

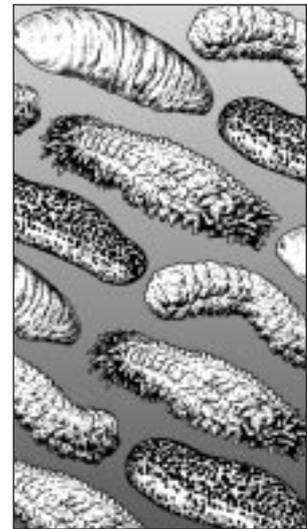


Secretariat of the Pacific Community

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Number 13 — July 2000

I N F O R M A T I O N B U L L E T I N



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Editorial

Dear Readers,

This is the 13th issue of the Bulletin. I would like to take this opportunity to thank all those who have contributed to it and ask that you take an active role in its improvement, as many of you have already indicated that the Bulletin is useful to you.

Is the current presentation by section, i.e. 1) New Information, 2) Correspondence, 3) Publications, satisfactory?:

- Which section should be given more space?
- In the 'New Information' section, would you have new information for the columns on 'In situ spawning observations' and 'Asexual reproduction through fission observations'? Are these columns suitable?
- The 'Aquaculture' column has been continued thanks to the collaboration of S. Battaglene from ICLARM. We regret the closure of the Coastal Aquaculture Centre (CAC) Solomon Islands.
- Are there any other new columns that you would like to see included?

Your suggestions and comments are both useful and necessary for the Bulletin's development, so please do not hesitate to share them with us.

This issue includes original articles on:

- problems related to maintaining broodstock for aquaculture on page 2;
- the Philippines, which is making its first appearance in our Bulletin – even though it is the top trepang producer worldwide – on page 10;

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and more. . .



- Kenya on page 12;
- traditional uses of sea cucumbers in the South Pacific, a subject for which not much research had been carried out previously, on page 18; and
- many other interesting topics.

Summaries of the papers and posters presented at the 10th International Echinoderm Conference, 31 January – 4 February 2000, University of Otago, Dunedin, New Zealand are presented on page 35.

Due to the length of this issue (52 pages), we could not include the New Members column. It will be included in the next issue. If you would like to receive this list, please contact the SPC Information Section (see contacts on cover page).

Previous issues of the Bulletin are now available on the SPC's website at:
www.spc.int/coastfish/News/bdm/bdm.htm

The "Echinoderms Newsletter" is also available on the Web at:

www.nmnh.si.edu/iz/echinoderm .

An echinoderms forum has also been created following the International Conference in Dunedin.

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Chantal Conand



new info
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Aspects of sea cucumber broodstock management (Echinodermata: Holothuroidea)

*Andrew David Morgan*¹

Abstract

Broodstock *Holothuria scabra* were obtained from Stradbroke Island, Moreton Bay (27°30' N, 153°24' E) in Queensland, Australia during the spawning season of November 1996 to February 1997 and October to November 1997. They were placed in a sand bottom, 12-tonne, indoor holding tank, equipped with a sand bio-filter and flow-through seawater. During the first post-spawning period, from March to May 1997, individuals did not recover from the loss in weight that occurred during the period in which they were used in spawn induction, despite the addition of a food supplement. From October to November 1997 the addition of various feed supplements reduced the amount of weight loss of *H. scabra*, which were kept in captivity at a constant temperature and light cycle. After five weeks, animals showed signs of infection, shedding copious amounts of mucoid material. The use of an appropriate diet and the affect of temperature and light conditioning regimes on the coupling of feeding behaviour and the reproductive cycle need to be ascertained.

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Introduction

Information explaining how the captive environment affects the coupling of reproductive synchronicity and the feeding behaviour of sea cucumbers is limited (James *et al.*, 1994; Ito, 1995; Yanagisawa, 1995; Ramofafia *et al.*, 1997; Battaglione & Bell, 1997). The feeding biology of sea cucumbers has been quantified *in situ* (Cameron & Fankboner, 1984; Weidemeyer, 1992; Ahlgren, 1998; Uthicke & Karez, 1999), and may indicate further appropriate conditions and diets to use in captivity. Species of kelp, *Eysenia bicyclis* and *Undaria pinnatifida*, have been ground into a paste and frozen or dried and placed in broodstock tanks, containing *Stichopus japonicus* (Masaki, pers. comm.; Ito, 1995; Yanagisawa, 1995), and consumed the following day. Battaglione and Bell (1997) stated that *Holothuria scabra* broodstock in India and Indonesia were fed soybean powder, rice bran, chicken manure, ground algae and prawn-head waste.

Yingst (1976) noted that in captivity, the sea cucumber *Parastichopus parvimensis* assimilated decomposed sterile crabmeat with a high efficiency whereas sterile plant material was of little or no nutritional value. The meat was removed from the crab and placed in a beaker inoculated with bacteria, which was then placed on a shaker table for 14 days to stimulate decomposition. McClintock *et al.* (1982) found that the urchins *Echinometra lucunter*, *Lytechinus variegatus* and *Eucidaris tribuloides* had an equal or greater preference for pulped or sodden *Donax variabilis*, a bivalve, over blades of the seagrass *Thalassia testudinum*, in the captive envi-

ronment. Food preference is difficult to ascertain in aspidochirote holothurians as they are detritus feeders and more likely to depend on the fungal and bacterial communities promoted by the decomposition of flora and fauna (Yingst, 1976; Moriarty, 1982; Moriarty *et al.*, 1985).

Sea cucumbers have been tagged *in situ* with limited success (Harriott, 1980; Shelley, 1981; Conand, 1989). A small t-bar tag is usually inserted through the body wall using a tagging gun. In these studies localised necrosis of the tissue occurred and in most cases the tag fell out within a few months. However, this method may be adequate for tagging broodstock in captivity over short periods of time.

At present, no study has determined how the regulation of exogenous cues and its effect on an endogenous rhythm influence feeding and reproduction of sea cucumbers in captivity. With little understanding of the interaction between feeding behaviour and reproductive state, broodstock have been collected late in gametogenesis or the vitellogenic period to avoid the problems associated with feeding and gametogenesis (James *et al.*, 1994; Ito, 1995; Battaglione, pers. comm.; Masaki, pers. comm.). Studies on captive sea cucumbers have addressed some of the preceding issues in part. Information on how the management of broodstock affects the sea cucumber *Holothuria scabra* is presented.

Materials and methods

Captive management

In October and November 1997, approximately 100 *H. scabra* were collected from Stradbroke Island, Moreton Bay (27°30' N, 153°24' E), and re-located to Bribie Island Aquaculture Research Centre (BIARC) using a 750-litre fish transporter aerated with oxygen. Individuals were placed into closed mesh cylinders (Figure 1). The bottom layer of mesh cylinders contained no animals and was used to keep the cylinders containing *H. scabra* off the bottom of the transporter. Animals were placed in a sand bottom, 12-tonne indoor holding tank, equipped with a sand bio-filter and flow-through seawater.

At the end of the 1996/97 summer spawning season (November to January), forty broodstock were separated into four areas by placing mesh screens in the holding tank. Animals in three areas were

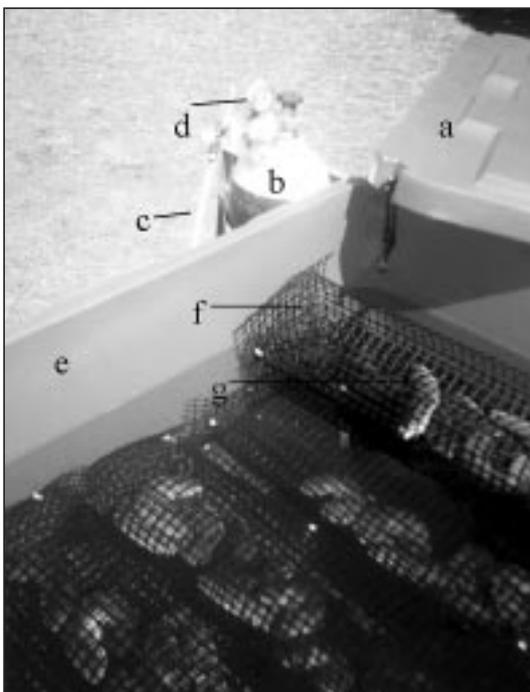


Figure 1.

Photograph of fish transporter (750-litre polycarbonate container) used to collect broodstock. a. Transporter lid; b. Oxygen cylinder; c. Air hose; d. Regulator; e. Fish transporter; f. Mesh screens; g. Broodstock of *Holothuria scabra*.

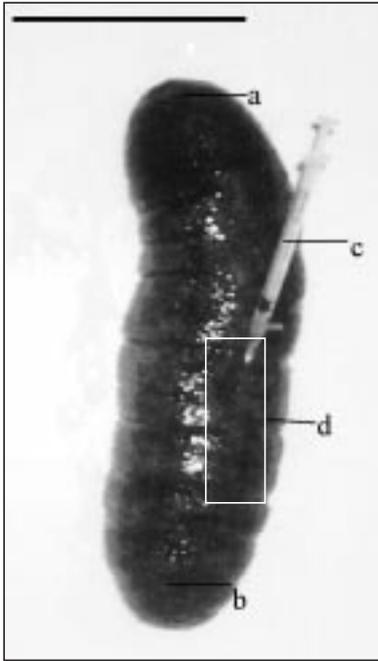


Figure 2.

Photograph of biopsy needle orientation during gonad sampling of *Holothuria scabra* (scale bar = 10 cm).
a. Posterior; b. Anterior; c. Syringe; d. Area of epidermis from which the biopsy was taken.

fed either prawn pellets, lucerne pellets (grass) or mixed lucerne and prawn pellets. Food was fed *ad libitum* to these three quadrats and the fourth quadrat was a control and contained no added food. The weights of individuals were recorded periodically to determine change in size over time.

During the 1997/98 summer, animals were placed in one of four divided areas in the holding tank (n = 18 animals per area), and conditioned using a 16:8 L:D cycle at a seawater temperature of 27°C. Animals in three areas were fed either a formulated powdered blue crab or abalone diet, available from Gulf Feeds South Australia, or a mixture of species of dried, powdered brown kelp (*Durvillaea potato-rum*, *Ecklonia radiata*, *Macrocystis angustifolia*, *Cystophora platylobium* and *Cystoseira trinodis*) obtained from Beachport Sea Products, South Australia. Animals in the remaining area acted as controls and their food was limited to naturally-occurring detrital matter contained in the sand. Before feeding, the incoming seawater was turned off and any current allowed to dissipate. Some transfer of material occurred in the water column through the mesh screens that separated each quadrat. Nutrient loading of the sediment was assessed visually. Too much food resulted in the growth of fungus on the substrate and the inability of the bio-filter to handle the excess loading.

Once the animals were obtained from the wild, individuals were removed from the tank and placed

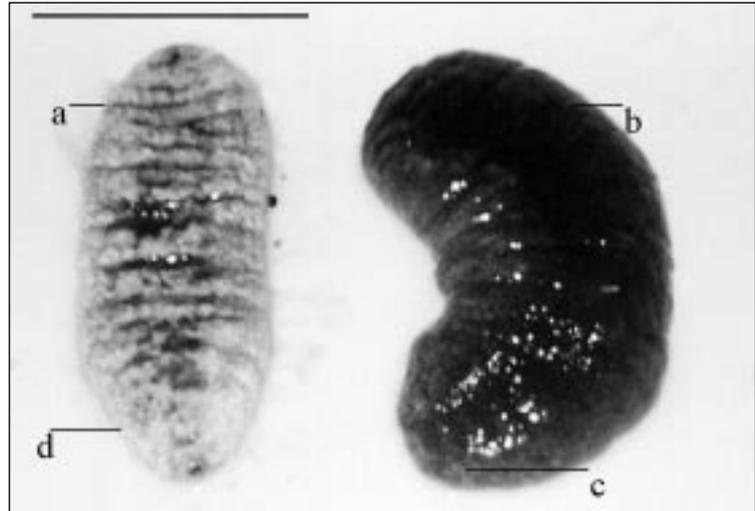


Figure 3.

Photograph of heavily infected sea cucumber contrasted with an individual at the early stages of infection (scale bar = 10 cm).

- a. Heavily infected sea cucumber;
- b. Sea cucumber with normal epidermal complexion;
- c. Lesions appearing on the epidermis;
- d. Loss of pigmentation.

in a tub containing 20 to 30 cm of seawater. They remained undisturbed for approximately 10 minutes and were tagged using a Dennison model 3030 tagging gun (Harriott, 1980), with a small t-bar tag (available from Hallprint South Australia). The tagging needle was inserted mid-dorsally, penetrating the body wall before the tag was fired from the gun. Tagged animals were replaced in the holding tank and animals losing tags were immediately re-tagged and their new tag number recorded.

One day later, a biopsy on animals was done to determine the sex of individuals. A portion of gonad was extracted using a hypodermic needle and syringe, inserted at an angle to the left of the mid-dorsal line approximately one third to half way down the body (Figure 2), and examined under a dissecting microscope. Penetration of the dermis with the needle at too steep an angle (> 45° from horizontal) resulted in the puncturing of visceral organs and caused evisceration.

Detection and treatment of infectious pathogens

During week five of captivity, broodstock obtained in October 1997 became infected, resulting in 95 per cent mortality within three to seven days. Four animals (two in late stage, two in early stage of infection) were sent to the Yeerongpilly Veterinary Laboratory for pathological examination (Figure 3).

The second group of *H. scabra* broodstock (obtained in November 1997) was transported to BIARC and weighed, tagged and biopsied after the holding tank at BIARC was chlorinated, rinsed with fresh tap water and the biofilter restarted. During weeks three and four of captivity the same infection was observed in this group. Holding and conditioning of broodstock was halted and the remaining healthy animals were separated and placed in another tank through which clean seawater flowed at > 20 L/min. The remaining animals continued to show signs of infection but the infection progressed at a slower rate.

Results

Prawn and lucerne pellets placed in the broodstock tank to enrich the substrate and provide a food source after the 1996/97 spawning season did not halt the weight loss of *Holothuria scabra* that occurred during the spawning season. During May 1997 the epidermis in some animals in all treatments started to split open but no pathogenic infection was observed. During the 1997/98 summer spawning season the decline in the weight of *H. scabra* for all four diets containing either kelp, no food, blue crab and abalone was reduced (n = 18; Figure 4). Approximately 10 per cent weight loss

occurred in the first week of captivity while a net weight gain was observed in the second week of captivity. The mean weight of *H. scabra* continued to decline in the kelp, control and abalone diets for weeks three and four. Weight loss after four weeks, was least in the blue crab diet, where it fluctuated between 5 to 10 per cent. During week five, a marked weight loss was observed in all diets at a time corresponding with a visible sign of infection with a pathogen that killed most animals within three to seven days (Figure 4).

After two weeks of captivity, tag-loss was five per cent, increasing to eight per cent after a further two weeks. At five weeks of captivity the cumulative percentage tag-loss of *H. scabra* was 10 per cent.

Diagnosis of infectious pathogens

The infection that occurred in broodstock during the 1997/98 summer was first observed around the mouth and/or anus of an animal and then spread laterally before encompassing the whole animal in the worst cases. At the collection site, 10 per cent of animals had similar lesions. Surface damage to the epidermis of *H. scabra* was not a prerequisite for infection, but infection progressed more rapidly from an existing wound. Infection of animals in the

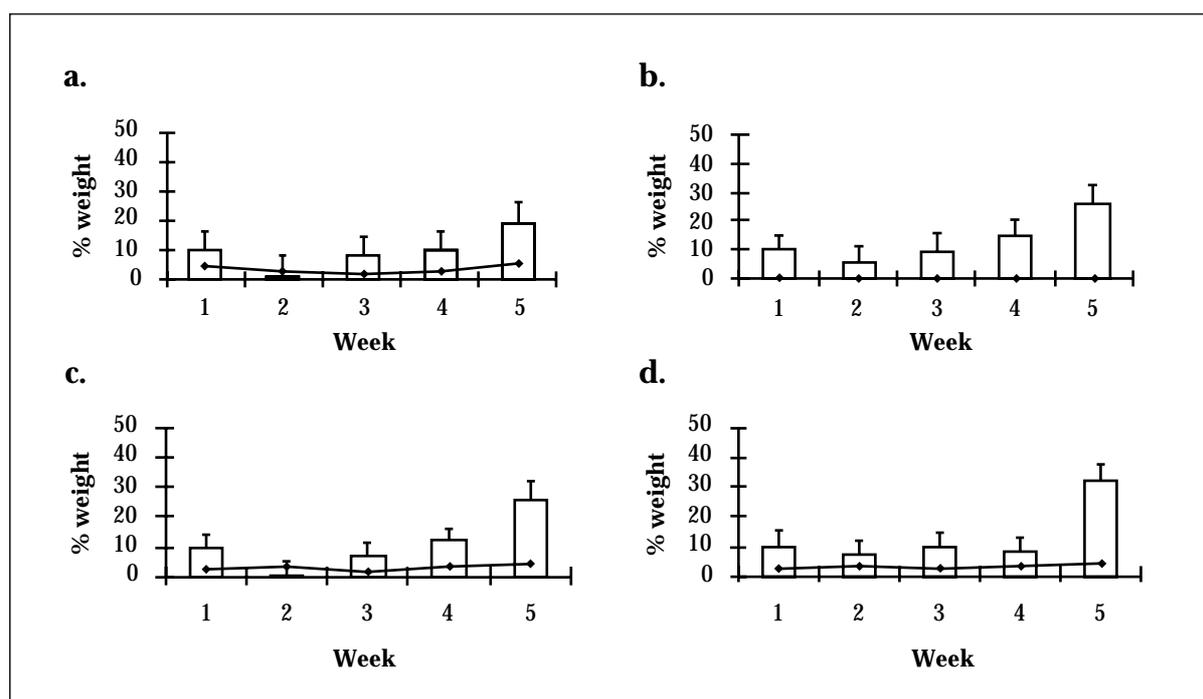


Figure 4.

Percentage weight gain or loss, based on a proportion of total weight (g), of *Holothuria scabra* broodstock in each area containing a diet of either kelp, no food, abalone or blue crab formulated feed (n = 18 tagged individuals per treatment). a. Kelp diet; b. Control; c. Abalone diet; d. Blue crab diet (line represents amount of feed as a proportion of biomass fed to animals).

holding tank occurred in all treatments and was slow to start (five to seven days), but spread to the remaining sea cucumbers rapidly (three days).

The pathology report from the Queensland Department of Primary Industries (QDPI) Yeerongpilly Veterinary Laboratory indicated that the two animals with the most overt signs of infection exhibited a loss of epidermal pigmentation associated with the presence of copious amounts of viscous mucus. Minimal mucus production and discolouration of the epidermis was seen in apparently healthy animals. There was no obvious pathological condition present in the viscera of the four animals. Wet mounts of skin scrapes taken from the four animals differed only in that copious filamentous mucoid material was present in the scrapes from the two 'sick' sea cucumbers.

Giemsa-stained sections of skin scrapes were examined in all four sea cucumbers. Slides from the two apparently healthy animals contained moderate numbers of mixed populations of bacteria. Slides from the two sick animals contained fine, stringy, mucoid material plus moderate numbers of bacteria in which one population appeared to predominate. *Vibrio harveyi* was the predominant bacterium on skin mucus samples from sick animals. There were also low numbers of a motile gram-negative rod bacterium that were probably not significant. No diagnosis was possible from existing results.

Discussion

Management during the spawning season

Weight loss during the 1997/98 summer may have been due to the captive environment, and/or inadequate nutrition. Masaki (pers. comm.) found that broodstock of the Japanese sea cucumber *Stichopus japonicus* did not retain weight and initiate gametogenesis outside of the spawning season. Active feeding by captive animals during the reproductive season may not compensate entirely for the diversion of resources to reproduction. Animals from the control containing no diet supplement, for the 1997/98 period of captivity, exhibited a similar degree of weight loss over one month (approximately 20 per cent). Animals in the areas containing the kelp, abalone and blue crab diets, during the 1997/98 summer, did not lose as much weight.

The regulation of temperature and photoperiod during the 1997/98 summer may have affected the feeding behaviour of *H. scabra*. Ito (1995) and Masaki (pers. comm.) collected *Stichopus japonicus* several months prior to spawning, during gametogenesis. The animals were maintained on a long light cycle at a lower than normal ambient summer

seawater temperature and fed quantities of dried algae, which was consumed by the following morning. Temperature regimes may influence the feeding behaviour and metabolic activity of *H. scabra* in captivity. The use of temperature and light regimes to promote gametogenesis and vitellogenesis may come at a cost to feeding and other metabolic processes.

