344 mm (SD = 58 mm, n = 203, range 160–500 mm). Small adults and juveniles were not observed. The mean distance between *S. herrmanni* individuals was 221 cm (SE = 50 cm, n = 82, range = 0–3570 cm).

Discussion

One Tree Reef supports a diverse and abundant assemblage of aspidochirotid sea cucumbers. This may be because of the high nutrient retention of this reef system due to its structure, which limits lagoon circulation and loss of nutrient rich water (Larkum et al. 1988). In a recent translocation study, lagoon sands were shown to support remarkable growth with an annual length increase of up to 100% in *Holothuria atra* (Lee et al. 2008).

The density of *S. herrmanni* at One Tree Island back reef areas (i.e. 736 individuals ha^{-1}), was very high, and is likely to represent some of the highest densities reported for this species. We recognize that density comparisons are affected by differences in sampling method, replication and spatial effort. In the northern GBR, Hammond et al. (1985) reported densities of 10 animals ha^{-1} (extrapolated from 0.4 animals 400 m^{-2}). In the northwest Australia area (Scott, Ashmore and Seringapatam reefs) and Torres Strait, densities of 0–14 individuals ha^{-1} and 0–21 individuals ha^{-1}, respectively, have been reported (Skewes et al 1999, 2004). Densities at One Tree Reef are also much higher than those found in Papua New Guinea (0.1–31 individuals ha^{-1} as reported by Kinch et al. 2008b). *S. herrmanni* is noted to be common in the southern GBR (Roelofs 2004), but it is not known if the extraordinary high density is similar in other areas in the region; therefore, further surveys of neighbouring reefs are required.

The conspicuous population of *S. herrmanni* has been present in the back reef site at One Tree Reef for at least 20 years (Byrne pers. observ.). At this site, this species occupies sand at the base of coral reefs and small patch reefs in the lagoon. The presence of *S. herrmanni* along reef edge strata is noted for the Torres Strait (Skewes et al. 2004) but elsewhere it is more common in soft sediment and seagrass habitats (Desurmont 2003). At One Tree Reef, *S. herrmanni* were often found nestled among corals and may be an important nutrient resource through ammonia production (Uthicke and Klumpp 1998). However, it is not known why *S. herrmanni* is so abundant in this area of One Tree Lagoon. Further investigation of local sediment nutrient dynamics may be informative. In other regions of One Tree Lagoon *S. herrmanni,* while conspicuous, is less dense in sandy substrates that are some distance from coral (Eriksson and Byrne pers. observ.). Data are needed to determine distribution patterns. Continuous surveys of this back reef population and the larger lagoon area will provide time-series data on population metrics. Our current understanding of population dynamics of unfished and commercial populations of *S. herrmanni* and other species is a major impediment for designing sustainable harvesting strategies. It is not known how stocks respond following harvesting. Empirical data on population biology for tropical sea cucumbers are key for management, not only in the GBR fishery, but also throughout the tropics where sea cucumber resources are harvested.

With respect to the fisheries biology of *S. herrmanni*, the stable and dense population at the surveyed site provide an excellent opportunity for future research into population dynamics, distribution, spawning and Allee effects. We aim to collect seasonal information regarding stock density and aggregation. *S. herrmanni* spawns in the summer at One Tree Reef (Eriksson and Byrne pers. observ.). The planktonic larval duration of tropical aspidochirotida sea cucumbers is generally 14–21 days (Ramofafia et al. 2003). This survey was performed in May, but juveniles or small sub-adults were not observed. The smallest animals observed were 160 mm. The size at sexual maturity for *S. herrmanni* is estimated to be 220 mm (Conand 1993), suggesting that the majority of the surveyed population is mature. For the Queensland fishery, size at first maturity is 140 mm with harvest size limits proposed to be 200 mm (Roelofs 2004). If this were applied to the surveyed population at One Tree Reef, virtually the entire population would meet the harvest criterion. In comparison the minimum size listed for the Torres Strait *S. herrmanni* fishery is 270 mm (Lloyd and Prescott 2004).

Most beche-de-mer species have different recruitment habitat, juvenile nursery areas, and adult habitat. We do not have data on the location of these sites. It is likely that juveniles were hidden in reef structures, and would only be found by destructive measures. No juveniles were found during night-time surveys (Eriksson, pers. observ.), demonstrating that even for a conspicuous species such as *S. herrmanni* in a protected reef at One Tree Reef, its is difficult to observe and establish recruitment processes and life history parameters of these organisms. Addressing this knowledge gap is key to informing future management decisions regarding beche-de-mer species.

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Natural spawning observations

Stichopus monotuberculatus

Location: La Reunion, Saint Leu reef, near the back reef.
Date: 28 November 2008, 12:30 local time.
Observer/photographer: Stéphanie Bollard
Note: This species was supposed to be nocturnal.

Synapta maculata

Location: La Reunion, Saint Leu reef, la Varangue.
Date: April 2009
Observer/photographer: Sonia Ribes
Note: Several individuals were spawning; they were first retracting then re-erecting their tentacles, before expelling their gametes.