Post-spawning recovery

Despite the addition of feed supplement appropriate to promote bacterial and fungal growth in the substrate after the 1996/97 summer spawning season, re-absorption of the epidermis still occurred, indicating that the experimental animals were unable to utilise the nutrient resources available. Once a critical low weight was exceeded, *Holothuria scabra* may not have been able to recover successfully. Perhaps only large animals should be collected from the natural environment to avoid problems associated with starvation and re-absorption of the epidermis over extended periods in captivity.

Continuous feeding by *H. scabra* may be needed to optimise ingestion and digestive processes (Hammond, 1982; Penny & Jumars, 1987) and mobility may depend on food availability and the energy required to search for it (Cameron & Fankboner, 1985). Penny and Jumars (1987) stated that the gut of sea cucumbers was like a continuous flow, stirred tank reactor while Hammond (1982) indicated that continuous feeding by the sea cucumber *Stichopus chloronotus* may be needed to assist peristalsis because gut muscles were weak. Mobility in the urchin *Lytechinus variegatus* and the sea cucumber *Parastichopus californicus* was shown to be dependant on food availability and the energy required to search for it (Cameron & Fankboner, 1985). The lack of food during the 1996/97 spawning season may have reduced the capacity, over time, of *H. scabra* to move. Cameron and Fankboner (1985) reported that after *P. californicus* had been transferred to aquaria lacking detritus, they ceased all locomotor and feeding activity. The same occurred for *H. scabra* in the present study after approximately three months in captivity, post-spawning, during the 1996/97 summer.

It may be necessary to manipulate temperature and photoperiod to ensure that broodstock are not affected adversely in the period of post-spawning by the disturbance of interactive feeding and reproductive rhythms. The time in which animals can be kept in captivity without seriously affecting metabolic processes may be limited if food is not provided. When extending the spawning season artificially, it may be important to minimise body wall weight loss and the effect of temperature and

photoperiod regimes on conditioning for spawning and subsequent post-spawning recovery.

The distribution of food in the holding tank, boundary effects and photoperiod and temperature regimes may have influenced the activity patterns and feeding behaviour of *Holothuria scabra*. The effect of fine scale regulation of environmental parameters in captivity on feeding behaviour and egg production, in combination with species-specific feeding processes, is likely to be important in obtaining successful spawning. Further, the type of diet may not be as critical as the bacterial and fungal communities the diet sustains.

Handling

Collection and tagging

The ability to recognise individuals was essential for interpretation of spawning behaviour (Morgan, 1999). A red-heat wire was used successfully in Japan to brand the sea cucumber *Stichopus japonicus* (Yanagisawa, 1995) eliminating dermal puncture of the animals as occurs when t-bar tags are used. In the present study, tag-loss (10 % of animals after five weeks of captivity) was preceded by necrosis of the tissue surrounding the tag, resulting in the tag being expelled or taken into the coelomic cavity. Loss of tags can be controlled to some extent by ensuring that the t-bar is pushed right through the dermis and that the puncture wound is as small and clean as possible.

Previous researchers have used fluorescent dye to stain the calcareous plates surrounding the buccal cavity of sea cucumbers (Harriott, 1980) with limited success. Successful staining depended on the relative timing of injection of the dye and deposition of calcium for growth of the mouthparts. The hypodermic extraction of gonadal material also involved handling, which may have had deleterious effects. Extraction of gonadal material from *H. scabra* in the present study was useful in determining the sex of sea cucumber broodstock. Once this technique had been refined, no animals eviscerated the gonad, stomach and respiratory trees because of puncture of the viscera with the biopsy needle.

Infectious pathogens

The unidentified infection that spread through broodstock during collection from Stradbroke Island in the 1997/98 summer did not occur during the 1996/97 summer. Lesions were not observed on animals collected during the 1996/97 summer nor were they observed on individuals obtained from the north end of Moreton Bay during the 1995/96 summer.

Removing animals from the holding tank as soon as symptoms were noticed prevented the spread of infection. Animals were then placed in a tub with a high rate of flow-through seawater where lesions stopped secreting mucus and eventually closed, leaving scar tissue. The predominance of one type of bacterial community on heavily infected animals warrants further investigation as to the effects of pathogens on bacteria inhabiting the epidermis of *H. scabra*. Investigation of this relationship between host and bacteria may assist in identification of the pathogen affecting broodstock in the present study.

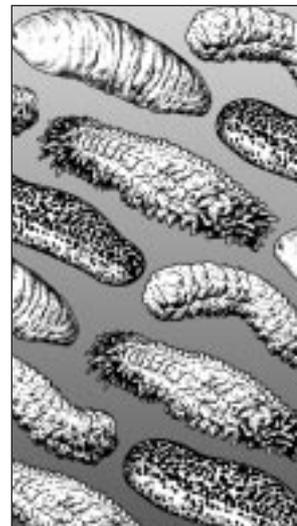
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Athyonidium chilensis

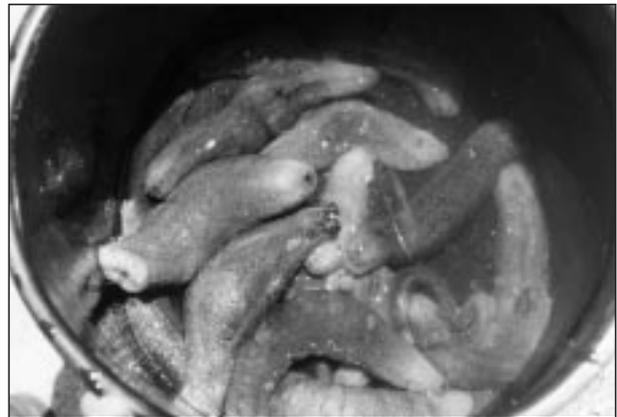
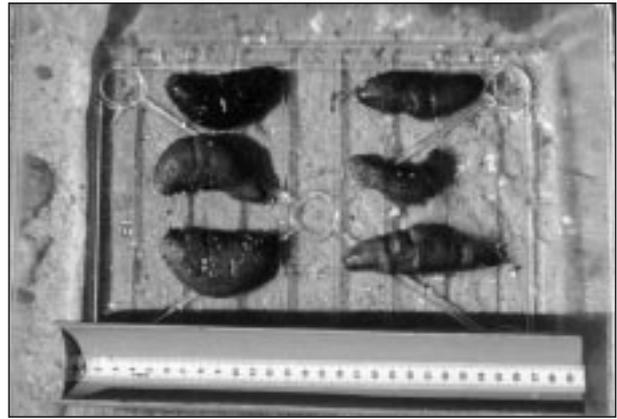
Carlos Ravest Presa¹

Athyonidium chilensis (Dendrochirotida; Cucumariidae) (Figures 1 and 2) is distributed between Ancón, in Peru, and Punta Gaviota, in Chile (11°45'S and 42°03'S, respectively).

A. chilensis has been collected in the exposed intertidal area between rocky pools, and from the sand where it extends its tentacles over the surface of the bottom. High biomass has also been found in the sandy subtidal area, though this could be related to reproductive migration because only large individuals were found. *A. chilensis* is a non-selective filter-feeder and its action is of great importance due to the predation of larvae, shepherding of algae, filtering of plankton and the recycling of organic particles. A length/weight relationship of *A. chilensis* is given in Figure 3.

In Chile, this resource has scarcely been studied or exploited. There is some information regarding a toxin observed in *A. chilensis* that inhibits the settlement of other animals near it, although it could also be utilised as an alert signal because the other animals immediately retract their tentacles in its presence. Its reproductive cycle has also been studied, specifically in relationship with the annual cycle of its gonadic index.

Other studies regarding ecological and larval aspects have been carried out, but this information is unavailable. It seems that this species of holothurid has a low commercial value, even though the interest in monospecific fisheries in cold waters has increased steadily. Nevertheless, its aquaculture potential is interesting due to the fact that it could be the source of a natural product, or, in great abundance, could be used as a biological filter of organic particles in the discharges from fish farms.



Figures 1 & 2. *Athyonidium chilensis*

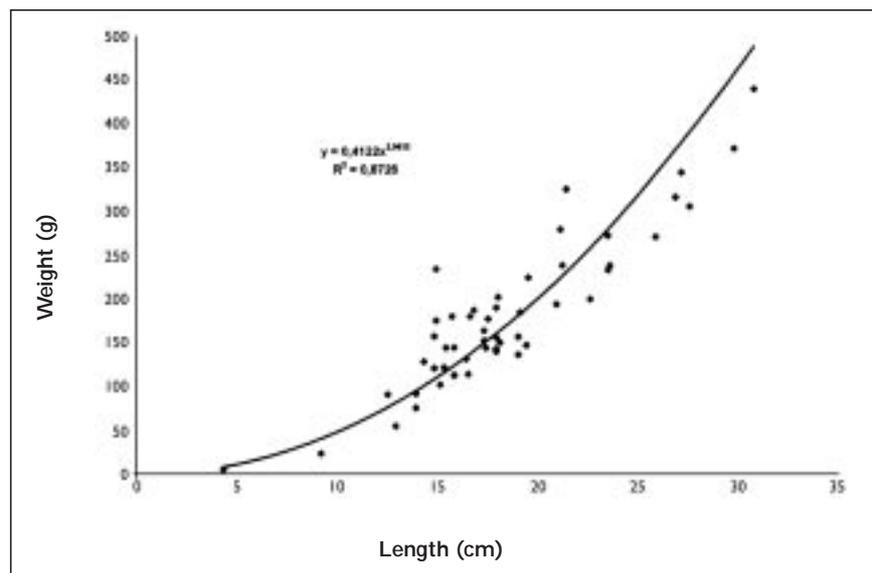


Figure 3. *Athyonidium chilensis* length/weight relationship

Sea cucumber fishery in the Philippines

Sabine Schoppe¹

For almost a century, the harvesting and processing of sea cucumbers into trepang has been a source of income for many Philippine families. Exports, however, increased tremendously in recent years, from 250 t in 1977, and 1189 t in 1984 (1977–1984 statistics from the Bureau of Fisheries and Aquatic Resources, Philippines) to 2123 t in 1996 (FAO, 1996). The Philippines is now the second major producer and exporter of dried sea cucumber in the world (Conand & Byrne, 1993; Conand, in press). Despite its importance in the world market, no comprehensive study about the bêche-de-mer exploitation in the Philippines has been conducted. The increasing depletion of sea cucumber stocks is obvious and has only been sporadically documented (Trinidad-Roa, 1987; Schoppe *et al.*, 1998; Schoppe, in press). In the mean time, sea cucumber sizes have become smaller and collections must be conducted in deeper waters.

A preliminary study on the sea cucumber fishery in Palawan from October 1999 to March 2000 revealed that of the 100 Philippine sea cucumber species, about 25 are regularly collected and processed (Table 1). Traders differentiate between 23 different species (local names) of dried sea cucumbers. Among local fisherfolk, greater variety of local names exists, due to several facts: (1) species characteristics are clearer in live specimens, (2) sometimes colour varieties of a species are assigned a separate name, and (3) the diversity of local dialects. However, the total number of collected species probably does not exceed thirty, including those that are used fresh and for local consumption only. The species most frequently collected and processed for export are *Holothuria scabra*, *Bohadschia marmorata*, *Actinopyga lecanora*, *Holothuria fuscocinera*, *Holothuria* sp. (**Patula**), *Holothuria atra*, and *Stichopus hermanni*. The highest prices (per kilogram of dry weight) are achieved with large specimens of *Actinopyga lecanora*, *Holothuria nobilis*, *H. whitmaei*, *H. scabra* and *Stichopus* spp. (Table 1). The lowest-priced species include *H. coluber*, *H. fuscocinera*, and *Pearsonothuria graeffei* (Table 1).

The sea cucumber fishery in Palawan is a year-round activity with a peak season from March to June. Holothurians are collected during low tide, mainly during the night. They are collected by

hand while walking along the intertidal zone with a lamp. It is mainly the women who are involved in the collecting of sea cucumbers from shallow areas, while the men skin dive or use an air-compressor connected to a breathing hose to reach deeper areas.

Sea cucumber processing involves four major steps: cleaning, cooking, smoke drying and sun drying. The duration of each process depends on the species and the size of the specimens. Processing has been sufficiently described in Trinidad-Roa (1987), Espejo-Hermes (1998), and Schoppe (in press).

After processing, the dried products are either sold to middlemen or directly to one of the four sea cucumber traders in Palawan. Prices received are up to 25 per cent higher if sold directly to the trader than selling to a middleman. Dried products are sold about 8.5 times per month during peak season. During this time, an average of 1.72 kg of dried sea cucumbers are sold per fisherfolk. This is equivalent to US\$ 13.93 (PHP 557.33) and amounts to a gross monthly income of US\$ 118.43 (PHP 4,737.31) during peak season. Between March and June, the sea cucumber fishery is supplemented through fishing, which is the main source of income during the rest of the year.

The processed sea cucumber (trepang) is shipped to Manila where exporters sell it to China, Hong Kong and Singapore. Prices have increased over the years; however, stocks are decreasing according to some fisherfolk. Local traders have not noticed a decline, probably because more and more fisherfolk have become engaged in the sea cucumber fishery due to its profitable nature.

Much more information on the sea cucumber fishery in the Philippines is needed to analyse the nation-wide situation. After Alcala & Alcazar (1984) and Trinidad-Roa (1987), nothing more has been published about the sea cucumber fishery in the Philippines. In the last decade, the results of only one other related study were published (Schoppe *et al.*, 1998). In that report, the importance of molluscs, sea cucumbers and other reef organisms as sources of income for the fisherfolk of the Cuatro

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Table 1. Regularly collected sea cucumber species from Palawan, Philippines. Prices achieved from traders in Puerto Princesa are given in Philippine pesos and in US dollars. Exchange rate: US\$ 1.00 = PHP 40.00 as of Feb. 2000.

No	Scientific name	Local name (Tagalog)	Price / kg (PHP)	Price / kg (US\$)
1	<i>Actinopyga echinites</i>	Brown beauty	180.00	4.50
2	<i>A. lecanora</i>	Buli-buli / Monang / Munang	Extra small: 350.00 Small: 430.00 Medium: 650.00 Large: 840.00	8.75 10.75 16.25 21.00
3	<i>A. mauritiana</i> c.f.	Bakungan	Small: 200.00 Large: 600.00	5.00 15.00
4	<i>Actinopyga</i> spp. (<i>A. obesa</i> , or <i>A. miliaris</i>)	Khaki	Extra small: 150.00 Small: 200.00 Medium: 350.00 Large: 400.00	3.75 5.00 8.75 10.00
5	<i>Bohadschia argus</i>	Leopard / Matang Itik	300.00	7.50
6	<i>B. marmorata</i>	Lawayan, Pulutan	Extra small: 100.00 Small: 170.00 Medium: 260.00 Large: ?	2.50 4.25 6.50 ?
7	<i>H. (A.) coluber</i>	Patola white / Tambor	20.00	0.50
8	<i>H. (C.) rigida</i> , <i>H. (C.) inhabilis</i>	Batunan	Fresh for local consumption	N/A.
9	<i>H. (H.) atra</i>	Black beauty	Small: 70.00 Medium: 100.00 Large: 200.00	1.75 2.50 5.00
10	<i>H. (H.) edulis</i>	Red Beauty	Small, medium: 150.00 Large: 200.00	3.75 5.00
11	<i>H. (H.) pulla</i> c.f.	Patola red	200.00	5.00
12	<i>H. (M.) fuscopunctata</i>	Sapatos	120.00	3.00
13	<i>H. (M.) nobilis</i> , <i>H. (M.) whitmaei</i>	Susuhan, Susan, Susuan	Medium: 700.00 Large: 1000.00	17.50 25.00
14	<i>H. (M.) scabra</i>	Cortido / Curtido / Putian	Extra small: 360.00 Small: 460.00 Medium: 700.00 Large: 900.00 Extra large: 1000.00	9.00 11.50 17.50 22.50 25.00
15	<i>H. scabra</i> var. <i>versicolor</i>	Curtido Bato	20.00	0.50
16	<i>H. (S.) fuscocinera</i>	Labuyo / Lubuyo	55.00	1.38
17	<i>Holothuria</i> sp.	White Beauty	200.00	5.00
18	<i>Holothuria</i> sp., <i>H. (M.) leucospilota</i> c.f.	Patola	190.00	4.75
19	<i>Holothuria</i> spp. (<i>Holothuria</i> black colour)	Patola black	Small: 70.00 Medium: 100.00 Large: 200.00	1.75 2.50 5.00
20	<i>Pearsonothuria graeffei</i>	Piña (Hanginan Mani Mani?)	70.00	1.75
21	<i>Stichopus chloronotus</i>	Cuatro Cantos, Hanginan black	850.00	21.25
22	<i>S. hermanni</i>	Hanginan	Extra small: 200.00 Small: 300.00 Medium: 450.00 Large: 850.00	5.00 7.50 11.25 21.25
23	<i>S. horrens</i>	Hanginan	Extra small: 200.00 Small: 300.00 Medium: 450.00 Large: 850.00	5.00 7.50 11.25 21.25
24	<i>Thelenotia ananas</i>	Talipan / Taripan	500.00	12.50
25	<i>T. anax</i> , <i>T. rubralineata</i>	Legs	170.00	4.25
26	?	Hodhod	500.00	12.50

Islands, an island group off Leyte, Philippines was discussed. Sea cucumber processing in the Philippines is treated as a minor chapter in Espejo-Hermes (1998) and Schoppe (in press).

This paper follows up initial efforts of the Philippine Council for Aquatic and Marine Research and Development, which encouraged the implementation of a management scheme for the sea cucumber fishery in the Philippines (PCAMRD, 1991). It is an appeal for further studies on stock assessment and catch statistics of sea cucumbers in the Philippines. The author started a long-term study on the sea cucumber fishery in Palawan in order to determine the current situation and to suggest management schemes appropriate for the local setting.

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Conservation of aspidochirotid holothurians in the littoral waters of Kenya

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Abstract

Aspidochirotid sea cucumbers (Echinodermata: Holothuroidea) are heavily fished in the littoral waters of Kenya, and stocks have plummeted. In order to conserve and manage these natural resources, appropriate conservation and management plans must to be developed. This can only occur if high quality research on different levels is done. This paper discusses five layers of understanding that should be achieved before holothurian conservation in East Africa can be effective.

Introduction

Along the Kenyan coast most aspidochirotid sea cucumbers are collected *en masse* and sold to foreign markets (sea cucumbers are not part of the Kenyan diet). Ferdouse (1999) reported on beche-

de-mer imports in Hong Kong and Singapore, the two main retailing centres. According to this source, Kenya exports only to Singapore, albeit in increasing levels (1.1 % of the total import in 1993; 2.9% in 1994; and 3.9 % in 1995). From the same data set it is clear that the Kenyan export is rising

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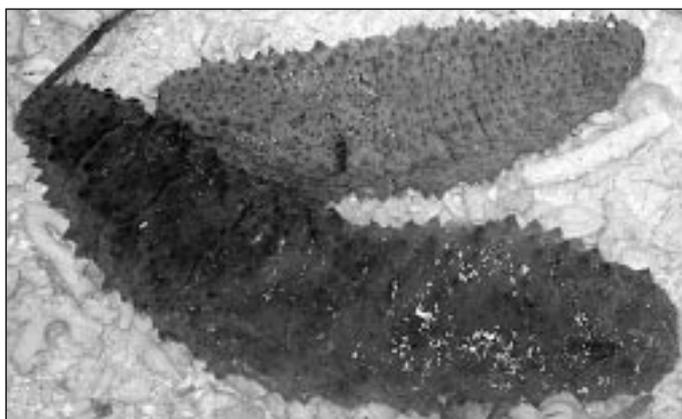
while other East African countries like Madagascar and Tanzania are decreasing their exports. Reasons for this decrease are basically unknown but are probably caused by overfishing, which has decreased the stocks dramatically (Massin, pers. comm.; pers. observ.). It appears that there is a shift from the collection sites of Madagascar and Tanzania to mainly Kenya. However, in Kenya collecting is taking place in a rather unbridled way since: (a) no regulations whatsoever exist for collecting sea cucumbers outside the protected marine parks, and (b) the immediate financial benefits for the collector and trader are considerable.

It is clear that if a sustainable exploitation of the large sea cucumber market is desired, good conservation and management plans will need to be made. Only then will it be possible to conserve and replenish Kenya's plummeting stocks (e.g. in Gazi Bay, some 60 km south of Mombasa all holothurians have disappeared since fishing started in 1995, pers. observ.).

This paper discusses some of the basic levels of scientific understanding that are essential in the fine tuning of conservation efforts for marine biota (and especially of sea cucumbers in the western Indian Ocean).