Bohadschia vitiensis

Location: Mayotte, N'Gouja.
Date: Avril 2009.
Observer/photographer: Lionel Bigot.

Communications

From Mike Reich:

Dear colleagues,
I would like to use this occasion to inform you of our "7th European Conference on Echinoderms". The pre-registration form can now be downloaded via http://www.ece2010.uni-goettingen.de/ (main page or registration page). Please pre-register by February 1, 2010 to help us plan the conference size and other details. It would be helpful if you could also comment on future volumes of the proceedings of our echinoderm conferences. An active discussion pertaining to this topic took place on the echinoderm list server in September and October 2009, where the pros and cons of our current publisher A.A. Balkema / Taylor & Francis Group were considered. One alternative would be to publish the volume in the journal "Zoosymposia", issued by Magnolia Press (www.mapress.com; Auckland, NZ), which, for example, recently released the proceedings volume of the "Ninth International Polychaete Conference", including a wide spectrum of articles. As in "Zootaxa", within the sister journal "Zoosymposia", faster printing, an impact factor as well as reprints and open access, is possible. I regret that we cannot make any specifications regarding conference fees before more details are known. If you have any questions, please do not hesitate to contact me, or our organisational team (tstegem@gwdg.de). The second circular will be issued in March 2010, and will contain all details of the event.

From Chantal Conand:

The WIOMSA 6th International Symposium was held in La Reunion in September 2009. The publications will appear in several journals in 2010. The oral presentation in the beche-de-mer session included:

The effects of fishing on the population structure and reproductive output of the commercial sea cucumbers *Holothuria fuscogilva* and *H. scabra* in Kenya – by Muthiga N.A.

Sea cucumber fisheries in the Western Indian Ocean, learning from the South Pacific – by Eriksson H., De La Torre Castro M. and Friedman K.

Sea cucumber Aquaculture – Promising opportunity for sustainable sea cucumber fishery in the Indo-Pacific region – by Giraspy D.A.B. and Ivy W.G.

Sea cucumber fisheries and mariculture in the Indian Ocean: present status and perspectives – by Conand C.

The poster session included:

Diversity of the holothuroid fauna (Echinodermata) in La Reunion (Western Indian Ocean) – by Conand C., Michonneau F., Paulay G., Bruggemann H.

Effect of food quality and rearing density on survival and growth of endobenthique juveniles of *Holothuria scabra* – by Lavitra T., Rasolofonirina R. and Eeckhaut I.

Sea cucumber fishery structure, management and importance in Zanzibar – by de la Torre-Castro M., Raymond C., Eriksson H and Jiddawi N

How much is known about sea cucumber fisheries in Mozambique – by Macamo C. and Muaves L.

Dr Claude Massin has retired as Curator of Malacology, Royal Belgian Institute of Natural Sciences. Claude's impeccable scholarship has immeasurably enriched our field with a large body of authoritative work. We wish him well in his new adventures and take comfort that his considerable passion for our science may yet grant us his continued professional presence.

The Aspidochirote Working Group (AWG) is a team of systematists from around the world who are revising the taxonomy of aspidochirote sea cucumbers. This work is amply funded by the National Science Foundation (NSF) under the program Partnerships for Enhancing Expertise in Taxonomy (PEET). This program aims to "support competitively reviewed research projects that target groups of poorly known organisms. This effort is designed to encourage the training of new generations of taxonomists and to translate current expertise into electronic databases and other formats with broad accessibility to the scientific community." Complementary funding to European Union members of AWG has been provided through Synthesys and the Global Taxonomy Initiative (http://www.guammarinelab.com/peetcukes/index.html)

Abstracts and new publications

Taxonomy of the heavily exploited Indo-Pacific sandfish complex (Echinodermata: Holothuriidae)

Claude Massin, Sven Uthicke, Steven W.Purcell, Frank Rowe and Yves Samyn

Source: Zoological Journal of the Linnean Society (2009) 155:40–59

Two commercially valuable holothurians, called the "sandfish" and the "golden sandfish" vary in colour and have a confused taxonomy, lending uncertainty to species identifications. A recent molecular study showed that the putative variety *Holothuria (Metriatyla) scabra* var. versicolor Conand, 1986 ("golden sandfish") is a distinct species from, but could hybridise with *H. (Metriatyla) scabra* Jaeger, 1833 ("sandfish"). Examination of the skeletal elements and external morphology of these species corroborate these findings. The identity of *H. (M.) scabra* has been unambiguously defined through the erection and description of a neotype, and several putative synonyms have been critically re-examined. The nomenclatorially rejected taxon *H. (Metriatyla) timama Lesson*, 1830 and *H. (M.) scabra* var. *versicolor* (a nomen nudum) are herein recognized as conspecific and are allocated to a new species, *Holothuria lessoni* sp. nov., for which type specimens have been described. In addition, the holotype, and only known specimen of *H. aculeata* Semper, 1867, has been relocated and is redescribed. It is considered a valid species. Taxonomic clarification of this heavily exploited species complex should aid its conservation and permit species-specific management of their fisheries.

Effective fluorochrome marking of juvenile sea cucumbers for sea ranching and restocking

Steven W. Purcell and Bernard F. Blockmans

Source: Aquaculture (2009) 296:263–270

Dermal spicules (or 'ossicles') of cultured sea cucumbers can be fluorescently marked with tetracycline and calcein for sea ranching and restocking but optimal immersion conditions are unknown. Lethal and non-lethal effects, and the efficacy of marking spicules in juvenile sandfish (*Holothuria scabra*), were examined under different immersion conditions. Fluorescence brightness and the proportion of marked spicules generally increased with concentration and duration of immersion. Frequency of burial (an indicator of stress) in sandfish increased with both fluorochromes at concentrations above 50 mg L^{-1}. Growth in the two-week post-marking was unaffected at immersion concentrations of 50 and 100 mg L^{-1} compared to controls, but appeared inhibited by immersion in solutions of 200 and 400 mg L^{-1} of tetracycline or calcein. Sequential marking by tetracycline (yellow) and calcein (green), in either order, showed that calcein was deposited in a higher proportion of spicules. Three other fluorochromes with disparate colors, alizarin complexone, calcein blue and xylenol orange, also marked sandfish spicules and expanded the variety of dichromic combinations. Both tetracycline and calcein fluoresced more brightly when juveniles were marked at 26 or 30 °C than at 21 °C, and this low temperature appears also to reduce the proportion of spicules marked by tetracycline. Our findings show that seawater temperature should be regulated for ex situ immersion marking. The behavioral and biological sensitivities of sandfish demand care in administering the fluorochromes. Fluorochrome immersion at 100 mg L^{-1} for 24 h at ≥26 °C provides a practical compromise-between minimizing the fitness of released juveniles and ensuring the efficacy of the markers for studies on the growth and survival of sea cucumbers stocked in the wild.

The ecological role of *Holothuria scabra* (Echinodermata: Holothuroidea) within subtropical seagrass beds

Svea-Mara Wolkenhauer, Sven Uthicke, Charis Burridge, Timothy Skewes and Roland Pitchera

Source: Journal of the Marine Biological Association of the United Kingdom doi:10.1017/S0025315409990518 (About doi). Published online by Cambridge University Press 09 Jul 2009

Some sea cucumbers species are heavily exploited as bêche-de-mer for the Asian food industry and the global decline of certain highly sought after species has generated an interest in determining the ecological function of those animals within their ecosystem. This study investigated the ecological role of *Holothuria scabra*, a commercially valuable tropical species closely associated with seagrass beds. Seagrass productivity, seagrass and benthic microalgae (BMA) biomass and organic matter (OM) were measured during two exclusion experiments conducted using *in situ* cages deployed for two months both in 2003 and 2004. Density of *H. scabra* was manipulated in caged exclusions (near-zero density, 'EX'), caged controls (natural densities, 'CC') and uncaged controls (natural density, 'NC'). Seagrass growth was lower when holothurians were excluded (5% in 2003, 12% in 2004). Seagrass biomass decreased in all treatments, but reduction was greater in EX than in controls (18% in 2003, 21% in 2004). Both BMA biomass and OM increased in EX compared to NC/CC (in 2004). From a multivariate perspective, a principal component biplot separated EX from both types of controls in 2004, and multivariate tests based on four attributes supported this separation. These results indicate that seagrass systems may suffer in the absence of holothurians; however, the effect size varied between the two experiments, possibly because experiments were conducted at different times of the year. Nevertheless, our results suggest that holothurian over-fishing could have a negative impact on the productivity of seagrass systems.

A new method to induce oocyte maturation in holothuroids (Echinodermata)

Aline Léonet, Richard Rasolofonirina, Ruddy Wattiez, Michel Jangoux and Igor Eeckhaut

Source: Invertebrate Reproduction and Development (2009) 53(1):13–21

Oocyte maturation in sea cucumbers is stopped during the meiosis at prophase I. Maturation naturally concludes just before spawning leading to a mature oocyte ready to be fertilized. Although thermal shocks applied on mature individuals can induce spawning, it is currently not possible to perform reliably *in vitro fertilization of sea cucumber oocytes. The present paper reports the discovery of* a new and highly effective oocyte maturation inducer (OMI), called MIF (for Maturation Inducing Fractions). MIF's effects on oocytes of the marketable species *Holothuria scabra* were analysed and compared to that of the few OMIs described in literature. MIF induces the maturation and fertilization of more than 90% of oocytes while other OMIs [1-Methyladenine, dithiothreitol (DTT), dimercapto-propanol (BAL) and L-cysteine] induces 28 to 90% of oocytes to mature depending on the tested inducer. Moreover the use of the other OMIs results in fertilization rates that never exceed 40%, and the obtained larvae often present developmental abnormalities. MIF's action on *H. scabra* oocytes is efficient yearlong even outside the spawning period of *H. scabra*. MIF is effective on the oocytes of all aspidochirote species tested so far but only when it is prepared from spawns of regular female sea urchin.