Level one: Nomenclature & taxonomy

In conserving biodiversity, the first step is to know what to conserve. For that, we need to correctly identify the species in an unequivocal and universally understood way. However, nomenclature and taxonomy are scientific disciplines that are often neglected by a large number of biologists, since these disciplines are often seen as a burden rather than a facility. The necessity for respecting the rules of nomenclature, whose aim is 'to provide the maximum universality and continuity in the scientific names of animals compatible with the freedom of scientists to classify according to taxonomic judgments', can be illustrated with the following exam-



ple of a commercially important species from the family Stichopodidae.

The large species, bright-olive green with numerous conical light green papillae with dark green stripes and yellow to orange distal tips, bears the name *Stichopus variegatus* Semper, 1868 in a large part of the literature before 1995. *S. variegatus* is, however, not a valid name since Rowe & Gates (1995) stated that *S. horrens* Selenka, 1867 is the senior synonym of *S. variegatus* Semper, 1868. The same authors elevated the variety *S. variegatus hermanni* Semper, 1868 to the species level. When mapping holothurian biodiversity, based on species accounts in literature, all records regarding *S. variegatus* (and *S. horrens*) must be regarded as doubtful and cannot be assigned to one or the other species unless one is able to examine the specimens per se.

Level two: Systematics

Systematics is the discipline that describes and interprets the patterns that are produced by taxonomy. Systematics aims at understanding the relationships between lineages, the evolutionary trajectories, and the biogeographic distributions of organisms. This knowledge is crucial for understanding, for example, the ecological role of a species within an ecosystem.

The following two examples show that a profound knowledge of systematics and the existing literature is also necessary in naming, ordering and understanding biodiversity.

The species *Stichopus variegatus* Semper, 1868 is known to be an invalid species (see above). The specimens collected as *S. variegatus* before 1995 are known to belong to at least two different species (Massin, 1999; pers. comm.): *Stichopus hermanni* Semper, 1868 and *Stichopus monotuberculatus* (Quoy & Gaimard, 1833). The reef-dwelling species *Pearsonothuria graeffei* (Semper, 1868) was originally described as *Holothuria graeffei* Semper, 1868. Examination of spicule morphology showed that this species is unrelated to the species in the genus *Holothuria*. Hence, it was transferred to the genus *Bohadschia* since the rosettes of the body wall bear some resemblance to the rosettes found in the genus *Bohadschia*. The taxonomic status of *Bohadschia graeffei* (Semper, 1868) was critically examined later by Levin *et al.* (1984),

Figure 1.

Stichopus hermanni Semper, 1868 can be seen in the shallow reef lagoons of Kanamai, Kenya.

who found that the nature of the chemical characters of this species needed a new genus name: *Pearsonothuria* Levin, Kalinin & Stonik, 1984. Indeed, by assigning the genus name of *Pearsonothuria*, the anomalous structure of the typical ‘racket-shaped’ spicules, and the translucent and weakly developed calcareous ring, now get a more appropriate systematic position. However, the name *Bohadschia graeffei* still appears in numerous papers that deal with conservation of holothurians.

The consequence of such different classifications can easily be grasped if one considers the following hypothetical example. Suppose you were given a grant to study the inductive potential of diatoms on the metamorphosis of a sea cucumber that thrives in your study area: a species identified by specialists as *Bohadschia graeffei*. From the literature you know that all the species studied thus far within your study area hold a sensitivity towards induction by diatoms. If you are unaware that *Bohadschia graeffei* and *Pearsonothuria graeffei* are synonymous, you might deduce the following:

- That each individual genus (and species) has a well-defined niche and that, as a consequence, larval metamorphosis will hardly be induced by the same diatom genera. In which case you would look for different diatoms, but end up wasting precious time and many thousands of dollars, and with a failed project.
- That, because *Bohadschia* and *Pearsonothuria* belong to the same family, susceptibility to diatoms

as a means of inducing metamorphosis is a monophyletic character at the family level. It is quite possible, however, that you would make erroneous conclusions about phylogeny.

Incorrect taxonomy and systematics can bring erroneous conclusions at the fundamental and applied level. Unfortunately, more grants are given to applied research than to fundamental. The result is taxonomic and systematical errors are often perpetuated over time.

Level three: *Faunistics*

Assessing holothurian biodiversity of a narrow geographical entity like the Kenyan Coast is not a simple endeavour because only few studies have recently been devoted to this region (Levin, 1979; Humphreys; 1981; Rowe & Richmond, 1997). Our team, in collaboration with the Kenya Wildlife Service and WWF Kenya, is currently re-evaluating the biodiversity of the Kenyan holothurian fauna. Our first results from the Kiunga Marine National Reserve (Samyn & Van den Berghe, submitted), the largest marine reserve in Kenya (250 km²), show that the biodiversity of the aspidochirotid sea cucumbers in Kenya is currently underestimated (see Figure 2).

In the Kiunga Marine National Reserve we observed 24 different aspidochirotid holothurians, and deduced from literature that two more species were to be found within the boundaries of the Reserve. Our published (Massin *et al.*,

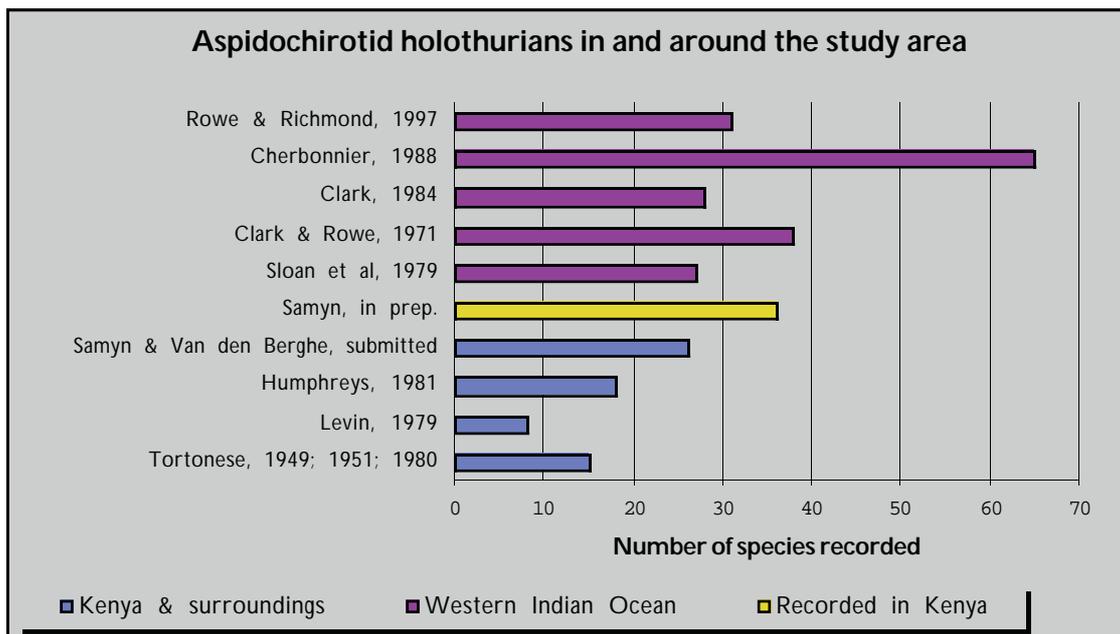


Figure 2 . Biodiversity of aspidochirotid sea cucumbers in and around Kenya as deduced from literature and sampling.

1999) and unpublished data on the entire Kenyan coastline adds at least seven more species to that list, and a search through the literature indicates that three additional species can be added, bringing the total aspidochirotid fauna to 36 species (Table 1).

When the holothurian fauna of the western Indian Ocean is examined, some 40 additional aspidochirotids have to be considered (see Cherbonnier, 1988). Whether these species also occur in the littoral waters of Kenya can only be known if further systematical sampling is done in the region.

Table 1 . Aspidochirotid sea cucumbers from Kenya, as deduced from literature and sampling.
x indicates records from the Kiunga Marine National Reserve (Samyn & Van den Berghe, submitted);
xx indicates unpublished records from Kenya.

Current species name	Kenyan records by our team	Kenyan records by others	Known geographical distribution
HOLOTHURIIDAE			
1 <i>Actinopyga echinites</i> (Jaeger, 1833)	x	x	Indo-West Pacific
2 <i>Actinopyga lecanora</i> (Jaeger, 1833)	xx	x	Indo-West Pacific
3 <i>Actinopyga mauritiana</i> (Quoy & Gaimard, 1833)	x	x	Red Sea; Indo-West Pacific
4 <i>Actinopyga miliaris</i> (Quoy & Gaimard, 1833)	x	x	Red Sea; Indo-West Pacific
5 <i>Actinopyga plebeja</i> (Selenka, 1867)		x	Red Sea; Mombasa; Zanzibar; Querimba; Madagascar; Mauritius
6 <i>Bohadschia atra</i> Massin <i>et al.</i> , 1999	x		Western Indian Ocean
7 <i>Bohadschia cousteaui</i> Cherbonnier, 1954	xx		Red Sea, Madagascar
8 <i>Bohadschia marmorata</i> Jaeger, 1833	x	x	Red Sea; Indo-Pacific
9 <i>Bohadschia similis</i> (Semper, 1868)	xx	x	Mauritius, Réunion, Philippines, New Caledonia, Tahiti
10 <i>Bohadschia subrubra</i> (Quoy & Gaimard, 1833)	x	x	Western Indian Ocean
11 <i>Holothuria (Acanthothrapeza) pyxis</i> Selenka, 1867		x	Mombasa, Bay of Bengal; east Indies
12 <i>Holothuria (Cystipus) rigida</i> (Selenka, 1867)	x		Red Sea; Indo-West Pacific
13 <i>Holothuria (Halodeima) atra</i> Jaeger, 1833	x	x	Red Sea; Indo-Pacific
14 <i>Holothuria (Halodeima) edulis</i> Lesson, 1830	x		Red Sea; Indo-Pacific
15 <i>Holothuria (Lessonothuria) pardalis</i> Selenka, 1867	x	x	Red Sea; Indo-Pacific
16 <i>Holothuria (Mertensiothuria) fuscocinerea</i> Jaeger, 1833	x	x	Red Sea; Indo-West Pacific
17 <i>Holothuria (Mertensiothuria) leucospilota</i> Brandt, 1835	x	x	Red Sea; Indo-Pacific
18 <i>Holothuria (Mertensiothuria) pervicax</i> Selenka, 1867	xx	x	Red Sea; Indo-Pacific
19 <i>Holothuria (Metriatyla) scabra</i> Jaeger, 1833	x	x	Red Sea; Indo-West Pacific
20 <i>Holothuria (Microthele) fuscopunctata</i> Jaeger, 1833	xx		Indo-West Pacific
21 <i>Holothuria (Microthele) nobilis</i> (Selenka, 1867)	x	x	Red Sea; Indo-Pacific
22 <i>Holothuria (Platyperona) difficilis</i> Semper, 1868	x		Red Sea, Indo-Pacific
23 <i>Holothuria (Selenkothuria) parva</i> Lampert, 1885		x	Red Sea, Indian Ocean
24 <i>Holothuria (Semperothuria) cinerascens</i> (Brandt, 1835)	x	x	Red Sea; Indo-Pacific
25 <i>Holothuria (Theelothuria) turriscelsa</i> Cherbonnier, 1980	x		Indo-West Pacific
26 <i>Holothuria (Thymiosycia) arenicola</i> Semper, 1868	x		Red Sea; Indo-West Pacific
27 <i>Holothuria (Thymiosycia) hilla</i> Lesson, 1830	x	x	Red Sea; Indo-West Pacific
28 <i>Holothuria (Thymiosycia) impatiens</i> (Forsk., 1775)	x	x	Mediterranean Sea; Red Sea; Indo-Pacific
29 <i>Labidodemas pertinax</i> (Ludwig, 1875)	x		Kenya, Glorioso Isl; Maldives; Java; Samoa
30 <i>Labidodemas semperianum</i> (Selenka, 1867)		x	Red Sea; Indo-West Pacific
31 <i>Pearsonothuria graeffei</i> (Semper, 1868)	xx		Red Sea; Indo-West Pacific
STICHOPODIDAE			
32 <i>Stichopus chloronotus</i> Brandt, 1835	x		Indo-West Pacific
33 <i>Stichopus hermanni</i> Semper, 1868	x	x	Red Sea; Indo-West Pacific
34 <i>Stichopus monotuberculatus</i> (Quoy & Gaimard, 1833)	x	x	Red Sea; Indo-West Pacific
35 <i>Thelenota ananas</i> (Jaeger, 1833)	xx	x	Indo-West Pacific
36 <i>Thelenota anax</i> H.L. Clark, 1921	xx		Indo-West Pacific

Level four: *Ecology*

Protecting and managing the holothurian fauna of Kenya is not a simple endeavour, as conservation measures cannot be limited to one group of interest alone. The interconnectivity in ecosystems forces us to study not only in an 'autoecological' way but also in a 'synecological' way. Indeed, both theoretical and experimental studies have shown that the stability of an ecosystem is influenced directly by the interactions between the various players. In coral reefs, echinoderms are unmistakably important actors (reviewed by Birkeland, 1988); however, a lack of knowledge of the species (see the three levels above) and on the interactions between the other actors in the ecosystem, hinders in-depth understanding of the ecological roles of sea cucumbers in coral reefs. As a consequence, the impact of overfishing sea cucumbers from coral reefs is largely unknown.

Despite the large gaps in our knowledge of holothurians, we are not starting from nil; the biology and ecology of tropical holothurians were already reviewed by Bakus in 1973. Since then, the ecology of several species is better known, although the need for further studies can be demonstrated with examples on the feeding biology of holothurians.

It is assumed that the ecological distribution of sea cucumbers on coral reefs is largely dependent on microhabitat structure rather than on the type of food selected. Still, the literature indicates that aspidochirotid sea cucumbers are selective for organic matter content in the sediment. The impact herewith on the environment appears to be temporarily and spatially variable and above all, taxon-specific. For instance, in Kenya we observed that *Pearsonothuria graeffei* is often found grazing on dead coral and sponges, and that *Actinopyga mauritiana* and *A. lecanora* are often found grazing on live and dead coral. Such observations, however, are seldom made by reef ecologists since they are hindered by the lack of correct species lists and descriptions for holothurians in their study area.

Level five: *Education*

Conservation of holothurians depends on the participation of local communities, a fact that the Kenyan Government acknowledged by creating the Community Wildlife Program (Western & Wright, 1994). This programme allows local communities to benefit from conservation efforts, for instance through sustainable use of the natural resources (Muthiga, pers. comm.).

For generations, coastal peoples of Kenya have developed traditional management strategies that en-

able them to conserve and protect their natural heritage and resources. The impetus for these local customs is however not conservation, but soothing of the spirits (McClanahan *et al.*, 1997). In recent and future times these traditional conservation plans are or will not longer be sufficient for four main reasons: 1) Coastal urban populations in Kenya are increasing rapidly, and are putting demands on the environment. 2) In Kenya, the Islam religion is rapidly replacing the traditional culture where traditional leaders had more power (McClanahan *et al.*, 1997). As a consequence, authority has shifted towards national organisations like Kenya Wildlife Services, which local communities show increasing resistance to because it is thought that these instances will prohibit access to resources (McClanahan *et al.*, 1997). 3) The harvesting techniques employed by the sea cucumber fishermen are not 'traditional': with the advent of motorised boats and SCUBA gear, local fishermen can now reach areas that were formerly unreachable or inaccessible. In Gazi, we witnessed local SCUBA-divers (not using depth gauges) at 45 m collecting holothurians. 4) Not only 'locals' collect sea cucumbers on the fishing grounds. In Kenya, SCUBA-divers are hired to go fishing on grounds that are hundreds of kilometres away from their native fishing grounds. Obviously, these fishermen do not have an incentive towards sustainable resource utilisation. Education at all levels (from local resource users to biology students to policy makers) can help trigger awareness of the problems and make for the loss of traditional management strategies. Therefore, our team makes it the highest priority to inform local people on the purposes and consequences of our research.

Conclusions

Conservation and management plans will be optimal if the five, above mentioned, levels are grasped. First, a correct naming according to the rules of zoological nomenclature allows communication between scientists in an unbiased way. Second, because scientific naming implies ordering of the living world, understanding of the observed biological patterns within biodiversity becomes possible. Third, complete faunal lists must be constructed both for narrow political areas and for broader zoogeographical provinces, since these hold information that enables scientists to understand the faunal make-up of the landscapes and regions that need conservation. Fourth, because zoogeography is not only the consequence of history but also of ecological interactions a clear understanding of the current ecological interactions is needed. Fifth, education at all levels, from scientists to policy makers to fishermen, will ensure that conservation efforts will be understood and evalu-

ated and that sustainable management will replace unthoughtful environmental rape.

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The subsistence use of *Stichopus variegatus* (now *S. hermanni*) in the Pacific Islands

by Lyn Lambeth¹

The collection of sea cucumbers for subsistence use and some local sale is widespread in many parts of the Pacific. Various species are eaten fresh, cooked or pickled in lime juice. Some are harvested for the body wall, while other species are harvested for their gonads or intestines. Some commonly used species are: *Actinopyga miliaris*, *A. echinites* and *A. mauritiana*; *Holothuria scabra*, *H. verrucosa* and *H. fuscopunctata*; *Bohadschia argus* and *B. marmorata*; *Thelenota ananas*; *Stichopus horrens* and *S. variegatus* (Conand, 1990; Matthews & Oiterong, 1991; Smith, 1992; Dalzell *et al.*, 1996; Lambeth, 1999).

In the Pacific, the intestines of *Stichopus variegatus*, or curryfish, are collected. Afterwards, the sea cucumber is thrown back onto the reef where it regenerates its internal organs. Although it has rarely been documented or researched, the practice appears to be common in Samoa, Tonga, Cook Islands, Palau, Pohnpei, and probably many other places (Baquie, 1977; Lambeth, 1999; Malm, 1999). The lack of documented knowledge on this can perhaps be attributed to the fact that this is a non-commercial fishery practised by women – an area that has often been overlooked in fisheries research, development and management projects in the region. Added to this is the fact that *S. variegatus* is considered to be of low value to the commercial beche-de-mer industry, due to the tendency of the body wall to fall apart after harvesting and during boiling.

When harvested for subsistence use the intestines of *S. variegatus* are eaten raw on the spot, or squeezed into a bottle to be taken home and eaten. In some places the bottled intestines may be sold locally. The taste is rich, slightly metallic, with a strong but pleasant aftertaste, similar to raw oysters, and is often enjoyed with a little lime juice. Another *Holothuria* sp. is harvested in Tonga and Rarotonga, Cook Islands for the gonads (Baquie, 1977; Malm, 1999). It is widely believed the animal recovers if immediately thrown back into the sea after the body is cut and the gonads and/or intestines are removed.

In some sea cucumbers the ability for local, softening of the connective tissue enables them to

forcibly eject parts of their internal organs or body in response to attack. Others literally melt when attacked – an occurrence many people have experienced when picking up *Stichopus* sp. If the animal is returned to the water immediately this disintegration is reversed.

All echinoderms are able to regenerate arms, visceral and gonadal tissue. Aspidochirote and dendrochirote holothurians are known to eviscerate in response to rough handling, probably as a diversion to predators. Depending on the species, the anterior or posterior end of the animal ruptures and parts of the gut and associated organs are expelled. A seasonal absence of viscera has also been observed in some species and this appears to be caused by atrophy and absorption of the visceral organs, perhaps as well as spontaneous evisceration in some cases (Byrne, 1985). The seasonal loss of visceral organs, either by discharge through the cloaca or internal absorption is, according to Ruppert & Barnes (1994), a normal phenomenon in some species, perhaps initiating a period of inactivity during adverse conditions, or eliminating wastes stored in internal tissues.

Subsistence use of evisceration and regeneration in Palau

Matthews & Oiterong (1991) liken the regular harvesting of *S. variegatus* intestines in Palau to a form of farming. *S. variegatus*, or *ngimes*, in Palau are collected during the morning low tide before the animals have eaten and when the intestines are clean and free of sand. The animal is cut open or sliced in two halves; intestines are removed by shaking the animal and squeezing along the body. The body is then thrown back in the water to regenerate.

It is believed that both halves of the cut sea cucumber will regenerate into a complete organism and the women say that they observe many small individuals in areas where *ngimes* are often collected (Matthews & Oiterong, 1991). Some women prefer to obtain the intestines by just making a small slit in the underside of the animal rather than cutting it in two, believing that cutting the animal in two takes longer for it to regenerate and results in too many

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Figure 1. Collection of *Stichopus variegatus* intestines in Palau



Figure 2. Squeezing a finger into the underside of the body wall is usually enough to cause auto-evisceration.

small *ngimes* (Lambeth, 1999). Other women believe that the intestines taste better if they come from animals recently cut in half. If the *ngimes* from an area have never been harvested by this method, the intestines are said to have a bad aftertaste.

Little or no research has been undertaken on this process of regeneration after the removal of intestines for food in the Pacific. Women in Palau believe the animal regenerates its intestines within a few days. Some studies suggest it takes from 15 to 120 days for temperate water species to regenerate (Byrne, 1985; Bai, 1994). Bai (1994) reported that the tropical species *Holothuria scabra* can begin feeding around seven days after induced evisceration and that the 'rate of regeneration, in all the tissues studied, seems to be more

rapid when compared to that of temperate forms.'

Some research has been undertaken on the ability of sea cucumbers to regenerate into complete organisms from two halves. The potential for asexual propagation through induced transverse fission in several tropical species of sea cucumber, including *S. variegatus*, has been evaluated in the Maldives (Reichenbach & Holloway, 1995; Reichenbach *et al.*, 1996). Transverse fission was induced by placing rubber bands midbody on the sea cucumbers. The studies showed that adult *S. variegatus* (with a median wet weight of 3,650 g) were able to regenerate only the posterior part into a whole animal, in around 100 days, with zero per cent survival of the anterior parts and 80 per cent survival of the posterior parts. In contrast, medium size (median weight 1,300 g) and small (median weight 600 g) animals were able to regenerate both anterior and posterior parts (with 100 per cent survival) into whole animals in around 40 to 80 days. The shortest regeneration time was for the posterior parts of the smallest weight class of *S. variegatus*. The subsistence harvesting of *S. variegatus* observed in Palau and Pohnpei involved animals in the small to medium size range.

Subsistence use of evisceration and regeneration in Pohnpei

In Pohnpei, Federated States of Micronesia, the internal organs of *S. variegatus*, or *werer*, are collected by women in much the same manner as in Palau – being cut in half, or cutting a small slit with a knife, or using the finger to make a hole in the underside to remove the intestines. The sea cucumber is then returned to the water where it regenerates its internal organs after an unknown amount of time. The intestines are collected in the early morning before the animal has started feeding, when there is no sand in the gut, but they may be collected for use as bait at any time. Some people cut the animal with a knife to remove the intestines (as in Palau) but others believe that this can kill the animal and it is better to use the finger to make a hole in the underside. The body wall dissolves around the pressure from the finger and the intestines are then ejected rather than having to be squeezed out.

As in many parts of the Pacific, the women believe that the animal regenerates its intestines overnight,

or at least within a few days, and if the animal is broken in half, both halves will grow into two complete animals. Recently harvested animals appear normal from the outside but contain little or no internal organs. While collecting *werer* intestines for bait in a heavily harvested area, it was observed that most animals had sand in their intestines from feeding all morning, but that there were a few that contained no sand. The women believe that these are the most recently harvested animals, unable to feed, because their intestines are not yet fully regenerated (Lambeth, *in press*).

While the intestines are eaten by both men and women, they are believed to be particularly good for pregnant women and new mothers. As in Palau, the taste of the intestines from the smaller animals or those that have been harvested before are preferred to the taste of those from the larger ones. When used for bait, the intestines are tied to a hook with a hair and are said to be good for catching snapper.

One-litre bottles of intestines are sometimes sold in the local market for around AU\$ 3.00; it takes up to 20 animals to fill a bottle. The intestines are bottled in seawater and are usually sold the same day they are collected. Ice or refrigeration is not used.

Stichopus japonicus intestines – a Japanese delicacy

In Japan, an expensive fermented delicacy, *konowata*, is prepared from the visceral mass of *Stichopus japonicus* (Tanikawa, 1985; Conand, 1990).

The intestines are obtained as a by-product of the processing of this sea cucumber for its body wall and is, therefore, unlike the Pacific Island renewable use of *S. variegatus*. In the preparation of *konowata*, the visceral mass (alimentary canal and reproductive organs) is washed, drained in a bamboo basket, and then salted. Once drained it is placed in a barrel, covered and stirred occasionally during one week of fermentation. The finished product is sold in small glass bottles that last without spoilage over several weeks (Tanikawa, 1985). *Konowata* is used as an accompaniment with drinks and sells for around AU\$ 100 for a 65 g jar (Morgan & Archer, 1999).

Traditional knowledge and resource management

The traditional environmental knowledge of Pacific Island people has been gained through centuries of practical experience and has often been used to effectively manage their marine resources. The beliefs and harvesting practices that have evolved based on the unusual biology of *S. variegatus* are an interesting example of this. In Palau, the collection of *ngimes* only during morning low tide was an effective management measure. Morning low tide meant the animals were in shallow water, easily accessible to the women, and the intestines were free of sand. It also meant they were only harvested over four mornings, twice a month, leaving around 10 days between harvesting trips – which was, according to the women, more than enough time for the internal organs to regenerate. In



Figure 3.

Collecting intestines in the afternoon to use as bait.



Figure 4.

Bottled intestines for sale in Kolonia, Pohnpei.

Pohnpei, the preference of using a finger to cause the animal to slightly disintegrate the body wall and auto-eviscerate, rather than cutting or halving the animal, could conceivably lead to less trauma, greater survival and faster regeneration times.

Today, an increasing human population and the development of the cash economy are leading to overharvesting in some areas, especially around the main urban centres. The sale of intestines in the local markets has meant there is now a greater incentive to harvest more than an individual or family would normally eat. The increase in the number of people in formal employment has led to a market for what was previously only a subsistence food. Those in full-time jobs have little time for reef gleaning or fishing, but are able to pay others to provide the local foods they enjoy.

In Samoa a number of villages, concerned about harvesting practices for sea cucumbers, have banned the collection of *S. variegatus* for removal of the intestines away from the place of harvest. The animals must be processed on the spot and returned to the water. Some of these village laws have now been set as local by-laws, enforceable under national law (King & Faasili, 1999). These laws recognise the importance of the regenerative properties of the animal to the sustainability of the fishery. Without the inclusion of women's groups in the process of developing village fisheries management plans, their knowledge and concerns over this subsistence resource may not have been heard or included in the plans.

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Taxonomic interrelations of holothurians *Cucumaria frondosa* and *C. japonica* (Dendrochirotida, Cucumariidae)

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Abstract

Morphological features, distribution, ecology and some of the chemical characters of *Cucumaria frondosa* and *C. japonica* are described. The two species are well distinguished by the spicule-shaped body wall, the structure of the introvert, tentacles and ambulacral podia, the colour of internal organs, the size of ova and the chemical structure of triterpene glycosides. The data points to the taxonomical independence of these species. Previous opinion that *C. japonica* is a subspecies of *C. frondosa* is not supported.

1. Introduction

Cucumaria frondosa and *C. japonica* belong to the largest and most abundant order of holothurians, order Dendrochirotida, and have great commercial value (especially *C. japonica*). Their systematic relations and biology are described in numerous publications, yet their taxonomic relations are still disputed.

Species independence of *Cucumaria japonica* has been repeatedly doubted since Britten (1906–1907). Many scientists considered *C. japonica* as a sub-species of *C. frondosa* (Saveljeva, 1941; Lambert, 1984) or a variety (Mortensen, 1932; Panning, 1949; 1955).

Mortensen (1932, p. 45) suggested that ‘...it may be rather a matter of personal choice whether *C. japonica* should be regarded as a separate species or only as a variety of *C. frondosa*. However, new data, important for the taxonomy of the two species, has emerged. These data include a new type of information – chemical composition of triterpene glycosides, helpful for solving taxonomic problems (Kalinin *et al.*, 1994). This helps the present understanding of the taxonomic relations between *C. frondosa* and *C. japonica*.

2. Material

Material examined includes original samples of *C. japonica* from different areas of the Peter the Great Bay (Japanese Sea), the Busse lagoon and the Gulf of Aniva (Sakhalin Island); original samples of holothurians preliminarily identified as *C. japonica* from east and west Kamchatka; the collection at the Zoological Institute (St Petersburg) from the Kuril and Commander Islands (several thousand speci-

mens in total); holothurians preliminarily identified as *C. frondosa japonica* from the west coast of Canada and the Aleutian Islands (the Royal Museum of British Columbia, Victoria, Canada – 12 specimens); and original collection from the Barents Sea (mainly from the Kanin area and the Seven Islands – several hundred specimens).

3. Comparison of *Cucumaria frondosa* and *C. japonica*

3.1. Gross morphology

In external appearance there is practically no difference between *C. frondosa* and *C. japonica*. The body of these holothurians is dense, cylindrical or barrel-shaped, slightly curved dorsally, especially in live animals, with a rounded or slightly stretched posterior end. The body is almost globular when the animals contracts.

The tube feet are large and retractile; in adults they are located usually on the ventral radials in two to four rows. On the dorsal side, the tube feet are smaller and very often transformed into papillae. The tube feet location varies greatly: in some specimens there are few feet and they are absent in the middle part of the body, even on the radii. In other animals, the feet are found and located in the inter-radii. In general, the tube feet location has no taxonomic value. In young holothurians the tube feet are spread in more regular bands, either in zigzags or in single rows. Tentacles are 10; they are large and similar in size, however two ventral tentacles can be smaller.

Data on the size of cucumarians are rather conventional since it depends greatly on the degree of the body contraction. For *C. japonica* maximum known

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length is 40 cm, whereas for *C. frondosa*, maximum known length is 50 cm (Deryugin, 1915), but most animals are much smaller (≈ 20 cm). Body mass of large animals comes up to 1.5–2.0 kg, but average weights are 500 g.

The colour of the body varies greatly: dark brown, dark purple, brown, greyish, yellowish, with the dorsal side clearly lighter. Completely white animals in both species are known; in some populations of *C. japonica* the ratio of white animals is large.

The structure of viscera is also similar. The body wall is thick and its mass constitutes up to 20 per cent of the total mass of the animal. We failed to find difference in the form, location and dimension of the stone canal, retractor muscles, polian vesicle, gonads and other structures, only the attachment of mesentery is an exception (see below).

In both species a strong reduction (up to absence) of body spicules is typical in the adults. Spicules are found more often in the posterior end of the body. The literature often mentions that spicule reduction is more expressed in *C. frondosa* than in *C. japonica*, however our observations did not confirm that: this character is strongly variable in both species.

Spicule changes during somatic growth are similar in *C. frondosa* and *C. japonica*. Spicules in *C. frondosa* are mainly round plates with regular perforations. The plate edge is smooth or slightly wavy; in large specimens the plates may have a spinous edge and rounded knobs on the surface. Buckle-shaped plates with four perforations are also found (Edwards, 1910a, pl. 13, fig. 8–11; Deichmann 1930, pl. 12, fig. 6–9). Spicule changes during somatic growth in *C. japonica* are discussed in detail by Levin and Gudimova (1997 a, b).

The difference between spicules in young and adult specimens is so great that juvenile *C. frondosa* is often considered as a separate species, usually as *C. fucicola* (McKenzie, 1991). At the same time, spicules in young cucumarians can be similar to those in adults of another species and even genus. Thus, some plates of young *C. japonica* are almost identical to spicules of *Leptopentacta sachalinica*.

Similarities also exist in the type of spicules in adult cucumarians. Some spicules are almost rectangular plates with numerous regularly-located perforations: large holes are closer to the narrow end, whereas small ones are at the opposite, usually more spinous end (according to Panning these are *japonica*-type spicules). Besides, there are plates with more or less developed processes and

irregularly located perforations (*frondosa*-type after Panning).

The calcareous ring of *C. frondosa* and *C. japonica* has a typical form, as all the species of the genus *Cucumaria*, with radial pieces lacking posterior processes. Radial and interradial pieces of the ventral side do not merge. The ring is very flexible owing to the mobile joint of the pieces and their elasticity. The form of the pieces varies greatly depending on the state of the animals before preparations and their age (Levin & Gudimova, 1997b).

Therefore, the calcareous ring is of no taxonomic value for this genus. The degree of development of the calcareous ring in the two species also varies with age and between individuals.

Based on the features discussed, some of the authors distinguished between *C. frondosa* and *C. japonica*. However, according to our data the range of variation is interspecific. At the same time, a number of important features vary greatly between *C. frondosa* and *C. japonica*.

3.2. Spicules

Cucumaria frondosa

Body wall – Irregular, square, rounded or slightly elongated perforated plates. Some spicules bear processes and lobes of various shapes. The surface of plates is either smooth or scattered with spines. In the central part of the plates, especially in large ones, an irregular perforated process is often formed. Plates are 170–320 μm in size.

Introvert – The plates are elongated or irregular, with a smooth or spinous margin. Usually plates have two to three layers with pronounced irregular central process. Plate size ranges from 160 to 370 μm (see Fig. 1, next page).

Tentacles – The tentacle spicules in large specimens are complicated, often with a secondary meshwork; some also are straight or curved rods, sometimes with single holes present. The surface of both types of spicules is with knobs. The size of plates ranges from 160 to 350 μm (Fig. 1).

Tube feet – Spicules are wide plates, with one end narrow and usually bearing round processes, and the other end notched or spinous. The endplate in adults is always complex and is formed by numerous (up to 70) small plates and rosettes. Figures of spicules of *C. frondosa* are given in Edwards (1910a, pl. 13, fig. 8–19; 1910b, pl. 19, fig. 2–4); Cherbonnier (1951, pl. 16, 17); Panning (1955, Abb. 1, 2).

Cucumaria japonica

Body wall – Mainly elongated perforated plates with a spinous edge and one end usually narrowing. Round irregular and triangular plates are also common. Perforations are numerous and round. The surface is covered with knobs or spines. The size of plates ranges from 190 to 280 µm (Fig. 2).

Introvert – Usually the spicules are perforated plates of different shapes with a notched margin. Spicules become thicker during development; ‘bridges’ and spinous projections may appear on the surface (at any place of file plate, not only in file centre, as shown by Ohshima, 1915). Elongated plates during development may transform into 3-dimensional, perforated spindle-like or conical structures (Fig. 2).

Tentacles – Three main spicule forms were found in the tentacles: 1) Elongated plates with double-sided or unilateral central bulb. The size of these plates is 240–320 µm; 2) Small, thin perforated plates of different shape and a size of 80 to 120 µm; 3) Large, elongated massive plates with a smooth surface or 3-dimensional meshwork of projections in the centre; and a size of 300 to 420 µm.

Tube feet – Spicules resemble those of the body wall, but are smaller. In the original description of *C. japonica* Semper (1866) pointed to very large plates with numerous small perforations radially spread around the cloacal opening. These types of spicules are absent in *C. frondosa*. These plates were also noticed by Augustin (1908) and Edwards (1910b, pl. 19, fig. 16), however other authors (Britten, 1906-1907; Mitsukuri, 1912) failed to find them. In our material, these plates were absent. Illustrations of spicules of *C. japonica* are given in: Semper (1868, Taf. 39, Fig. 18), Edwards (1910a, pl. 19, fig. 150, Mitsukuri (1912, fig. 48), Djakonov *et al.* (1958, fig. 2) and Baranova (1971, fig. 1).

3.3 Mesentery attachment

In *Cucumaria frondosa* the intestine mesentery passes from the anterior end in the dorsal inter-ambulacrum, crosses the left dorsal and ventral longitudinal muscles (being perforated by the retractors), and finally runs along the left side of the midventral muscle and its median line to the cloaca (Deichmann, 1930; personal observations). In *C. japonica*, the attachment of mesentery in file posterior part of the body is significantly different: the mesentery crosses the midventral muscle at the basis of a correspondent retractor, then forms a loop in the interradius and approaches the cloaca along the median line of the midventral muscle (Fig. 3).

3.4. Colour of visceral organs

The colour of some visceral organs differs greatly between the two species, as shown in the following table.

Visceral organs	<i>C. frondosa</i>	<i>C. japonica</i>
Stone canal	Bright-red	Light-orange
Madreporite	Pink	Light-orange
Polian vesicle	Orange	Pink
Female gonad	Dark red, brownish	Dull-green
Eggs	Bright or cherry red	Green

3.5 Reproductive system

Significant differences are found between the female reproductive organs in the two species. Besides the difference in coloration of gonads and eggs, there is also a significant difference in file egg size between *C. frondosa* and *C. japonica*: the ripe oocytes reach 875–900 µm and 500–600 µm, correspondingly. The gonads in both *C. frondosa* and *C. japonica* are composed of two tufts of tubules.

3.6 Chemical composition

The chemical composition of specific triterpene dycosides in *C. frondosa* and *C. japonica* indicate (Kalinin *et al.*, 1994) that the general feature of these compounds is the presence of pentasaccharide branched at the second monosaccharide link (quinovose) of carbohydrate chain, the sulphate group in the position 4 of the xylose residue and 7(8)-double link in aglycone. For *C. japonica* the composition of 11 dycosides (cucumariosides) has been described. Cucumariosides contain glucose as the third monosaccharide residue of carbohydrate chain and the 16-ketogroup in the aglycone. The main component of the glycoside sum of *C. japonica* is cucumarioside A₂-2. The glycosides of *C. frondosa*, in contrast to those of *C. japonica* are frondosides, and they contain xylose in the carbohydrate chain and 16-beta-acetate in the aglycone. The main component of the glycoside fraction in *C. frondosa* is frondoside A (Fig. 4).

3.7 Distribution

C. frondosa is widely distributed in the Arctic region: it is known from the Hardanger fjord in the Norwegian Sea to the Novaya Zemlya and Franz Joseph Land in the Barents Sea, and in the southwestern part of the Kara Sea (probably farther to the east, although no reliable data are available). Near the British Isles it is known in the North Sea,

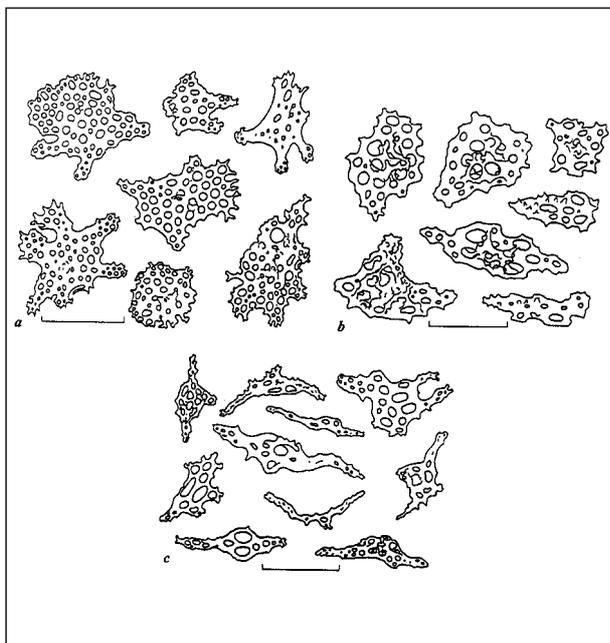


Figure 1.
Ossicles of *Cucumaria frondosa*:
a - body wall; b - introvert; c - tentacles.
Scale bar = 200 μ m

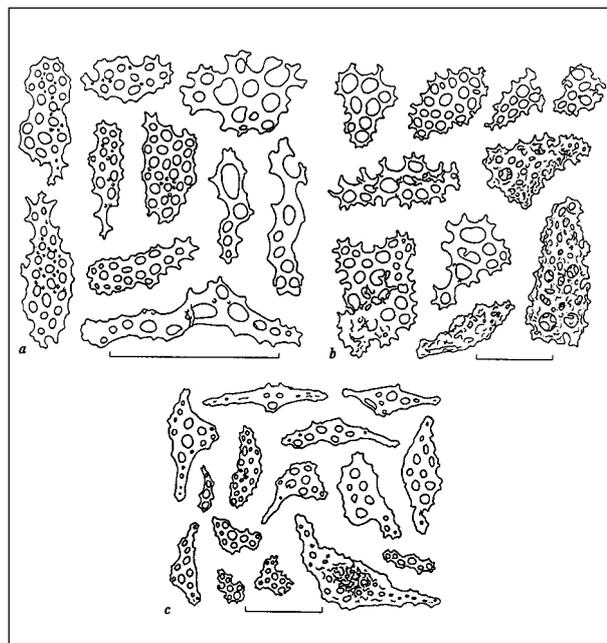


Figure 2.
Ossicles of *Cucumaria japonica*:
a - body wall; b - introvert; c - tentacles.
Scale bar = 200 μ m

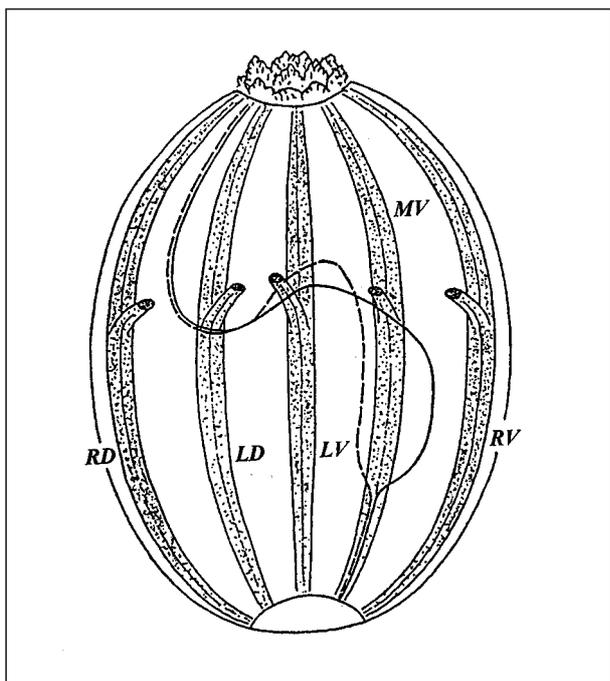


Figure 3.
Arrangement of mesentery in *Cucumaria frondosa*
(solid line) and *C. japonica* (broken line).
Radii: LV - left ventral; RV - right ventral;
MV - midventral; LD - left dorsal; RD - right dorsal.