Coral Reef Sea Cucumbers in Malaysia

Kamarul Rahim Kamarudin, Aisyah Mohamed Rehan, Ahmad Lutfi Lukman, Hajar Fauzan Ahmad, Mohd Hanafi Anua, Noor Faizul Hadry Nordin, Ridzwan-Hashim, Rosnah Hussin, and Gires Usup

Source: Malaysian Journal of Science (2009) 28(2):171–186

This study aims to document species presence and distribution of sea cucumbers (Echinodermata: Holothuroidea) in Malaysia. Several coral reef habitats in Peninsular Malaysia, West Malaysia and Sabah, East Malaysia were selected as study sites. In summary, the present data showed the-presence of 50 species of sea cucumbers from three orders and seven genera, with 34 species require further species identification. It was found that Order Aspidochirotida in general and genus *Holothuria* in particular were the major species classes. The most dominant species in Malaysia was *Holothuria leucospilota*. As many as 37 species were found in Sabah, 21 species were recorded in Peninsular Malaysia and 10 species were present in both regions. Of 15 *Actinopyga* species, 14 species recorded were from Sabah. These findings may be due to the extensive distribution of coral reefs and low level of marine pollution. However, the possibility of biogeography factors within and out of the Sunda Platform area cannot be ruled out. In contrast, low level of species diversity was observed in few study sites in Peninsular Malaysia especially in Langkawi Island possibly due to anthropogenic threats. Future studies including more study sites and molecular phylogeny are to be incorporated in order to obtain better view on the presence and distribution of sea cucumbers in Malaysia.

Origins and biomechanical evolution of teeth in echinoids and their relatives

Mike Reich and Andrew B. Smith

Source: Palaeontology (2009) 52(5):1149–1168

Echinoid teeth are without doubt the most complex-and highly specialized skeletal component to have-evolved in echinoderms. They are biomechanically constructed to be resilient and tough while maintaining a self-sharpening point. Based on SEM analysis of isolated tooth elements collected primarily from the Ordovician and Silurian of Gotland, we provide a detailed structural analysis of the earliest echinoderm teeth. Eight distinct constructional designs are recognized encompassing various degrees of-sophistication, from a simple vertical battery of tooth spines-to advanced teeth with multiple tooth plate series and a reinforced core of fibres. These provide key data from which we reconstruct the early stages of tooth evolution. The simplest teeth are composed of stacked rod-like elements with solid calcite tips. More advanced teeth underwent continuous replacement of tooth elements, as a simple self-sharpening mechanism. Within echinoids tooth design was refined by evolving thinner, flatter primary plates with buttressing, allowing maintenance of a sharper and stronger biting edge. Despite the obvious homology between the lanterns of ophiocistioids and echinoids, their teeth are very different in microstructural organization, and they have evolved different self-sharpening mechanisms. Whereas echinoid teeth evolved from a biseries of mouth spines, ophiocistioid goniodonts evolved from a single series of mouth spines. Rogeriserra represents the most primitive known battery of tooth elements but its taxonomic affinities remain unknown.

Status and management of the sea cucumber fishery of La Grande Terre, New Caledonia

Steven W. Purcell, Hughes Gossuin and Natacha S. Agudo

Source: WorldFish Center Studies and Reviews N° 1901 (2009). The WorldFish Center, Penang, Malaysia. 136 p.

In New Caledonia, the sea cucumber fishery has operated since the 1840s. In 2007, the reported export value of sea cucumbers from New Caledonia (~5.3 million USD) was twice that of tuna – ranking it the second-most valuable marine export commodity after farmed shrimp. This project was conducted by the WorldFish Center from October 2006 to May 2008, under support from the national ZoNéCo programme. We used field population surveys, landing surveys, socio-economic surveys with fishers and processors, and a stakeholder workshop to evaluate the sea cucumber fishery of the main island, La Grande Terre, and provide recommendations for its management.

Sea cucumbers, trochus and giant clams were surveyed on 50 lagoon and barrier reef sites using stratified, replicate, belt transects that were geo-referenced using GPS technology. More than 6,000 sea cucumbers were counted. Additionally, we measured and weighed 1,724 sea cucumbers, of medium or high value, collected along the 1,475 transects. We used structured questionnaire-based interviews of 26 fishers and seven processors to describe the social context of the fishery. We measured and weighed 2,433 individual sea cucumbers from a total of 54 landings from fishers among the six study regions.

About 12 sea cucumber species of high and medium value are harvested. Distributions were quite patchy for most species. On average, we observed 8 sea cucumber species per site. Species richness was similar between the two Provinces and between reefs in reserves and those open to fishing. Populations of a few commercial species appear depleted, namely *Holothuria fuscogilva*, *Holothuria lessoni* and *Actinopyga lecanora*. Several other species were relatively sparse, namely *A. mauritiana*, *A. miliaris* and *H. scabra*. Most of the other commercial species were relatively common and have breeding populations at some sites that should allow for some further recruitment.