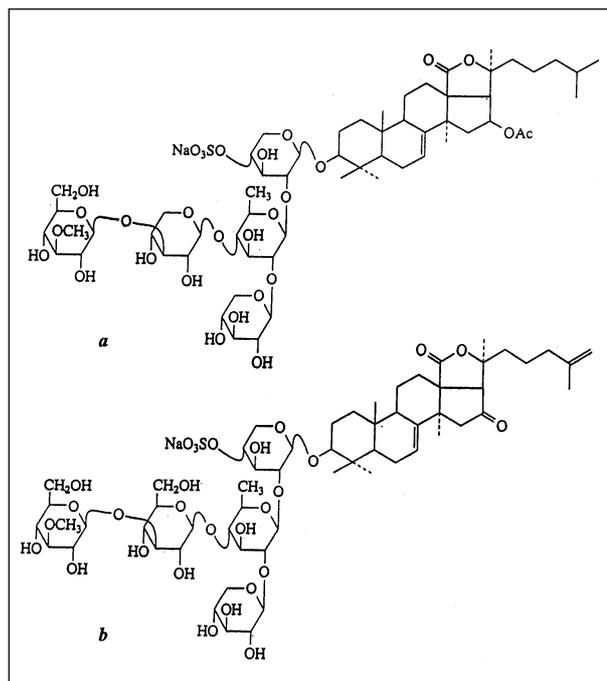


Figure 4.
Structure of triterpene glycosides:
a - frondoside A from *Cucumaria frondosa*;
b - cucumarioside A₂-2 from *C. japonica*

up to Dogger-bank in the south and near the Shetland and Orkney Islands. This species was earlier observed near the west coast of Scotland and Hebrides as far south as the Clyde, however, there is no recent data (McKenzie, 1991). In North America, the southern border of its distribution is the Cape Cod Peninsula and Nantucket Island (Edwards, 1910a; Smith *et al.*, 1964).

The report on species occurrence in Florida (Pourtalés, 1869) is obviously erroneous (see Deichmann, 1930). Semper (1868) has described *C. frondosa* var. *mediterranea*. Since there were no other data on species occurrence in the Mediterranean and the description was based on the museum specimens, it is not reliable.

In the Pacific, *C. frondosa* has been observed by Ayres (1855), but this record was questioned by Verrill (1867), Ludwig (1901) and Clark (1904). Edwards (1910a) indicated in 1907 that this species was reported from the west coast of North America; however, after studying a large collection from the National Museum he came to the conclusion that at least four species, similar but not identical to *C. frondosa*, inhabit the Pacific Ocean. One of them is *C. japonica*, although the specimen identified under this name by Lampert (1885), Clark (1904) and Edwards (1907) appeared to belong to *C. miniata* Brandt.

***C. japonica*.** In the literature, the species range of *C. japonica* is usually given as the northeastern part of the Yellow Sea; the northeastern coast of the Honshu Island; along the continental coast of Russia in the Sea of Japan; the Sea of Okhotsk, the Kuril Islands, the Kamchatka Peninsula; and in the Bering Sea at least to the north of Kamchatka; near the Commander Islands; and along the northwestern coast of North America, from Sitka Island to Vancouver Island (Baranova, 1957, and others). However, according to present data, the real range of this species is much smaller.

The early opinion that this species is distributed up to the Bering Sea is apparently erroneous, as noticed first by Baranova (1980) who assumes that specimens from the north Kuril Islands and Kamchatka, earlier referred to as *C. japonica*, in fact belong to two new species: *C. savelijevae* (Paramushir Island, Shumshu Island, Achomten Bay on the east coast of Kamchatka) and *C. djakonovi* (Cape Olutorsky, Bering Island, in the Bering Sea,). Species composition and distribution of *Cucumaria* from the north Kuril Islands, Kamchatka, Commander Islands, Aleutian Islands and western Alaska appeared to be very complicated. The taxonomic status and the species range of *C. savelijevae* and *C. djakonovi* remains unknown

(material is in work), although we agree with Baranova that large *Cucumaria* from this region are not *C. japonica*. Our preliminary results have shown that this species does not occur to the north of southern Kuril Islands.

The presence of *C. japonica* to the south of Sendai is unlikely. Sluiter's report of this species in the Molucca Strait has been most likely a mistake as was first noticed by Mitsukuri (1912).

C. japonica has been reported from the coast of northeast Pacific (Clark, 1902; Edwards, 1907; Baranova, 1971). Some authors, in particular Lambert (1984), believe that the species occurring south from Alaska, near the Vancouver peninsula, is *C. frondosa japonica*.

However, examination of specimens of '*C. japonica*' has revealed erroneous identification. '*C. japonica*' collected near Sitka Island, Alaska (Clark, 1902) appeared to be *C. miniata* (Brandt) (Mortensen, 1932). Specimens from the Royal British Columbia Museum (Canada), identified as *C. frondosa japonica*, appeared to be neither *C. frondosa* nor *C. japonica*. Thus, it is almost certain that *C. japonica* does not occur near the coast of America.

It is much more difficult to interpret the record by Mortensen (1932) of *C. japonica* (he considered this species a variety of *C. frondosa*) from the high-Arctic, near the northwestern coast of Greenland (Thule-Jones Sounds and Devis Strait). Taking into account a great number of intermediate forms between *C. frondosa* and *C. japonica* recognised by this author, it can be suggested that the specimens of *C. frondosa* from Greenland have an increased number of the *japonica*-type plates. Recent data have shown a possible parallelism of morphological features in the populations of the two species inhabiting the area of extreme temperatures, north-west Greenland and Kamchatka. Ecophysiological interpretation of this phenomenon has been suggested by Kafanov (1977; pers. comm.).

3.8 Ecology

C. frondosa and *C. japonica* live in similar conditions. They are known from the intertidal zone down to approximately 300 metres depth, with the peak in abundance at depths of 30 to 60 metres. Juveniles prefer kelp forests and shallow areas warmed up in the summer. Adults keep in relatively open and deeper water, on the loose gravel, shell debris, rocks or mud. In general, any solid substrate may be utilised if other conditions are favourable. The lower temperature range for both species is -1.8°C ; upper temperature range is about $+18.0^{\circ}\text{C}$ for *C. japonica*, and about $+8.0^{\circ}\text{C}$ for *C. frondosa*.

Thus, the data show that *C. frondosa* and *C. japonica* are well-defined separate species. The synonymy summarising the data discussed is as follows:

Cucumaria frondosa (Gunner, 1767)

Holothuria frondosa Gunner, 1767: 114, t. 4, fig. 1-2; Muller O.F., 1788: 36;

- *pentactes* Fabricius, 1780: 352; Muller O.F., 1776: 71, t. 1; 1788: 36, pl. 31, fig 8;
- *grandis* Forbes and Goodsir, 1839: 647;
- *fucicola* Forbes and Goodsir, 1839: 647 (erroneous *fusicola*)

Pentacta frondosa Jaeger, 1833: 12;

Cucumaria fusicola Forbes, 1841: 227;

Botryodactyla grandis Ayres, 1851: 52;

- *affinis* Ayres, 1851: 145.

Cucumaria frondosa Forbes, 1841: 209; Selenka 1867: 347; Semper, 1868: 234-235 (excepted *T. frondosa* var *mediterranea*); Norman, 1869: 316; Ludwig, 1901: 141; Michailovskij, 1904: 463, 1904: 159; H. Clark, 1904: 564; A. Clark, 1920: 12; Edwards, 1910a: 333-358, pl. 13, figs. 1-26; Hérouard 1923: 108, taf. 7, fig. 5, 6; Mortensen 1927: 398-399, fig. 236; Koehler, 1927: 151, pl. 14, fig. 12a-c, Deichmann, 1930: 161-162, pl. 12, fig. 6-9; Gorbunov, 1932: 96; Engel 1932: 61, fig. 23, 24; Djakonov, 1933: 141, fig. 71B; Grieg, 1935: 7; Keys..., 1948, tab. 123, fig. 5; Ivanov *et al.*, 1946: 580-586, fig. 782-788, colour tab. (anatomy); Panning, 1949: 417-418 (partly), Abb. 4; 1955: 34-38 (partly), Abb. 1, 2; Ivanov & Strelkov, 1949: 39-41, tab. 28, fig. A-G, Cherbonnier, 1951: 37, pl. 16, fig. 1-23, pl. 17, fig. 1-10; Smith *et al.*, 1964: 188; Rowe, 1970: 683, 686; Baranova, 1977: 439-440; Pawson, 1977: 7; Ivanov *et al.*, 1985: 339-348, fig. 342-349 (anatomy); McKenzie, 1991: 146-147, fig. 8d; Gudimova & Denisenko, 1995: 1-44; Gudimova, 1998: 453-528 (non Pourtalés, 1869; non Edwards, 1907).

Non *Pentacta frondosa* Ayres, 1855; non *C. frondosa* var. *mediterranea* Semper, 1868; non *C. frondosa japonica* Lambert, 1984.

Cucumaria japonica Semper, 1868

Cucumaria japonica Semper, 1868: 236, Taf. 39, Fig. 2, 3, 7, 18; Lampert, 1885: 143; Theel, 1886: 110; Ludwig, 1901: 143; Britten, 1906 (1907): 133-135; Augustin, 1908: 25-26, fig. 18; Edwards, 1907: 61, 1910b: 603-604, pl. 19, fig. 1516, Mitsukuri, 1912: 242-246, pl. 8, figs. 67, 68, textfig. 48; Oshima, 1915: 255; Saveljeva, 1933: 44; Djakonov, 1938: 484; 1949: 70-71; Djakanov *et al.*, 1958: 266-268, fig. 1, 2; Panning, 1949: 417-418 (partly), Abb. 4, 1955: 34-38 (partly), Abb. 1, 2; Pogankin 1952: 183 (ecology); Ushakov, 1953: 298 (distribut., partly); Strelkov, 1955: 217, Tab. 64, fig. 1; Baranova, 1962: tab. 1 (distribut.); 1971: 243-245; 1976: 115, fig. 266; 1980: 109-120 (compari-

son); Djakonov *et al.*, 1958: 367; (non Lampert, 1885; non Baranova, 1957).

C. frondosa japonica Saveljeva 1941: 80; (non Lambert 1984). *C. frondosa* var. *japonica* Mortensen, 1932: 44-48, 52; Panning 1949: 417-418 (partly), Abb. 4; 1955: 34-38 (partly);.

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aquaculture news

beche-de-mer

News from ICLARM Coastal Aquaculture Centre in the Solomon Islands

Prepared by Stephen Battaglione

As I reported in the last *Beche-de-Mer Bulletin*, ICLARM has, with much regret, had to close the Coastal Aquaculture Centre (CAC) near Honiara in the Solomon Islands due to ethnic tension. That decision is now final and the station has been handed back to Solomon Islands government. ICLARM will continue its presence in Solomon Islands and the field station at Nusa Tupe in the Western Province remains open and will be expanded over the next few years. Projects investigating the collection of larval reef fish, the grow-out and restocking of giant clams and sea cucumbers, and investigations to determine the affect of logging on coral reefs continue. Research on the mass production of sea cucumbers has been curtailed over the past six months, although a very successful restocking of sandfish occurred early this year. The details of this release can be found in the accompanying article. ICLARM is exploring the possibility of new partnerships in New Caledonia, Vietnam and Indonesia, all having expressed an interest in restocking programmes for tropical sea cucumbers. The research effort in Solomon Islands is being

co-ordinated by Susan Dance who can be contacted by email on nusatupe@iclar.org.sb.

Anyone interested in ICLARM's plans to develop sea cucumber programmes in Southeast Asia could contact Johann Bell on j.bell@cgiar.org or Rayner Pitt on r.pitt@cgiar.org for further details.

The team of researchers who worked at the CAC on sea cucumbers continues to be productive. Chris Ramofafia is making excellent progress towards his PhD at the University of Sydney and has been busy publishing a description of egg and larval development in *Holothuria scabra* and a paper on reproduction in *Actinopyga mauritiana*. Drs Annie Mercier and Jean-Francois Hamel's CIDA-funded project on the ecology of sandfish will end in June 2000. Their research provides a sound biological basis to the release of sandfish. On a personal note I will be scaling down my involvement in sea cucumber research and have been busy writing the remaining scientific papers on spawning induction and larval rearing.

ICLARM restocks sandfish in Western Province

Saturday 29 April 2000, 2,600 juvenile sandfish bred by ICLARM were released into the Vona Vona Lagoon near the village of Boe Boe, in the Western Province.

The sea cucumbers were raised from eggs by Rayner Pitt, Joe Olisia, Maxwell Sau and Susan Dance, a graduate in aquaculture from the University of Stirling in Scotland who has been working as a volunteer scientist with ICLARM.

The methods for rearing sandfish were developed by ICLARM during a 5-year project funded by the Australian Centre for International Agricultural Research (ACIAR). The methods involve collecting mature sandfish, stimulating them to release eggs and sperm, incubating the fertilised eggs, rearing the developing larvae through various stages and then growing the young sea cucumbers in tanks until they were large enough for release. The work was complicated at first, but is now fairly

routine. 'The juvenile sandfish can be produced within 3–4 months at relatively low cost because they do not need expensive food like prawns', said Susan Dance. 'They actually grow well by eating only the algae and bacteria that grows on surfaces of the tanks used to raise them', she said.

The release of the juvenile sandfish at Boe Boe is the first time that ICLARM has put back large numbers of this species in the wild. ICLARM paid special attention to returning the juveniles to the place where the adults used for spawning were collected. Dr Johann Bell, the Officer-in-Charge of ICLARM's operations in Solomon Islands, explained that this was a precaution to maintain the genetic diversity of stocks within Solomon Islands. 'At this stage, we do not know whether there are different stocks of sandfish in Solomon Islands and so it is best not to mix sandfish from different areas until we find out', he said.

ICLARM will use the results of the release at Boe Boe to help design a new project on sandfish. The new project is also funded by ACIAR and aims to develop the best methods for releasing cultured juveniles into the wild in the Pacific region. 'Now that we know how to produce the juveniles in hatcheries, we need to learn how, where and when to let them go into lagoons so that they survive in large numbers', said Dr Bell.

Ms Michelle Lam from the Fisheries Division in Honiara and Lionel Laka who is the Provisional Fisheries Officer for the Western Province assisted with the release of the young sandfish at Boe Boe. Fisheries Division has given their full support to ICLARM during the project on the breeding of sandfish. When the ICLARM staff was having difficulty finding enough sandfish to breed, Fisheries

Division realised that stocks of this important species had been over-harvested. In 1997, Fisheries Division amended the Fisheries legislation to put a total ban on the export of sandfish. The regulation makes catching, retaining, selling, buying or exporting of sandfish a criminal offence.

The ban on exports will be in place until stocks throughout Solomon Islands have been restored to levels where they can support good levels of harvest each year. Michelle said that the problem with the sandfish at the moment was the low numbers of breeding animals. 'There simply are not enough adult sandfish to provide sufficient juveniles to support a good fishery. We need to allow the total number of animals to build up to the point where the offspring they produce each year provide us with a good harvest', she said. Lionel added 'The great thing about the ICLARM project is that it should help stocks in Vona Vona Lagoon to recover even faster because the released animals should spawn within a couple of years. Their babies will then grow-up and spawn and, eventually, sandfish would be plentiful again. The Government could then consider reopening the fishery'.

The Fisheries Division would be making regular checks on the exporters of marine products to ensure that they did not buy, store or ship sandfish and remind them that anyone caught breaking the law will be liable for severe penalties, including imprisonment for three months. Michelle added 'We want the people of Solomon Islands to realise that a lot of money and effort is being spent to restore the stocks of sandfish so that coastal dwellers will have a source of income in the years ahead. We want people to understand and respect the process and to see the ban as an investment in the future, not a penalty'.

New Zealand collaborates with Japan on sea cucumber farming

Andrew Morgan¹

In January this year, Kunihiro Masaki, chief researcher of the Saga Sea Farming Center in Japan visited the Leigh Marine Laboratory and offered some valuable insights into the farming of sea cucumbers. A meeting with Andrew Morgan, Kunihiro Masaki, Dr. Russ Babcock (scientist in charge) and John Croft, research director for McFarlane Laboratories, a pharmaceutical company (now Healtheries).

The purpose of this meeting was to discuss ways of developing a sustainable industry and a viable commercial venture for the sea cucumber *Stichopus mollis* in New Zealand. The production of seed to alleviate the pressure such a venture may have on wild stocks; the sustainable and renewable harvesting of the gut for export to Japan; and the development of food supplements from pharmacologically active compounds known to exist in this animal, were discussed.

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Scientists at the Saga Sea Farming Center have been restocking commercial amounts of sea cucumber seed (*Stichopus japonicus*) for a number of years now. Using standard hatchery procedures they produce thousands of juvenile sea cucumbers, which are settled in primary grow-out tanks (16-tonne rectangular concrete tanks). Kunihiko commented on the nature of the hatchery set up that has been designed and developed at Leigh Laboratory. The improvement of sea cucumber culture and grow-out techniques was discussed as was spawn induction and diatom films for settlement and primary grow-out.

At the other end of the scale product development and the sourcing of raw materials was discussed. Researchers in Japan successfully farm sea cucumbers with sea urchins and abalone. Seed (1 to 5 cm) is also placed out on artificial reef structures made of rocks and boulders (40 by 20 metres). An industry partner in New Zealand is farming wild caught adult sea cucumbers in raceways containing the effluent water from raceways containing abalone (10,000 to 50,000 sea cucumbers at full scale). This is proving successful and the nutritional benefits of waste and effluent from abalone in polyculture with *S. mollis* and how this may affect the quality of products produced from this animal are being assessed.

Farming practices are being developed and refined while raw materials are being provided to develop pharmacological products and commercial products from the gut. John Croft commented that the source of raw materials was critical in obtaining the backing of commercial partners. Incentive for

industry to support this venture is given further impetus by the claim that raw materials are sourced from environmentally friendly and sustainable farming and fishing practices.

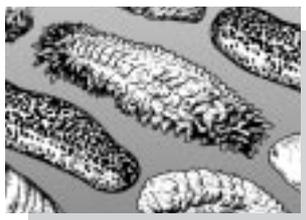
The development of pharmacological compounds from sea cucumbers is relatively new. For hundreds of years anecdotal evidence has suggested that extracts of sea cucumber were have been used to treat inflammation and joint problems, arthritis and various other ailments. Initial tests by McFarlane Laboratories (Healtheries) have been positive and with ongoing research, we hope to develop a marketable product.

The issues outlined above are being developed and strategies implemented to ensure this new industry is successful. Continued collaboration with Japan and industry both locally and internationally is ensuring that the refinement of commercial scale production and product development occurs alongside research. Both Kunihiko Masaki and John Croft have indicated their willingness to see this venture come to fruition.

From the Solomon Islands to Australia and New Zealand restocking and/or farming is seen as an alternative to overexploited fisheries. The Great Barrier Reef sea cucumber fishery is non-sustainable as are other tropical sea cucumber fisheries. A lucrative market exists for products from sea cucumbers and in addition to protecting the environment, sea cucumber farming will help lead the way in sustainable and renewable marine farming practices.