A comparison of size-frequencies of sea cucumbers in landing and those from field surveys suggest that there was some selection by fishers for larger individuals, but not in all regions. Most of the sea cucumber fishers are men aged 30–50 years with many years of fishing experience. Sea cucumbers were the most important source of income for most of the fishers and many of them only spent a couple of days fishing each week. The catch-per-unit-effort (CPUE) of fishers varied among regions. Fishers in Province Nord processed their own catches more often than fishers in Province Sud because they are further from processing centres. Compared to perceived historical CPUE, estimates of current CPUE from landing and interviews with fishers indicate that catch rates have declined in some regions. The CPUE of fishers has increased near Nouméa and further south, but the catch has broadened to include many low-value species that can dominate the catch volume.

Some stocks of sea cucumbers in New Caledonia can probably sustain further fishing impact, at modest levels. Stocks for some other species are low or depleted and management regulations should be brought in to ensure their breeding populations do not decline further. Fishers in some areas are still harvesting sea cucumbers intensely even though the average sizes of animals have declined and even though they believe the abundances have declined. The capture of some small animals and responses from questionnaires shows that more education of fishers is needed through regular visits by fisheries officers.

We propose and discuss 13 recommendations for actions to be taken by the fisheries services and fishery regulations to be imposed on fishers. In particular, we propose fishing closures of several species and advise regulations to limit industrial-type fishing. A management plan needs to be rapidly established in the Provinces of New Caledonia that will safeguard the reproductive potential of sea cucumber populations and their biodiversity on reefs. We recommend an adaptive management approach, whereby the management plan can be changed over time through new information from the social-ecological system.

Elucidation of molecular diversity and body distribution of saponins in the sea cucumber *Holothuria forskali* (Echinodermata) by mass spectrometry

Séverine Van Dyck, Pascal Gerbaux, Patrick Flammang

Source: Comparative Biochemistry and Physiology (2009), Part B 152:124–134

Sea cucumbers contain triterpene glycosides called saponins. We investigated the complex saponin mixture extracted from the common Mediterranean species *Holothuria forskali*. Two different body components were analyzed separately: the body wall (which protects the animal and is moreover the most important organ in terms of surface and weight) and the Cuvierian tubules (a defensive organ that can be expelled on predators in response to an attack). MALDI/MS and MALDI/MS/MS were used to detect saponins and describe their molecular structures. As isomers have been found in the Cuvierian tubules, LC/MS and LC/MS/MS were performed to identify each saponin separately. Twelve saponins have been detected in the body wall and 26 in the Cuvierian tubules. All the saponins from the body wall are also present in the Cuvierian tubules but the latter also contain 14 specific saponins. The presence of isomeric saponins complicated structure elucidation for the whole set but 16 saponins have been described tentatively. Among these, 3 had already been reported in the literature as holothurinosides A and C, and desholothurin A. Molecular structures have been proposed for the 13 others which, in the present work, have been provisionally named holothurinosides E, F, G, H, I, A1, C1, E1, F1, G1, H1 and I1 and desholothurin A1. The diversity and organ specificity of the saponins described here are much higher than what had been reported to date in any sea cucumber species.

Reproductive biology of *Actinopyga echinites* and other sea cucumbers from La Réunion (Western Indian Ocean): Implications for fishery management.

Sophie Kohler, Sylvie Gaudron and Chantal Conand.

Source: Western Indian Ocean Journal of Marine Science (in press)

The sea cucumber fishery is important in several countries of the western Indian Ocean (WIO) but is generally not adequately managed. A regional MASMA programme (Marine Science for Management) granted by WIOMSA (Western Indian Ocean Marine Sciences Association) is providing data on the reproduction of some commercial species. In La Réunion, the 2 target species are *Actinopyga echinites* and *Holothuria leucospilota*. These sea cucumbers are very abundant on the fringing reefs and were sampled monthly during 2005–2006. Data on the population structure and on the reproductive cycle of *Actinopyga echinites* are presented here. The main results are: 1) gutted weight (EW) distribution of individuals within the population of Planch'Alizés site is plurimodal with a main mode at 85–95g, 2) sex-ratio is skewed toward females, 3) anatomy of gonads is described in 5 maturity stages, 4) a seasonal reproductive cycle with a major spawning event in December–January and a minor spawning event in April, 5) size at first sexual maturity EW_{50} equal to 45 g is determined from another site (a sea grass bed with juveniles). These results are integrated with data from other holothurian species such as *H. leucospilota*, *H. atra* and *Stichopus chloronotus* previously studied in La Réunion and will be useful for research on the reproductive biology of sea cucumbers conducted in the other countries of WIO. 'Seasonal closure' using results on the spawning season during the warm waters period and 'minimum size' using size at first sexual maturity are tools for enhancing sustainable management of the fisheries.

PhD THESIS ABSTRACTS

Phylogeny, systematics, population dynamics and nutrition of aspidochirote holothuroids (Echinodermata) in an Algerian *Posidonia oceanica* meadow

Karim Mezali – Université de Mostaganem, Algeria

The aspidochirotid holothurians commonly named "sea cucumbers" are major component of the *Posidonia oceanica* meadow. They play an important role in recycling the organic matter and the oxygenation of the bottom sediment.

The systematic study of Mediterranean aspidochirotid holothurians was established in the 19th century, when all these species were described on the morphological and anatomical level. The identity, the validity, and limits of these species has been the subject of considerable debates through the 20th century, mostly because there is substantial intraspecific variations, and limited interspecific differentiations among them. Until now species limits and relationships in this assemblage have not been explored with molecular techniques. Thus, our study proposes to describe and determine the phylogeny, the systematic, the population's dynamics and the nutrition of this class of Echinodermata in the Algerian coasts.

The systematic study was carried out, by using modern molecular systematic and morphological methods (clustering). These two methods enabled us to differentiate six sampled holothurians forms [*Holothuria (Holothuria) tubulosa*, *Holothuria (Roweothuria) polii*, *Holothuria (Holothuria) stellati*, *Holothuria (Panningothuria) forskali* and both morphotypes of *Holothuria (Platyperona) sanctori*]. Many individuals were sampled for each species in various localities of the Algerian coast in particular in the two studied stations: Sidi-Fredj and Tamentefoust. These individuals were photographed alive, their DNA was analyzed starting from fraction of gene (rRNA 16S) and the morphology of their endoskeleton was described and measured. This study has led to a definitive test of species boundaries in the Mediterranean species and showed that:

- The two color morphs of *Holothuria (P.) sanctori* that have been debated in some of the literature are genetically identical and thus represent the same species;
- *Holothuria (H.) stellati* whose confusion was always admitted, is genetically distinct and well defined species and present characteristics which characterize it as well on the morphological and genetic levels;
- *Holothuria (H.) tubulosa* the most common species, and "best known" species in the Mediterranean Sea, is not one species, but two cryptic species that have not been previously recognized or even suspected. We determined their distinctiveness on genetic, morphologic, anatomic and endoskeleton levels;
- However few specimens of holothurians analyzed in our collection, have given unusual sequence data. It remains to confirm them by analyzing other sequences data using other molecular markers to interpret these specimens. However, it is clear that one specimen will probably represent either another species previously unknown, or a hybrid between the two known species [i.e. *H.* (*R.*) *polii* and *H.* (*H.*) *stellati* for the non identified specimen *Holothuria* (*R.*) *polii* B].

The seasonal evolution of biomass/ density ratio exhibited a maximum in summer and a minimum in fall for both species [*H.* (*H.*) *tubulosa* and *H.* (*R.*) *polii*]. The minimum value of biomass/ density ratio may be interpreted as an indication of recruitment. The mean abundance of *H.* (*R.*) *polii* was significantly lower in the polluted station (Tamentefoust) than in unpolluted station (Sidi-Fredj). The collected data confirm the importance of *H.* (*R.*) *polii* as an indicator of pollution.

The analysis of digestive contents of the various species illustrates the alimentary specificity of each species: The holothurians, which ingest the coarse and fine sediment [*H.* (*H.*) *tubulosa*, *H.* (*L.*) *polii* and *H.* (*H.*) *stellati*]; the holothurians that select fine and very fine sediment [*H.* (*P.*) *forskali* and *H.* (*P.*) *sanctori*]. Concerning the selectivity of organic matter, *H.* (*P.*) *forskali* is the most selective species followed by *H.* (*P.*) *sanctori*, *H.* (*H.*) *tubulosa*, *H.* (*H.*) *stellati* and *H.* (*L.*) *polii.*

Characterisation of an agent that induces oocyte maturation in aspidochirote sea cucumbers including *Holothuria scabra* (Jaeger, 1833), a high market-value species

Aline Léonet – Marine Biology, University of Mons, Belgium

(Developer: Igor Eeckhaut)

Certain sea cucumbers such as *Holothuria scabra* are considered highly nutritional food resources by Asian communities. Intensive harvest of these animals has brought about a sharp drop in their populations over recent decades, particularly along the coasts of Madagascar. This very alarming situation gave rise to an inter-university project involving the marine biology laboratories of the U.L.B. (*Université libre de Bruxelles*) and the University of Mons along with the Tulear Fisheries and Marine Sciences Institute in Madagascar. This project led to the creation of a company, "Madagascar Holothurie SA", the first of its kind in the western Indian Ocean. The company's goal is to sell farm-raised sea cucumbers. One of the major hurdles that have to be overcome in order for this kind of company to be profitable is getting a maximum number of specimens to sell in as short a time as possible. So, at the beginning of the farming process, you need to have as many fertilised eggs as possible. However, when sea cucumber oocytes are removed by dissection, they remained blocked at prophase I of meiosis, a blockage that is only naturally removed during spawning. There are, of course, various techniques to induce spawning but these methods are very spotty and can only be used during the sea cucumber's reproduction period, which in Madagascar goes from November to March. This Belgian-Malagasy project has developed a very unusual patented procedure to make it possible to have millions of fertilised eggs on a continuous basis, i.e. anytime of the year. This process is based on *in vitro* maturation and fertilisation of oocytes removed from genitors. It involves the use of a new extract called nirine. Nirine induces maturation in sea cucumber oocytes that are blocked in prophase I of meiosis and would only naturally be unblocked by spawning. Our work is designed to understand the action mechanism behind nirine's active ingredient, determine its nature, isolate and identify it. The sea cucumbers used for this experiment were *Holoturia scabra*, a high market-value Indo-Pacific species found in Madagascar, and *Holothuria tubulosa*, a Mediterranean species tested in our laboratory in Belgium.