Kunihiko Masaki and Andrew Morgan at Leigh Marine Laboratory



correspondence

beche-de-mer

1- From Pradina Purwati (17 September 1999)

I have read the *Beche-de-Mer Information Bulletin* on a number of occasions and noticed your section, 'Observation on fission and spawning'. I have been studying a black holothurian, *Holothuria leucospilota*, inhabiting Darwin waters (Nightcliff and East Point reef) since last year. I have found evidence of a low percentage of fission in this species through monthly monitoring at both study sites. Fission also occurred on the following dates when I kept several animals in an aquarium: 25 August, 15 September 1998, 16 March and 25 April 1999. The aquarium was maintained in a shed with no direct solar radiation, and the water temperature was kept between 27 and 28°C. There was no wave action; the only water movement was produced through slow aeration.

There appears to be only two reports on asexual reproduction of *H. leucospilota*, in La Saline, Heron Island (Conand *et al.*, 1977) and in Fanning Island (Townesley & Townesley, 1977). Fission did not occur in other parts of Heron Island, southern Heron Cay (Franklin, 1980), Rongelap Atoll, Marshall Islands (Bonham and Held, 1963) or HongKong waters (OngChe, 1990).

In the populations I am working with, gonads were rare during July and August. When gonads were

collected several months after August, found that gonads in populations inhabiting tropical waters, develop simultaneously. In this respect, these populations differ from *Holothuria scabra*, which I examined at Ambon Island, eastern Indonesian approximately four years ago.

Last year I was unable to collect spawned eggs, as I did not know the sexual reproductive season. However, between January and April 1999, I induced spawning of several individuals by raising the water temperature 4–5°C above normal (27–28°C). However, during low tide in their natural habitat, the water temperature in small pools reaches 35–36°C. It seems unlikely that spawning can be induced in individuals by raising the water temperature to 33°C, a lower temperature than they experience at certain times within their natural environment. However, it may be possible that fluctuations in water temperature stimulate spawning. I am curious as to whether you know of any other way to stimulate spawning.

Thank you in advance for your help.

Pradina Purwati (P_Purwati@mimosa.ntu.edu.au)

2. From K.P. Manikandan (19 September 1999)

I am working as a hatchery manager in a private company named Bandaveri Seacucumber Pte Ltd. Our site is located on Banlaveri island in Raa Atoll in the Republic of Maldives. The site is about 12 hours by sea in a dhoni from the capital Male. The entire island of Bandaveri is dedicated to sea cucumber hatchery. Our system has the potential for the production of one million juveniles. My wife, Biji Thomas, also works with me and is in charge of the microalgal facility. We have about 1500 broodstock of *Holothuria scabra*, all from India after scanning them with ultrasound during the mature season for their

sex. The ratio of male to female is 3:1. Irrespective of the spawning season, our first occurred on April 25, 1999. The spawning was weak; only one female spawned. We got about 130,000 Auricularia. They were fed with a combination diet of different algae: *Isochrysis galbana*, *Dunaliella salina*, *Pavlova lutherii* and *Tetraselmis chuii*. The water was 29–30°C. Intake water went through a biological filter followed by a series of cartridge filters ranging from 10, 5, 1 and 0.22 microns. The water was not chlorinated. Water was changed every second day. In about 10 days, about 80,000 became Doliolaria. Thin transparent

fibre sheets were put in seawater for 15 days for the development of benthic algae (as recommended by ICLARM scientists). They were put in the Doliolaria tanks and 70,000 of them settled to form pentacula. After they attained 1.5 cm in length, the juveniles were sea-ranched in an enclosed lagoon about six hours away by sea from our site. The place is in Shaviyani Atoll in the Maldives. The depth of the lagoon rarely exceeds 3 m and the place is highly rich in detritus matter. In about six months time, the juveniles reached about 10 cm in length. Now they are about 15 cm in length being ready to be harvested. We got our second spawning in June 1999 and faced problems due to marine purple photosynthetic bacteria. We got about 50,000 juveniles, even though the spawning was profuse, with three females. Now we have installed an UV disinfecting unit and we are expecting the next spawning.

3. From Rob Lowden (11 November 1999)

My name is Robert Lowden, and I live in Cairns Australia and have been a harvest fishery diver all of my working life (\approx 26 years). For the last nine years I have been principally engaged in diving for sea cucumber and trochus on the Great Barrier Reef, Coral Sea reefs and the Kimberley region of Northwestern Australia.

At present, I am the sea cucumber industry representative on the Queensland Fish Management Authority's advisory group. You may be aware that recently (1 October 1999) the Queensland government closed the blackteat fishery due to over-fishing on the Queensland east coast, south of 10° 41'S. Because efforts were expected to shift to whiteteat, a ceiling was imposed on the Total Allowable Catch for whiteteat, at 127 tonnes. The majority of industry supported the government's initiative, although a vocal minority still claim that catches of 100 kilograms per day of blackteat are acceptable. Personally, I fully support the government action, having seen the decline in several Australian sea cucumber fisheries in recent years.

4. From Scott Seale (15 May 2000)

Hello, I am a resident of the Caribbean island of Barbados, and I have been reading about the sea-cucumber fisheries in your part of the world with great interest. While diving on the reefs off Barbados, I see a large species of *Holothuria mexicana*. Is this an edible species of sea-cucumber, and would it be a valuable species with regard to edi-

Best regards

Manikandan K.P.

E-mail: manikandaan@hotmail.com

Please address surface mail to my house address, as there is no letter correspondence in our place in Maldives.

K.P. Manikandan, M.sc.
Plot D31,13, Nehruji Street
Jegatha Illam, First floor, Fifth stop house
Tirunagar, Madurai, Tamilnadu, India - 625006

Could you assist us by providing some information on the following :

- What are the approximate growth rates for black and white teatfish?
- What is the approximate age of sexual maturity for black and white teatfish?
- What are the spawning seasons for black and white teatfish?

It would be very much appreciated if you could provide any information at your earliest convenience.

Rob Lowden

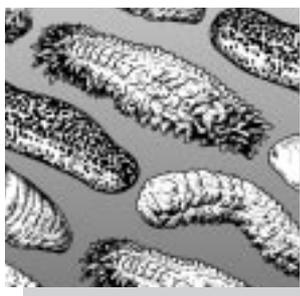
Seafresh Australia Pty Limited
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P.O. Box 712N North Cairns Q 4870 Australia

Ph.: 61 7 40550800 Fax: 61 7 40550491
RB Lowden Pty Ltd - RBL Holdings Pty Ltd -
Pacific Blue Technologies Pty Ltd
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bility? As far as I know, there is no local fishery for them, but perhaps a small export might be viable.

Thank you for your assistance and best regards,

Scott Seale (ers@sunbeach.net)



abstracts, publications, workshops & meetings beche-de-mer

Abstracts from the 10th International Echinoderm Conference 31 January- 4th February 2000, University of Otago, Dunedin, New Zealand

1- Contributed oral papers

Brooding behaviour of two southern New Zealand cucumariids (Echinodermata: Holothuroidea)

Niki Alcock

NIVA Nelson, P.O. Box 893, Nelson

Recent field collections at Stewart Island and Fiordland revealed brood-protection by *Squamocnus brevidentis* (Hutton, 1872) and *Squamocnus niveus*, O'Loughlin & Alcock, in press. At the time of the collections, a detailed reproductive study of *S. brevidentis* was in progress (Alcock, 1998), allowing the environmental parameters, day length and water temperature, to be related to the brooding cycle. *Squamocnus brevidentis* is an external brooder where the young are brooded under the adult female for period of one-to-three months. Early embryonic and pentacula larvae stages are brooded over this three-month period. Juvenile holothurians emerge as tiny replicas of the adults, and settle nearby. Collections of *Squamocnus niveus* were opportunistic, and brooding was found in only three specimens. Two specimens were collected in March 1998 and one in July 1997. *S. niveus* is an internal brooder with the young held in two large coelomic sacs in the body cavity. Specimens collected during September were found to be not brooding. The results indicate both species brood over the winter period and release eggs during spring when the water begins to warm. Paucity in the collections of *S. niveus* warrants further collecting.

A ganglionated plexus in the podial connective tissue of a sea cucumber

Michael J. Cavey

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The locomotor tube feet of echinoderms have a trilaminar organisation, consisting of an outer epidermis, a middle layer of collagenous connective tissue, and an inner coelomic myoepithelium. Flagellated adluminal cells and myofilament-bearing retractor cells populate the coelomic myoepithelium which lines the water-vascular canal. Adluminal and retractor cells anchor to a robust basal lamina at the interface of coelomic myoepithelium and connective tissue. Another prominent basal lamina segregates the epidermis from the connective-tissue cells and fibres. The connective tissue along the tube-foot shaft is typically aneural, so the closest neurones to the retractor cells are those in the subepithelial plexus of the epidermis. A more intimate relationship between neurones and retractor cells has been discovered in the trivial tube feet of the sea cucumber (*Parastichopus californicus*), where a neuronal plexus permeates the connective tissue. This connective-tissue plexus includes a large number of squamous ganglia near the basal lamina of the coelomic myoepithelium, as well as many slender connectives that link the ganglia to one another and to

the subepithelial plexus of the epidermis. The external lamina investing the ganglia and connectives is continuous with the epidermal basal lamina, indicating that the connective-tissue plexus is a component of the ectoneural division of the nervous system. Most neuronal somata situate within the ganglia, where they tend to concentrate along the external ganglionic surfaces. A few somata are apparent within the connectives. Clear membrane-bounded vesicles frequently aggregate in the neurites along the internal ganglionic surfaces. Since neurites never breach the basal lamina of the coelomic myoepithelium, they cannot synapse directly with the retractor cells. There is no ultrastructural evidence of neuroglial cells associated with either the somata or the neurites of neurones in the podial connective tissue.

Overview on the last decade of sea cucumbers fisheries, what means for a durable management ?

Conand C. & Jaquemet S.

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The data on the main world fisheries, tropical and temperate, traditional and contemporary, and their recent catches are analysed for the last decade. There is increasing interest in this commercial resource, many recent fisheries witnessing conflicts in relation to conservation needs. The processed product generally passes from the producer country to the main world markets in Hong Kong, Singapore and Taiwan, before being imported by the consumer countries. From different indices, overexploitation is becoming more and more noticeable worldwide as the demand for trepang increases. Durable management should become a priority and regulations should be adapted for these fisheries. Further studies should develop a greater understanding of the fisheries biology of the commercial species; stock assessments; improving available statistics on catches and markets. Despite an increasing interest, these fields are poorly understood, yet they deserve more attention, as their social value in small artisanal activities is high.

Spawning: Holothurian reproductive behaviour and egg quality in culture

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With the advent of sea cucumber aquaculture in the South Pacific region, a reliable method is needed to induce large numbers of animals to spawn in captivity. Successful husbandry of these animals depends on being able to obtain enough eggs for commercial scale production of seed. Broodstock of the sea cucumber *Holothuria scabra*, collected from Stradbroke Island, Moreton Bay (27°30' North, 153°24' East), Australia, during the reproductive season from October to January, were conditioned and used in spawning trials. During the 1997/98 summer, between one to five weeks of captivity, 100 % of animals were induced to spawn in four trials, occurring at dusk on, or close to, a new or full moon. Nine males and 9 females were contained in a 1.5 m² area, with 30 cm of 1 µm filtered sea water, using a 3 to 5°C temperature shock. *H. scabra* was induced to spawn in small numbers during 1996/97 and *en masse* during the 1997/98 summer, despite a marked degree of weight loss. The difference in fecundity (number of spawned eggs) between animals of similar size and mean fecundity in consecutive trials decreased, the longer the animals were held in captivity before spawning. The hatch rate of eggs was reduced significantly for broodstock held for more than one month. Hatch rate and fecundity are important indicators of egg viability of broodstock maintained in captivity for an extended period.

Dynamic mechanical properties of holothurian body-wall catch connective tissue

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The holothurian body-wall dermis is a well-studied catch connective tissue that shows rapid changes in its mechanical properties in response to various stimuli. Although there have been a number of publications that demonstrated 'stiffness' changes, their descriptions of the mechanical properties were superficial. The

catch connective tissues, as other soft biological materials, show viscoelasticity and non-linearity in stress-strain relationship and thus their mechanical properties show large dependencies both on strain and strain rate. There have been, however, no detailed descriptions on these dependencies. We performed dynamic mechanical tests in which sinusoidal deformations were applied to the isolated body-wall dermis of the sea cucumber *Actinopyga mauritiana*. Two series of tests were executed: one with a constant frequency of 0.1 Hz with varying strain amplitude of 2–20% (constant frequency experiment), and the other with a constant strain of 1.8% with varying strain rate of 0.005–50 Hz (constant strain experiment). In constant frequency experiments, we described the shape of the stress-strain curve, and measured stiffness and energy dissipation ratio. The non-stimulated dermis in normal artificial seawater above 5% strain showed a J-shaped stress-strain curve. The stiffness at 10% strain was 1 MPa and the energy dissipation ratio was 60%. The stiffened dermis, prepared by physical stimulation or chemical stimulation with media containing acetylcholine (10⁻⁴ M) or high concentration of potassium (100 mM), had a linear stress-strain curve with higher stiffness (3 MPa at 10% strain) and lower energy dissipation ratio (30% at 10% strain). The soft dermis prepared by Ca²⁺ removal had a J-shaped stress-strain curve with lower stiffness (0.3 MPa at 10% strain) and higher energy dissipation ratio (80% at 10% strain). The soft dermis showed the strain dependency that was never observed in other samples: when the dermis was deformed more than a certain limit (c. 10% strain), the stiffness decreased drastically as the strain increased. These results suggest that the dermis shows three distinct mechanical states, the standard state, the stiff state, and the soft state, that can be distinguished both qualitatively and quantitatively. In constant strain experiments, we measured storage modulus, loss modulus and loss tangent. From the modulus-frequency curves of three mechanical states, we could generate a smooth master curve by shifting the curve of stiff state towards the higher frequency direction and by shifting that of soft state towards the lower frequency direction.

The occurrence and role of a digitate genital papilla in holothurian reproduction

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An echinoderm genital papilla has been reported for only a few cucumariid and one gephyrothuriid holothurian species, and a few echinoid species. When present in holothurian species it normally occurs between or near the dorsal tentacle pair, and in some species it is digitate. In at least five holothurian species a long digitate genital papilla occurs on males and is reduced or absent on females. Evidence is presented in support of three hypotheses:

1. In cucumariid holothurian species a long digitate genital papilla is present on males, and reduced or absent on females, when the sexes are separate and when the females brood-protect in marsupia with external openings.
2. In cucumariid holothurian species embryos or juveniles in a marsupium are at the same stage of development when the sexes are separate and when the females brood-protect in marsupia with external openings.
3. In cucumariid holothurian species internal fertilisation, by means of the long male digitate genital papilla, occurs in the marsupium of the female when the sexes are separate and when the females brood-protect in marsupia with external openings.

Species discussed are the cucumariids *Cladodactyla crocea* (Lesson), the *Cucumaria georgiana* (Lampert) Group, *Cucumaria glacialis* Ljungman, *Cucumaria ijimai* Ohshima, *Cucumaria lamperti* Ohshima, *Ekmocucumis steineri* (Ludwig), *Heterocucumis coatsi* (Vaney), *Microchoerus splendidus* Gutt, *Neoamphicyclus lividus* Hickman, *Neocnus bimarsupii* O'Loughlin & O'Hara, *Ocnus sacculus* Pawson, *Pentocnus bursatus* O'Loughlin & O'Hara, *Pseudocnus laevigatus* (Verrill), *Pseudopsolus macquariensis* (Dendy), *Squamocnus niveus* O'Loughlin & Alcock (in press) and *Staurothyone inconspicua* (Bell); and the gephyrothuriid *Gephyrothuria alcocki* Koehler & Vaney.

Reproduction cycle of *Stichopus chloronotus* (Brandt, 1835) in the Straits of Malacca

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The reproductive biology of a commercially important sea cucumber, *Stichopus chloronotus* (Brandt, 1835), which is one of the dominant species found in the Straits of Malacca, has been investigated. Monthly sam-

ples were collected from February 1996 until March 1997. The reproductive state was assessed by the gonad index method and histological analysis of gonad tissue. The gonad index remained consistently high during March 1996 (3.2) and November 1996 (2.8), but reduced in April 1996 (1.4) and December 1996 (0.6). Differences for gonad indices between females and males of *S. chloronotus* were not significant. The maximum oocyte size was found in March 1996 and November 1996, indicating the time of gonad maturity. Maximum size of the mature oocytes measured was 91.8 µm with a mean size 74.5 µm. Analysis for correlation between gonad index and oocytes size were significant ($p < 0.05$). The gonad index increased with the increase in salinity and chlorophyll-a levels in the ambient seawater.

Correlation between the calcareous rings and zoogeographic distributions of *Thyone* species (Echinodermata: Holothuroidea) with a proposed management of the genus

Ahmed Thandar

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As a result of Panning's (1949) transference of *Havelockia* with its type species to the Sclerodactylinae and the remaining species to *Thyone* within the Thyoninae and the subsequent descriptions of numerous new species of *Thyone* by various authors, the latter genus has now assumed the status of a "super-genus" (Pawson & Miller, 1981). In fact, the genus has over time become a receptacle for all 10-tentacled dendrochirotidids with scattered podia, a complex calcareous ring and 2-pillared tables as body wall deposits. It currently comprises three groups of species: those with tables in the introvert, those with rosettes in the introvert and those with both tables and rosettes in the introvert. Thandar (1989) suggested a restriction of the subfamily Sclerodactylinae to forms with compact plates to their tubular calcareous rings as opposed to tubular rings with subdivided plates in the Thyoninae. He further erected the subfamily Sclerothyoninae to include those forms whose calcareous rings comprise compact plates which only meet at base and do not form a tube. Since Panning's (1949) revision some 81 species have been included in *Thyone*. Of these twenty have already been transferred to other genera or declared synonyms of some well-known species. Of the remaining 61 species, two do not belong in *Thyone* as defined by its type species, nine can be transferred to the Sclerodactylinae and seven to the Sclerothyoninae. To the remaining species must be added two species incorrectly assigned to *Havelockia* by Cherbonnier (1988), whereas two others, with half-rings to their tables, must be removed and referred to a new genus. The calcareous rings and body wall, tentacle and introvert deposits (where these characters are present) were examined in the remaining 43 species from literature or type and/or other material to demonstrate any correlation. Thandar and Rajpal (1999) reported three basic types of calcareous rings in *Thyone*: dorsal radial plates prolonged before bifurcation, dorsal radial plates incised (i.e. interradians prolonged), and dorsal radial (excluding processes) and interradial plates of same length. There is little or no apparent correlation between the type of calcareous ring and spicules but a strong correlation between the type of calcareous ring and the zoogeographic distribution of the various species. While all three types of calcareous rings occur in the Indo-West Pacific species, including southern Africa, it is observed that the Madagascar species have either the radials prolonged before bifurcation or are of the same length as the interradian plates, the North East Atlantic species have, with one exception, the radials prolonged and the West Atlantic and East Pacific species, without exception, have deeply incised radials. It is therefore suggested that if the calcareous ring and deposits are taken in combination, the genus can be split into smaller more manageable groups and the various species more clearly defined. However, no attempt is made here to erect any new nominal taxa.

The effect of fishing on the population structure of holothurians: Over exploitation of *Holothuria nobilis* on the Great Barrier Reef

Sven Uthicke & John Benzie

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Decreasing catch rates for *H. nobilis* (black teatfish) on the Great Barrier Reef prompted management agencies to close the fishery on this species in September 1999. The area most heavily fished is the Cairns and Cooktown Section and we surveyed densities and size structure of *H. nobilis* at several reefs in this area. Densities of *H. nobilis* on two reefs protected from fishing ('National Park Zone' or 'Buffer Zone') were nearly four times higher compared to nine reefs open to fishing ('Habitat Protection Zone'). Each of four further reefs investigated was divided into an area protected from fishing and an open area. On the largest

of these reefs (ca. 29 km long), densities of *H. nobilis* were nearly five times higher in the protected area compared to the area open to fishing. On three smaller reefs (ca. 5 to 11 km), however, densities were not significantly different between the open and protected area and were the same level as that on reefs completely open to fishing. Weight frequency distributions were unimodal on all reefs. Although there appears to be a tendency to find more large animals (> 2000 g total weight) on protected reefs, this cannot be unambiguously related to fishery, but may also be caused by environmental differences. Thus, beche-de-mer fishing lead to a strong reduction of density and biomass of *H. nobilis*. The division of smaller reefs into open and closed zones appears not to provide sufficient protection, but reefs that are completely closed to fishing appear to provide some degree of protection. However, until further information on connectivity, gene flow and recruitment processes are available, it is not possible to predict whether the number and size of the protected reefs is sufficient as a buffer and source of recruitment for the fished reefs.