Chemical defences in marine invertebrates: Body distribution, abundance and eco-physiological role of saponins in holothuroids (Echinodermata)

Séverine Van Dijk – Marine Biology, University of Mons, Belgium

(Supervisor: Patrick Flammang)

Holothuroids (sea cucumbers) are benthic marine invertebrates belonging to the phylum Echinodermata. The skeleton of these organisms is strongly reduced making the body wall flexible but also more vulnerable when facing predation. Among their anti-predatory mechanisms, two defence systems have been the subject of numerous studies: the Cuvierian tubules, a physical system only present in some species belonging to the family Hothuriidae, and the saponins, a chemical system common to all holothuroid species. Cuvierian tubules are little caeca, attached to the basal part of the left respiratory tree, which can be expelled outside of the animal in response to a potential aggression. Following their expulsion, tubules lengthen and become sticky when they enter in contact with their target. They can therefore entangle the predator, giving the holothuroid the opportunity to crawl away. As for saponins, they are triterpene glycosides contained in the body wall and the viscera of holothuroids. These secondary metabolites seem to be deterrent to all non-specific predators. Saponins appear to be particularly concentrated in the Cuvierian tubules, suggesting a particular relationship between tubules and saponins, a relationship probably linked to the defensive function. However, until now, studies performed on the saponins of the Holothuriidae have rarely made the distinction between the body wall and the Cuvierian tubules. The present work reports the study of saponins in these two body compartments for six holothuroid species from the Mediterranean Sea (*Holothuria forskali*) and from the Indian Ocean (*Actinopyga echinites*, *Bohadschia subrubra*, *Holothuria atra*, *Holothuria leucospilota* and *Pearsonothuria graeffei*). This study focuses on the detection, the description and the quantification of the saponins in all these species, as well as on the tissue localisation and the biological effects of the saponins of *H. forskali*.

Several mass spectrometry techniques were used to make a complete study of the body wall and Cuvierian tubules saponins of *H. forskali*. Matrix Assisted Laser Desorption/Ionisation (MALDI) and Electrospray Ionisation (ESI) methods were used to produce ions corresponding to the different saponins in gaseous phase. Information allowing the complete characterisation of these different ions (molecules) was obtained by performing tandem mass spectrometry experiments. Twelve saponins were then detected in the body wall and 26 in the Cuvierian tubules. All the body wall saponins are common to both tissues, 14 saponins are thus specific of the tubules. The presence of isomeric saponins detected by LC-ESI/MS complicated the elucidation of molecular structures. However, sixteen saponins were described including 3 previously described congeners known as holothurinosides A, C and desolothurin A. The 13 new ones were named holothurinosides E, F, G, H, I, A_1, C_1, E_1, F_1, G_1, H_1, I_1 and desholothruin A_1. This last one has recently been detected in the species *Bohadschia argus* in which it was named arguside E.

The saponin extraction and analysis methods that were established for *H. forskali*, allowed the realisation of a complete comparative study of the body wall and Cuvierian tubules saponins of the 5 tropical species (except for *H. atra* which lacks tubules). These saponins were classified into two categories; non-sulfated saponins detected in *B. subrubra*, *H. leucospilota* and *P. graeffei* and sulfated ones detected in *A. echinites*, *H. atra*, *H. leucospilota* and *P. graeffei*. The total number of saponins differs among species but there is also an important intra-species variation, between the body wall and the Cuvierian tubules. A semi-quantitative study, using two complementary methods (the measurement of the hemolytic activity and the orcinol reaction) allowed to show that the concentrations of saponins are always higher in the Cuvierian tubules than in the body wall, and also that the different species enclose saponin quantities varying in a ratio of 1 to 8.

The precise localisation of saponins in the holothuroid tissues had never been studied until now. The first method we used, a histochemical labelling on sections using lectins, did not yield convincing results. On the other hand, the use of Imaging Mass Spectrometry (IMS) led to interesting results and, moreover, highlighted differences between the tissues of stressed and relaxed individuals. In the body wall of relaxed individuals, saponins are mainly localised at the level of the epidermis, except the saponins detected at *m/z* 1287 and 1303 which are rather localised at the level of the mesothelium. In stressed individuals, these last ones are no longer detectable in the body wall, moreover, the epidermal localisation of the other saponins is more pronounced. These results have been confirmed by classical mass spectrometry analyses (MALDI) on saponins extracts of both internal and external fragments from the body wall. It is interesting to note that relaxed individuals of *H. forskali* seem to release only one saponin in their close surroundings (holothurinoside G) while stressed individuals secrete 6 saponins: 4 known congeners (holothurinosides C, F, G and desolothurin A) and 2 new ones detected at *m/z* 1301 and 1317. Eco-physiological experiments were realised to investigate the effect of saponins secreted by the body wall on potential fish predators. Saponins have been either added directly in the seawater or presented in pellets as food. Only the highest doses of saponins seem to have an effect on fish (deterrence to highly concentrated pellets or even death at high level of saponins in seawater). The different observations suggest that saponins of *H. forskali* could act as olfactory aposematic signals.

The whole body of results indicates that there are important qualitative and quantitative variations in the saponin content of the different species of Holothuriidae, but also between the different body compartments of a given species. These differences could be linked to the evolutionary history of the family. The various mass spectrometry techniques were well adapted to the study of saponins in holothuroids for their easy use as well as for their rapidity of execution.

NEW PhD THESIS

PHD student: Guillaume Caulier

(Supervisors: Patrick Flammang, Igor Eeckhaut)

Symbiotic relationships are vital to ecosystem structure. These interspecific relations require a means for the host and symbiont to recognise each other. The type of communication that makes this host selection possible is generally chemical and involves olfactory signals, known as kairomones, that have the power to attract a commensal or parasite host. Although the existence of kairomones has already been proven by a large number of studies, the exact chemical nature of these metabolites has never been revealed in marine symbiotic relations. This project will mainly concentrate on identifying kairomones and on their effects, which allow sea cucumbers and Crinoidae species to be recognised by their respective hosts (i.e. the sea cucumber crab *Lisocarcinus orbicularis* (Dana 1952) and the shrimp *Synalpheus stimpsoni* (De Man 1888). Behavioural experiments will be carried out to study the ability various kairomones have to attract symbionts. These compounds will be identified through mass spectrometry and chemoreceptors will be studied by electron microscope and IMS (Imaging Mass Spectrometry).

PhD THESIS UNDERWAY

Biology of symbiotic relationships in the marine setting: Characterising the epidermal and gill adaptations of Carapidae fish associated with echinoderms

Maité Todesco

(Supervisor: Igor Eeckhaut)

Biological diversity in coral reefs is extremely rich. Very close associations between interspecific organisms, known as symbiotic relationships, are very diverse there and involve a wide range of species. Some lesser-known fish, such as *Onuxodon*, *Carapus* and *Encheliophis* from the Carapidae family (Ophidiiformes), have lifestyles that are very similar to clownfish, which are acclimated to their anemones. These anguilliform fish do, in fact, have the ability to penetrate and remain inside various invertebrate hosts such as ascidians, bivalves, starfish and, more commonly, sea cucumbers. They live in their pharynxes, mantle cavities, body cavities or respiratory trees (i.e. the sea cucumber respiratory system). Only a dozen species from the genera *Carapus* and *Encheliophis* have the ability to live with echinoderms.

Recently, numerous aspects of symbiotic Carapidae biology have been elucidated. The main points of their biology, which have now been clearly established, can be summarised as follows: 1) *Carapus* are commensals that only use their hosts for shelter, while *Encheliophis* are parasites that mainly feed on the gonads of echinoderms; 2) their life cycles include a free larval stage; 3) these fish are opportunistic and most often infest more than one host species; 4) a single echinoderm very rarely hosts several Carapidae species at one time; and 5) these fish can communicate by emitting sounds.

Carapidea that are associated with echinoderms seem to be unaffected by their hosts' means of defence. In particular, those associated with sea cucumbers are not harmed by the Cuvierian tubules, defence organs consisting of several hundred tubules that attach to the base of the left respiratory tree. These tubules, which are expulsed when a specimen is disturbed, are sticky and toxic. Their toxins (also found in the epidermis of asteroids and sea cucumber) are saponins, strongly hemolytic triterpenoid derivatives. In the natural setting, these toxins mainly have a dissuasive effect on predators such as crabs and fish but they are lethal in aquariums. Carapidae are remarkable in that they do not become sticky when they come into contact with the Cuvierian tubules. In addition, preliminary observations have shown that when Carapidae are placed in aquariums with other fish and Cuvierian tubules, all the fish die within three minutes except for the Carapidae. In any event, Carapidae must have some remarkable adaptation in terms of their epidermis, mucus and gills as is the case with clownfish that are acclimated to their anemones. My work concentrates on these adaptations. In particular, it covers microscopic and biochemical characterisation of these three structures in those Carapidae, which are echinoderm symbionts. It is composed of three complementary sections (i.e. a physical-behavioural study, a microscopic analysis of the structures mentioned above and a biochemical analysis of the composition of their membrane mucus and sterols).

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