Confusion on the morphotypes of *Stichopus variegatus* in the South China Sea

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The sea cucumber *Stichopus variegatus* is a commercial species found sporadically in the South China Sea. Recently the specimen that was thought to be *S. variegatus* is actually *S. horrens*. Therefore, the common *S. variegatus* has been renamed *S. hermanni*. We observed several types of Stichopodids that resembled *S. hermanni* in the South China Sea with differences in colour variation and body wall patterns. In addition there were behavioural differences. *S. hermanni* is a diurnal species while the other specimens were strictly nocturnal. There are no differences in the morphometric measurements of the polian vesicles, madreporic body and the stone canal from the pharyngeal bulb between the specimens. Observation of the types and size of spicules also did not show any obvious differences between the two types of sea cucumber.

2. Poster abstracts

Circadian rhythms in *Chiridota rotifera* (Echinodermata: Holothuroidea).

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Chiridota rotifera is a small apodous holothurian that occurs in coarse sand, in the intertidal zone in São Sebastião, State of São Paulo, Brazil (23°49'S, 45°25'W). The main purpose of this work was to determine the factors that could influence the activity patterns of these animals in the laboratory. Two periods of observations were run: the summer experiment took place in February/99 when the holothurians were submitted to a photoperiod of approximately 14 hours of light and 10 hours of darkness. They were observed in two experiments that lasted 72 hours each. The winter experiments took place in July/99 with two periods of 48 hours of observation each with a photoperiod of approximately 12 hours of light and 12 hours of darkness. During these experiments the behaviour of the animals was observed at every 30 minutes. Three groups, with six animals each, were prepared: one with holothurians collected in their natural habitat and maintained in laboratory since 1993/94, one with specimens born in laboratory between 1995 and 1997, and the last with holothurians collected in the environment 24 hours before the beginning of the experiments. The animals were kept in 350 ml plastic cups containing a layer of 150 ml of sand from the same place where the first specimens were collected and 140 ml of seawater. Each cup contained only one individual. The cups were covered with a film of clear plastic, placed next to a large window in the laboratory and thus submitted to the natural lighting. Room temperature and seawater salinity were kept constant. At the end of the observations it was determined that the holothurians of the three groups behaved in the same way; remaining buried in the sand during daylight hours, exploring the sand surface between sundown and sunrise. In these periods they moved actively about the cups exploring the surface of the sand, the cup walls and the plastic film that covered them. Such data indicate that *C. rotifera* move about in their natural environment in the less illuminated hours of the day, probably avoiding desiccation and/or predation.

Extracellular matrix remodeling during intestinal regeneration in the sea cucumber *Holothuria glaberrima*

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Visceral regeneration in holothurians provides one of the most striking examples of regenerative organogenesis in nature. We are using the sea cucumber *Holothuria glaberrima* as a model system to study organ formation in adult organisms. Following evisceration, the free edges of the mesenteries give rise to a new digestive tract in six well described stages. Intestinal regeneration occurs by intense cell and tissue reorganisation within the regenerating structure giving rise to the tissue layers found in the normal digestive tract. We have used monoclonal and polyclonal antibodies against extracellular matrix (ECM) components to observe matrix changes in the regenerating structures by immunohistochemistry. ECM degradation and changes in composition are common events associated with embryogenesis and regeneration. Our results show that in the sea cucumber, dramatic changes in collagen expression and other ECM-related molecules occur within the intestinal primordium. However, certain components of the ECM, particularly those of the basal lamina, maintain their organisation throughout the formation of the new intestine. Reorganisation of the ECM components to pre-evisceration conditions begins to be reestablished after lumen formation. Immunohistochemical results coincide with enzymatic analysis for metalloproteases. In collagen gelatin zymographies, we have identified four 1,10-phenanthroline sensitive bands. The gelatinolytic activity of these bands is enhanced during early stages of regeneration, suggesting that metalloproteases are associated with the observed matrix remodelling. Our results show that significant changes in extracellular matrix occur during the process of intestinal regeneration in the sea cucumber.

Cuvierian tubules in tropical holothurians: usefulness and efficiency as a defence mechanism

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The tropical holothurians, *Holothuria leucospilota*, *Bohadschia argus* and *B. marmorata* responded to tactile stimulation by expelling Cuvierian tubules in proportion to the intensity of the stimulation. They were able to target the stimulated area with variable success depending on the location of the stimulus. Field surveys showed that 2.3–6.1% of *H. leucospilota* presented signs of having recently used their Cuvierian tubules and laboratory experiments revealed that they released tubules in response to several natural predators. The tubules did not adhere nor cause any distress to fish, but proved effective in discouraging attacks. Crabs, molluscs and echinoderms were entangled and also efficiently repelled. *H. leucospilota* without tubules were wounded and even killed by predators that were usually discouraged by tubule discharge. Conversely, after having induced the release of tubules once, 96% of the predators placed in the presence of *H. leucospilota* three days later remained at a distance. Released tubules that did not adhere to any surface were quickly retracted, while regeneration of a complete set of tubules took 15–18 days. The release of Cuvierian tubules by holothurians therefore appears to be an efficient and readily used defence mechanism.

A rearing method for *Chiridota rotifera* (Holothuroidea, Apoda)

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The apodous holothurian *Chiridota rotifera* is a small brooding species that occurs from the shallow waters of Bermuda to southeast Brazil. Its ten-centimetres-long body has a worm-like appearance and a skin

marked by white papillae containing skeleton plates in the shape of wheels. This benthic animal inhabits the coarse sandy substrata found around rocks and pebbles of varied sizes. The present work reports a new methodology to rear this species in captivity. The holothurians were kept in three reservoirs containing sand from Istmo do Baleeiro (23°49'44" S e 45°25'24" W), where these animals occur. The tanks supplied with running seawater had a volume of 250 litres each, and the animals were confined into small rearing PVC cages (10 centimetres in diameter). Both ends of these rearing cages were covered with a tightly fitted-piece of 500- μ m mesh plankton net. The use of plankton net allowed a continuous water percolation through the sand into rearing cages. Each cage received one or two holothurians and was filled with sand from the collecting site. The aim of such methodology was to minimise the differences between confined and natural environments. The rearing methods here devised for *C. rotifera*, provided the tools to follow the life cycle of this species for over 19 months. This technique also allowed the analysis of the growth rate and of aspects of offspring release by *C. rotifera*. The experiments also provided information regarding the best time intervals between sand changes inside the cages and on the need or not of adding extra food. It was observed that a 15-day interval between sand exchanges in the cages was appropriate. With this procedure it was possible to have mature animals, releasing dozens of young, at an age of six months.

Settlement preferences and early migration of the sea cucumber *Holothuria scabra*

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Also presented at: 34th European Marine Biology Symposium, 13-17 September, Ponta Delgada, Açores, Portugal.

Settlement and post-settlement processes of the sea cucumber *Holothuria scabra* were studied in the laboratory. Independent and paired choice experiments revealed that several substrates could induce metamorphosis into pentactulae but that specific substrates favoured settlement. *Thalassia hemprichii* leaves, with or without their natural bio-film, yielded the highest settlement rates (4.8 to 10.5%). *T. hemprichii* was preferred as a settlement substrate over sand, crushed coral, several other plant species and artificial seagrass leaves with or without a bio-film. Only settlement on the seagrass, *Enhalus acoroides*, was similar to that recorded for *T. hemprichii*. In the absence of a substrate, the larvae delayed settlement for nearly 96 hours and survival was less than 0.5%. Sand and crushed coral, either alone or together, attracted settlement from <1.5% of the available larvae. The pentactulae found on sand, coral and in bare containers were 10–35% smaller than those on *T. hemprichii* leaves. Soluble extracts from *T. hemprichii* and *E. acoroides* successfully induced metamorphosis and settlement on clean plastic surfaces. Newly settled juveniles remained on the seagrass leaves for 4–5 weeks before migrating to sand at around 6 mm in length. Prior to this, the juveniles spent 4–5 days moving on and off the leaves. Once on the sand, the juveniles became deposit-feeders, but did not show the typical burrowing behaviour of older specimens until they reached around 11 mm in length. The larvae of *H. scabra* appear to actively select seagrass leaves, possibly through chemical detection. We hypothesise that larvae settling on seagrass have an increased chance of growth and survival because they are provided with a suitable substrate on which to grow, and a bridge to sand substrates as they become deposit-feeders.

Movement, recruitment and size-related distribution of sea cucumbers *Holothuria Scabra* in Solomon Islands

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Field study of sea cucumbers *Holothuria scabra* conducted in Kogu Veke, Solomon Islands, showed monthly recruitment of newly-settled juveniles on seagrass and indicated that size distribution was a function of substrate type and depth. Adults >250 mm were found mainly on sand, with <5% organic matter (OM), at

depths of >1–3 m. Individuals >10–250 mm were found mostly in 30–120 cm of water, on mud and muddy sand with OM content between 5 and 10%. Specimens >40–150 mm were also found in the intertidal zone, sometimes burrowed on exposed sandflats at low tide. *H. scabra* avoided substrates of fine silt or shell and coral pebbles, and sediment with an organic content $\geq 30\%$. Juveniles ≤ 100 mm burrowed at sunrise and surfaced at sunset, whereas individuals >100 mm burrowed and surfaced a few hours earlier. *H. scabra* tended to burrow when salinity decreased, whereas increased water temperatures reduced normal burrowing behaviour. Spatial distribution observed during tank experiments suggested that adult *H. scabra* aggregated prior to spawning and in response to the lunar cycle. The formation of pairs, trios or larger groups increased during the new moon and was most common just before the full moon. Newly-settled juveniles up to ca. 9 mm were found on seagrass leaves. Typically, maximum densities and smallest recruits were observed a couple of weeks after the full moon, lower densities and slightly larger recruits were found a few days later. Juveniles with a mean size around 65 mm released on sand moved less and grew faster than juveniles released in seagrass beds or on substrates of shells and crushed coral.

The potential role of the holothurian *Pseudocnella sykion* as a bioindicator species of heavy metals, based on energy dispersive X-ray analysis (EDX)

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Considering the general lack of funds available for the assessment and maintenance of the environment, contemporaries in the field of ecotoxicology have stressed the scientific and economic importance of bioindicator species in pollution studies. The object of this study was to investigate whether the hard structures of the holothurian *Pseudocnella sykion* were accumulating heavy metals from their environment. A positive result could reveal a potential bioindicator species. The animal was chosen due to its abundance within its geographic range and the fact that it fulfilled the prerequisites of a bioindicator species. The study was conducted in South Africa, at two sites along the KwaZulu-Natal coastline. Tinley Manor beach was the control site, and Merebank Cutting beach the experimental site. In order to determine background levels of heavy metals at the control and experimental sites the soft tissues of the brown mussel *Perna perna*, a known bioaccumulator of heavy metals, were analysed by atomic absorption spectrometry (AA). Aluminium and iron were the only elements to have accumulated in mussels from the polluted area in significant amounts. Energy dispersive X-ray microanalysis (EDX) was used to analyse the elemental composition of spicules and calcareous rings. No significant accumulation was noted in calcareous rings and this aspect is not discussed in the present poster. However, aluminium levels in spicules were found to be higher in the experimental animals than in the control animals ($p = 0.0018$). This positively correlated with the atomic absorption spectrometry data from *Perna perna*. *Pseudocnella sykion* is tentatively regarded as a bioindicator species. Consequently, the validity of energy dispersive X-ray analysis in heavy metal analysis of this nature is briefly discussed.

Research and development of farming the sea cucumber *Stichopus mollis* for value-added products.

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Recently, interest has focused on the fishery potential of the Southern Hemisphere temperate sea cucumber *Stichopus mollis*. The New Zealand sea cucumber *S. mollis* forms a visible, yet relatively unstudied component of sub-tidal northeastern New Zealand. An aspidochirote holothurian, *S. mollis* is perhaps one of the best known of the New Zealand sea cucumbers. Common in shallow waters, it can be found on the rocky shores and sandy mud bottoms of many coastlines around this country and parts of southern and western Australia and Tasmania. The muscle bands of some species are used as clam substitutes in Asia and the United States, and the body wall has been consumed in dry tablet form. Even an extract of boiled skin is drunk as a tonic in Malaysia. The gut and gonad are consumed salted or dried. Only certain species are valued for beche-de-mer production, and are primarily composed of the aspidochirote sea cucumbers, (e.g. *S. mollis*). The expansion of sea cucumber mariculture and fisheries in

New Zealand and the development of value-added products would increase substantially the export value of *S. mollis*. Presently in aquaculture operations there is a tendency to cultivate a single species, resulting in a certain amount of un-utilised waste due to left over feed and high nutrient effluent from culture systems. The sea cucumber *S. mollis* may be able to utilise this waste, improving farm and effluent water quality and providing a secondary product at minimal expense. With the high demand from China and Japan for value-added sea cucumber products, the development of sea cucumber farming may return high dividends at a commercial scale.

Reproduction and development of sea cucumbers in Solomon Islands: implications for beche-de-mer broodstock availability.

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Tropical sea cucumber stocks have been severely overfished in many developing island nations. Overfished stocks can take over 50 years to recover and the release of hatchery-produced juveniles is being examined as a means of restoring stocks. Production of juveniles is dependent on the availability of good quality gametes. This study investigated reproduction of *Holothuria fuscogilva*, *H. scabra* and *Actinopyga mauritiana* in Solomon Islands. The reproductive cycles of these species were documented by the gonad index method, gonad histology and spawning trials. All three species have annual cycles with reproductive peaks for *H. fuscogilva* and *H. scabra* recorded from August to November and for *A. mauritiana* from October to December. During peak seasons, mature wild-caught broodstock were conditioned and induced to spawn either by thermal stimulation or by addition of dried algae, *Schizochytrium* sp., to holding tanks. Spawning results indicate *H. scabra* spawns year-round with greater spawning activity during the peak season. Spawning of *H. fuscogilva* and *A. mauritiana* is limited to the peak seasons. In all three species, larval development is planktonic with metamorphosis of auricularia into a non-feeding doliolaria stage. The pentacula stage marked the transition from a planktonic life style to a benthic mode of existence.

Holothurians from the Brazilian coast: an historical survey

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Echinoderm studies in Brazil have always been characterised by a generalistic approach where the group is shown at the most as a component of the benthic fauna of a given area. The history of such studies may be traced back to 1648, when Marcgrave reported the first echinoderm species from the Brazilian coast, till a recent paper by Hadel *et al.* (1999), on the biodiversity of echinoderms in Brazil. The literature concerning holothurians appears at the beginning of the nineteenth century, being composed by papers of European and North American researchers who identified echinoderms from Brazilian coastal waters collected by scientific expeditions. From Verrill (1868) to Tiago *et al.* (1999 a,b) 32 valid names have been ascribed to the Brazilian coast (7,367 km) and only 14 to the 622 km of coast of São Paulo State. These numbers represent, respectively, 2.6% and 1.1% of the 1250 known holothurians around the world (Smiley *et al.*, 1991). This comparison which, at a first glance may indicate a low occurrence of sea cucumbers on the Brazilian coast, should be more properly attributed to a lack of systematic sampling of these echinoderms. In fact, the number of identified holothurians in Brazil should grow quickly in the near future if one keeps in mind that the greatest diversity of holothurians occurs in shallow tropical waters (Pawson, 1982). Species with a wide geographical distribution predominate in the Brazilian holothurian fauna, with 75% of our holothurians reaching at least the Caribbean area. Another well-represented group is that of the so-called endemic species, which appears in a proportion of 21.9%. According to the literature, many holothurians have their southern point of geographical distribution in the São Sebastião Channel (SSC; São Paulo State). However, species such as *Isostichopus badionotus* and *Holothuria grisea* have been found at Santa Catarina State, some 750 km south of SSC (Dr. R.M. Rocha, personal communication, 1998).

otrophic, low oxygen conditions prevailed. Remains of holothurians from the Chalk of Rügen were mentioned by Schacko (1897) for the first time. Questionable holothurian sclerites from Rügen are figured by Ehrenberg (1840). Müller (1964) described six paraspecies of the paragenera *Theelia*, *Hemisphaeranthos* and *Eocaudina* (Apodida and Dendrochirotida). During new investigations of more than 150 samples (Reich, 1997), approximately 25,000 holothurian sclerites were isolated from the sediment. In all profiles on the Isle of Rügen the number of holothurian sclerites per 100 g of primary sediment varies between 500 and 2,000 specimens. Up to now 43 paraspecies of Holothuroidea from the Maastrichtian chalk of Rügen are known, representing the following orders: Dendrochirotida Grube, 1840; Aspidochirotida Grube, 1840; Elaspoda Théel, 1882; Molpadiida Haeckel, 1896 and Apodida Brandt, 1835. Pieces of the calcareous ring from the Rügen Chalk document the first record of these elements from the Upper Cretaceous. Remains of Aspidochirotida Grube, 1840; Molpadiida Haeckel, 1896 and Apodida Brandt, 1835 proved to be the most abundant groups in all investigated samples. Thus, in the Chalk of Rügen, deposit-feeders like Aspidochirotida, Apodida and partly Elaspoda and Molpadiida seem to predominate. Suspension feeders were found less frequently. The vast majority of the holothurians of Rügen lived vagile epibenthic and respectively vagile infaunal.

Ophiocistioids and holothurians from the Silurian of Gotland, Sweden

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Since records of complete specimens of the exclusive Palaeozoic Ophiocistioidea are extremely rare, the goniodonts of the masticatory apparatus give valuable clues for the stratigraphic and geographic distribution of this extinct group of Echinodermata. So far representatives of this animal group are known from the Middle Ordovician to the Permian. Smith (1984) suggested a closer relationship of the Ophiocistioidea with the Holothuroidea. Together with the holothurians they form the sistergroup of the Echinoidea, according to Smith (1988). Recently the Ophiocistioidea were assigned as a separate order to the class of Holothuroidea due to strong morphological similarities (Simms et al. 1993).

Silurian Ophiocistioidea are described exclusively from the lower Ludlowian of England (Dudley und Leintwardine): *Eucladia johnsoni* Woodward, 1869 and *Sollasina woodwardi* (Sollas, 1899) [see: Haude & Langenstrassen 1976a, 1976b]. Franzén (1979: 223) doubts the existence of ophiocistioids in the Vattenfallet section (Wenlockian) on the Isle of Gotland.

In the Upper Silurian Eke Beds (Ludlowian) of Petsarve (Isle of Gotland, Sweden) more than 30 isolated goniodonts of Ophiocistioidea were found. Three morphological types can be distinguished. They probably can be assigned to the genera *Anguloserra*, *Klukovicella* and *Sollasina*.

Determinations based on goniodonts are rather difficult and partly uncertain as investigations of morphological differences between juvenile and adult forms of the goniodonts are lacking so far due to material shortage. Further investigation is necessary, especially on species that were established based on one goniodont-specimen only (e.g. Schraut 1993: *Anguloserra austriaca*).

First sparse remains of Silurian holothurians were recorded from the Upper Silurian (Ludlowian) of Austria by Mostler (1968: Fig. 10). Silurian holothuroids were mentioned subsequently from the Lower Silurian (Wenlockian) of the Isle of Gotland (Sweden) (Franzén, 1979) and from calcareous marl erratics of Northern Germany (Lower Silurian; Reich, 1997: table 2). Wang & Li (1986: pl. 1, fig. 10) figured a sclerite (*Eocaudina septaforaminalis*) from the Pridolian of China. Remarkable is the record of a complete sea cucumber from the Pridolian of Australia under description by P.A. Jell (in Gilliland, 1993: 63; discussed by Haude, 1995: 193). According to Gilliland (1993: table 7) the latter is a representative of the Dendrochirotida/Dactylochirotida.

The senior author works on holothurian sclerites from the Slite Beds (Lower Silurian) of Gotland, mentioned by Franzén (1979: 218). Further new material of holothurian skeletal remains (ossicles and also pieces of the calcareous ring; see Reich, 1999) comes from Upper Silurian samples of the Eke Beds near Petsarve (Isle of Gotland, Sweden). Worth mentioning are the three processes of the radialia, which are already known from the Lower Devonian of the Czech Republic (Prokoph, 1993).

Differentially expressed genes during intestinal regeneration in the sea cucumber *Holothuria Glaberrima*

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The regeneration capability of echinoderms is well known, however few studies have focused on the cellular and molecular events underlying this phenomenon. We are using the sea cucumber *Holothuria glaberrima* as a model system to elucidate the molecular aspects of regeneration. In order to find genes that are expressed during the regeneration process, and specifically those needed to initiate, control and direct the regeneration of the digestive tract we have used two strategies: differential library screening and differential display. In the former we have compared two cDNAs libraries (non-eviscerated vs. regenerating intestine) searching for sequences found exclusively in one library. In the second strategy, randomly amplified fragments were generated by RT-PCR and separated by gel electrophoresis, obtaining a distinct pattern of bands that represent differentially expressed genes. Primary candidates are genes whose expression is regeneration specific or is up-regulated during the regeneration process. Preliminary results for the differential library screening produced 15 positive clones with different degrees of homology to known genes in genomic databases. Differential display produced 70 differentially expressed bands between non-eviscerated and regenerated tissue. Most of these bands were cloned and are being analysed. The positive clones will be used as probes for screening a regenerated tissue cDNA expression library to obtain full-length cDNAs. Preliminary results from our search suggest that the sea cucumber provides an excellent model to identify novel sequences relevant to the regeneration process as well as to characterise genes whose function is associated with organogenesis.

Population genetics of a commercially fished holothurian (*Holothuria scabra*, Sandfish) on the Queensland coast

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Along the east coast of Australia, *Holothuria scabra* occurs in two distinct colour variants and inhabits shallow intertidal areas and deeper (~18 m) subtidal areas. With the help of allozyme analyses we aimed to investigate I) if the two colour variants represent two species or are colour morphs of one species and II) if deeper populations are genetically distinct from shallow water populations. Seven polymorphic enzyme systems showed no significant differences in allelic frequencies between grey and black colour variants in three locations where these two variants occur sympatrically. It was thus concluded that these constitute colour morphs of the one species. F-statistic analyses revealed significant population differentiation (FST over all loci: 0.068, $p < 0.05$) caused by differences between populations around Fraser Island compared with one population ca. 800 km further to the north (Upstart Bay). Neither F-statistics nor UPGMA clustering revealed differences between the deep-water population sampled and the nearest (ca. 30 km) intertidal population. However, animals from the subtidal population are distinctly larger (average length: 26.9 cm) than shallow water animals (17.8 cm). These findings are consistent with the hypothesis that shallow water seagrass beds are important recruitment and nursery areas for juvenile *H. scabra*. Animals may then migrate to deeper areas during later stages of their live cycle. However, overfishing in shallow areas or different growth rates between habitats cannot be ruled out as alternative explanations for differences in sizes between shallow and deep areas.

Other abstracts from diverse publications

Daily activities of juvenile sea cucumbers *Holothuria scabra* in response to environmental factors.

Annie Mercier, Stephen C. Battaglene & Jean-François Hamel

Source: 34th European Marine Biology Symposium, 13-17 September 1999, Ponta Delgada, Açores, Portugal. 1999.

This study revealed that the daily activities of juvenile *Holothuria scabra* reflect their ability to inhabit shallow sandy areas with high terrigenous inputs and variable environmental conditions. All individuals exhibited daily burrowing and feeding rhythms in response to environmental factors. The activity cycle of the smallest juveniles, >10-40 mm, was linked to light; they began to burrow around sunrise and emerged close to sunset. Their burrowing activity was inhibited by continuous darkness. Juveniles >40-140 mm responded to changes in temperature; they burrowed earlier around 03:30, seeking shelter in the sediment as temperature declined, and emerged around mid-day. The maintenance of a constant warm temperature prevented them from burrowing. For all juveniles, time spent on the surface corresponded with feeding and periods of locomotion; while burrowed they remained stationary, did not feed and had a low intestinal transit. Organic matter content in the intestine was also found to vary with the daily cycle. Decreases in salinity from 35 to 30, 25 and 20 induced the burrowing of all juveniles within minutes, but they began to re-emerge after a few hours. Acclimation occurred most rapidly at salinity 30 and was slowest at salinity 20. However, nearly 40% of the juveniles were unable to cope with a decrease to salinity 15. Juveniles of all sizes demonstrated a strong selectivity for sediments of sand with a grain size around 0.4 mm and for organically rich material; their preferences were firmly expressed within an hour.

Distribution and population structure of the sea cucumber *Holothuria scabra* in the Solomon Islands.

Annie Mercier, Stephen C. Battaglene & Jean-François Hamel

Source: 34th European Marine Biology Symposium, 13-17 September 1999, Ponta Delgada, Açores, Portugal. 1999.

Surveys of sea cucumbers *Holothuria scabra* in Kogu Veke, Solomon Islands, indicated that the bay was colonised by multiple cohorts and that size distribution was a function of substrate type. Adults (150 mm) were found mainly on sand containing (5% organic matter (OM), in (1 m of water. Individuals 40-150 mm were usually found on muddy sand at the margin of the intertidal zone, burrowed on the shore at low tide and in the subtidal area where the OM content varied between 5 and 10%. Individuals <40 mm in length were located on muddy substrates and around seagrass beds at a depth of ca. 50 cm. Substrates of fine mud with an organic content (12% were virtually avoided by all size classes. Data compiled on rainy days indicated that *H. Scabra* tended to burrow in the sediment to avoid decreases in salinity. Inversely, the animals remained on the surface when water temperature was high even when they were 'normally' burrowed. Laboratory experiments showed that aggregative behaviours were in part responsible for the variability in the spatial distribution of adult *H. scabra* over time. The formation of pairs, trios or larger groups of adults increased during the new moon and was commonest just before the full moon. Newly-settled juveniles up to 10 mm were found on seagrass leaves. Maximum recruitment was recorded in the middle of the moon cycle, showing an inverse correlation with the abundance of larval predators. Data from the surveys should benefit stock enhancement and restoration programs in planning the release of hatchery produced juveniles.

Life cycle of the pea crab *Pinnotheres halingi* sp. nov., an obligate symbiont of the sea cucumber *Holothuria scabra* Jaeger

Jean-François Hamel, Peter K.L. Ng & Annie Mercier

Source: Ophelia 50 (3): 149-175 (July 1999)

A new species of pea crab, *Pinnotheres halingi* sp. nov. (Pinnotheridae), found encysted in the right respiratory tree of the sea cucumber, *Holothuria scabra* (Holothuridea), from Solomon Islands, is described. The

reproduction, infestation and pairing behaviour of the crabs were investigated through field observations and experiments. Infestation frequency in 8 monthly samplings of 25–30 holothurians was $98.6 \pm 2.6\%$ in Kogu Halingi bay and 0% in two nearby sites. Of 403 pea crabs, 91.4% were found in pairs of opposite sex, 7.9% were single females and <1% were single males. The embryos developed on the female pleopods over ca. 30 days from fertilisation to the release of first zoeae and subsequently went through five pelagic zoeal stages. Infestation occurred at the megalops stage after 59 days of development. A single pea crab (male or female) per host was found three months after larval infestation. Young males appeared to be strongly attracted to hosts that sheltered a single female, suggesting that pairing occurred as a male <6 mm carapace width joined a female. Larger crabs could not enter the host. Copulation was observed within the female cyst, preceding or overlapping oviposition. The male then progressed away from the female and from the anus, forming its own cyst along the way. Both larvae and small sub-adults invaded *H. scabra* with a minimum length of 80 mm, exclusively. *P. halingi* induced atrophy of the right respiratory tree of its host and can therefore be considered a parasite of *H. scabra*.

Induction of spawning in the sea cucumber *Holothuria scabra* (Echinodermata: Holothuroidea)

Anthony D. Morgan

Source: Journal of the World Aquaculture Society 31(2): 186-194. (2000)

With the advent of sea cucumber aquaculture in the South Pacific region a reliable method is needed to induce large numbers of animals to spawn in captivity. Broodstock of the sea cucumber *Holothuria scabra*, collected from Stradbroke Island, Moreton Bay (27°30' N, 153°24' E) Australia, during the reproductive season from October to January, and used in spawning trials. During the 1997/98 summer between one to five weeks of captivity, 100% of animals were induced to spawn in four trials at dusk on or close to a new or full moon, using 9 males and 9 females contained in a Reln tank and 30 cm of filtered sea water, using a 3 to 5°C temperature shock. *H. scabra* was induced to spawn in small numbers during the 1996/97 summer despite a marked degree of weight loss and all animals spawned during the 1997/98 with minimal loss of weight. The difference in the number of spawned eggs between animals of similar size and mean numbers of spawned eggs in consecutive trials decreased the longer animals were held in captivity before spawning. The hatch rate of eggs was reduced significantly for broodstock held for more than one month. Hatch rate and numbers of spawned eggs are important indicators of egg viability of broodstock maintained in captivity for an extended period.

Patterns of seasonal and tidal feeding activity in the dendrochirote sea cucumber *Cucumaria frondosa* (Echinodermata: Holothuroidea) in the Bay of Fundy, Canada

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Source: Marine Ecology Progress Series

In situ field observations of the suspension-feeding North Atlantic sea cucumber *Cucumaria frondosa* from the Bay of Fundy, Canada, conducted over a 3-year period, revealed a seasonal feeding rhythm. Sea cucumbers extended their tentacles and began feeding in March/April and ceased feeding in September/October. There were significant relationships between this feeding activity, day length and the quality of the seston, but not its concentration. Together day length and chloropigment concentration explained 49% of the variability in the percentage of feeding sea cucumbers. Feeding activity was not significantly correlated with the distinct temperature cycle observed in the study area. Feeding activity was influenced by the state of the tide, water temperature and by daylight during some periods of the feeding season. However, for most of the year these factors appeared not to be important. Sea cucumbers increased their rate of tentacle insertion into the mouth as the quality of the seston increased. The rate of tentacle insertions increased with increasing seston chloropigment concentration but decreased with increasing current speed. These two environmental variables explained about 28 % of the variability in tentacle insertion rates. Seston quality is likely the major environmental variable influencing seasonal feeding behaviour and feeding rate in this species.

The feeding ecology and reproductive cycle of the sea cucumber *Cucumaria frondosa* (Gunnerus) from the Bay of Fundy

PhD Thesis abstract by Rabindra Singh

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Preliminary observations indicated that *Cucumaria frondosa* (Gunnerus) in the Bay of Fundy did not feed throughout the year; hence, the overall objectives of this project were: a) to determine the factors influencing feeding activity using laboratory experiments and *in situ* video monitoring; and b) to correlate the seasonal feeding activity with the reproductive cycle. In laboratory experiments, sea cucumbers were exposed to different chloropigment concentrations by manipulating the seston concentration. As seston chloropigment concentration increased, the percentage of sea cucumbers feeding increased reaching a maximum before leveling off. Tentacle insertion rate of sea cucumbers increased with seston chloropigment concentration and up to a critical level, the amount of chloropigment in sea cucumber stomachs also increased. Field observations of *Cucumaria frondosa* at a shallow-water site revealed a seasonal feeding rhythm. Sea cucumbers extended their tentacles and began feeding in March/April and ceased feeding in September/October. Day length and seston quality explained most of the variability in percentage feeding. Feeding activity was not significantly related to the distinct annual temperature cycle. As in the laboratory, sea cucumbers increased their rate of tentacle insertions as seston quality increased, however, tentacle insertion rate was negatively related to the current velocity. Both long- and short-term observations indicate that seston quality is likely the major environmental variable influencing feeding activity. *Cucumaria frondosa* displays an annual spawning season from May to July. Sea cucumbers from both shallow and deep sites displayed synchronous reproductive cycles. Clear indications of spawning were shown by decreases in gonad dry weight, volume fractions of tubule wall and spermatids, and by dramatic increases in testis haemal fluid. Tubule cross-section areas were smallest just after spawning. Spermatogenesis starts immediately after one spawning event and tubules become filled with spermatids and spermatozoa months before the next spawning. Different sized oocytes were always present in ovarian tubules, however, dramatic decreases in the occurrence of the largest oocytes occurred at spawning. Environmental factors explained more of the variability of the histological measurements in males than females. Correlations between histological measurements and feeding activity were low. Gametogenesis continues throughout the seasonal non-feeding period indicating the probable use of nutrient reserves

Feeding response of the Dendrochirote sea cucumber *Cucumaria frondosa* (Echinodermata: Holothuroidea) to changing food concentrations in the laboratory

Rabindra Singh, Bruce A. MacDonald, Peter Lawton & Martin L.H. Thomas

Source: Can. J. Zool. 76: 1842–1849 (1998).

Sea cucumbers (*Cucumaria frondosa*) (Echinodermata: Holothuroidea) held in flow-through tanks were exposed to different chloropigment concentrations by manipulating the seston concentration via the use of water filters in the inflow lines and the addition of cultured algae or natural plankton to tanks. The percentage of sea cucumbers open and feeding increased asymptotically as the seston chloropigment concentration increased. Below 50 µg.L⁻¹ the percentage of sea cucumbers with tentacles extended and feeding decreased. The rate at which sea cucumbers inserted their tentacles into their mouths (0.96 ± 0.34 insertion/min (mean \pm SD)) increased with increasing seston quality. *Cucumaria frondosa* fed at faster rates at the higher concentrations. There was a significant positive relationship between the stomach content (amount of chloropigment) of sea cucumbers and the seston chloropigment concentration to which they were exposed ($r^2 = 0.200$, $p < 0.001$).

Reef-dwelling Holothuroidea (Echinodermata) of the Spermonde Archipelago (South-West Sulawesi, Indonesia)

Claude Massin,

IRScNB, Malacology Section, 29 rue Vautier, 1000 Bruxelles, Belgium.

Source: Zool. Verh Leiden 329, 30.x.ii. (1999): 1–144, Figs 1–114. —ISSN 0024-1652/ISBN 90-73239.74–5.

During a survey at the Spermonde Archipelago (22.viii-5.x.1994) 56 holothurian species were collected; ten are new to the fauna of Indonesia and one is new to science: *Stichopus quadrifasciatus* spec. nov. Most of the

species are described, figured and discussed. As far as possible, all literature records from 1970 onwards are listed and a distribution map is given for each species.

Distribution and biomass of the red sea cucumber, *Parastichopus californicus* (Stimpson), found in inlets of north British Columbia

K.E. Cripps & A. Campbell

Source: Can. Tech. Rep. Fish. Aquat. Sci. 2300: 14 p. (2000).

Population numbers and harvestable biomass of the sea cucumber, *Parastichopus californicus* (Stimpson) were surveyed, within a depth range of 0 to 15.24 m chart datum in six inlets of the north coast of British Columbia. The estimated mean split-weight biomass per km of shoreline ranged from 2.8 to 6.4 t km⁻¹. Sea cucumbers were found most frequently on hard complex substrates and least frequently on soft substrates. At depths surveyed, sea cucumbers were most abundant in depths between 1 to 2 m below which densities generally declined with depth. Drained eviscerated weight varied between survey locations, reflecting different population size structures, however, the percentage of perivisceral fluids, muscle, and skin, in relation to total weight, were similar between areas.

Scientific advice for management of the sea cucumber (*Parastichopus californicus*) fishery in British Columbia

J.A. Boutillier, A. Campbell, R. Harbo & S. Neifer

Source: G.E. Gillepsi and L.C. Walther [eds.]. Invertebrate Working Papers reviewed by the Pacific Stock Assessment Review Committee (PSARC) in 1996. Can. Tech. Rep. Fish. Aquat. Sci. 2221. 309–340. (1998).

Sea cucumbers from the coral reef to the world market

J. Akamine

Source: Jun Akamine. Bisayaon knowledge, movement & identity, VMAS III, 1996–1999. I. Ushijima and C.N. Zayas, (eds). Quezon City: Third World Studies Center, University of Philippines. (2000).

Balatan, Holothurian or sea cucumbers, is one of the major marine resources in the Philippines and an important export product. The *balatan* trade has undergone changes, mainly due to increasing demand and vanishing supplies that require serious consideration if the industry is to survive. The study provides an overview of the *balatran* trade in the world and Phillipines domestic markets, and its future.

Trepang industry in Mangsee: with reference to Philippine, Domestic Distribution

J. Akamine

Source: Proceedings of the seminar “Fisheries Today in the Philippines”, Kagoshima, Nov. 23–25, 1998 pp. 153–165.

Purpose of this presentation is to provide information on the sea cucumber (trepang) industry in Mangsee Island, Balabac Municipality, Southern Palawan. Trepang gathering is one of the important industries developed in the island. There are two kinds of trepang gathering practiced there. One is that they fish in the South China Sea or Sulu Sea near Cagayan de Tawi-Tawi. In both trips, trepang divers stay on their boat about 40 days. Another trepang gathering method observed is to fish trepang additionally to fish when fishermen dive for fish at reefs near Mangsee. Trepang gathering in the Philippines has been reported briefly in several papers but not fully described yet. This is because trepang gathering in other areas only provides an auxiliary income to fishermen. Stress will be given in that Mangsee fishermen have developed trepang gathering as an important industry. To understand its uniqueness, history of the island will be briefly overviewed.

Trepang is export-oriented food stuff so that it is needed to mention a current situation of the trepang industry in the Philippines. Export statistics of trepang from the Philippines indicate that Korea is surprisingly one of the main buyers. Data provided were collected during fieldwork conducted in July to October 1998.

Role of secondary metabolites and pigments in the epidermal tissues, ripe ovaries, viscera, gut contents and diet of the sea cucumber *Holothuria atra*

Bandaranayake, V.M. & A. Des Rocher

Source: Marine Biology 133: 163–169. (1999).

The epidermal tissues, ovaries, viscera, gut contents, and the diet of *Holothuria atra* (Jaeger) collected from the Great Barrier Reef (GBR), Australia, just prior to spawning, contained carotenoid pigments, mycosporine-like amino acids (MAAs) and three other metabolites in varying proportions. Mycosporine-glycine (mycosporine-gly), palythine, asterina-330, shinorine, mycosporine-2-gly, porphyra-334, and palythinol were present in the epidermal tissues. Mycosporine-gly was the major MAA in the epidermal tissues, gut contents and the diet, and the only MAA present in the ripe ovaries and the viscera. Gadusol, a metabolite with antioxidant properties, which co-occurs with MAAs, and in certain instances with trace amounts of 6-deoxygadusol in unfertilised and fertilised eggs and developing larvae of some marine invertebrates and vertebrates, was absent from *H. atra*. However, 6-deoxygadusol, with similar physical and chemical properties to gadusol, and the proposed biosynthetic precursor of MAAs in significant amounts in a marine invertebrate. Approximately 90% of the total carotenoids of the epidermal tissues, ovaries and viscera of *H. atra* are highly oxidised, the main component being astaxanthin followed by canthaxanthin. These were the major carotenoids present in the ovaries and the total carotenoid content was highest in the ovaries. β -carotene, a common egg carotenoid, was present in trace quantities in the ovaries but, along with the xanthophylls lutein and zeaxanthin, it occurred in significant amounts in the gut contents and the diet of *H. atra*. Carotenoid patterns in the epidermal tissues and viscera were strikingly similar, containing β -carotene, canthaxanthin and echinenone. The alkaloids homarine and isomeric trigonelline, (structurally unrelated to MAAs) and 6-deoxygadusol were present only in the ovaries and the viscera. It is suggested that these metabolites and pigments are either involved with photoprotection or reproduction, or associated with both processes. The origin, biogenetic relationships and the roles of these metabolites and pigments in *H. atra* are discussed.

Ecology and fishery biology of *Holothuria fuscogilva* (Echinodermata: Holothuroidea) in the Maldives, Indian Ocean

N. Reichenbach

Source: Bulletin of Marine Science. 64(1): 103–113. (1999).

The ecology of *Holothuria fuscogilva* was assessed in three habitats in the Republic of Maldives: marine grass beds, island gaps and lagoon floor habitat. *H. fuscogilva* was the dominant sea cucumber with relative abundances ranging from 70 to 94.4% in the two atolls studies. In one island gap area the median density (biomass), movement and growth rate were 29 ha⁻¹ (21 kg ha⁻¹), 2 m d⁻¹ and 0.29% d⁻¹, respectively. Based upon the weight distributions in the three habitats, *H. fuscogilva* appears to recruit to shallow marine grass beds, then migrates to deeper waters such as island gaps. It then moves to the deep waters of the lagoon floor, as it approaches sexual maturity (1.5 kg TW), where it matures and reproduces. Growth slows as the animal matures and individuals with total weights of 5000 g or greater were estimated to be at least 12 years old. Based upon micro and macroscopic examination of extracted gonads, mature individuals from the lagoon floor were found primarily from August through May. Spawning of both male and females was observed between December and March or essentially the N. east monsoon season in the Maldives.

A new species of *Bohadschia* (Echinodermata, Holothuroidea) from the Western Indian Ocean with a redescription of *Bohadschia subrubra* (Quoy & Gaimard, 1833).

C. Massin, R. Rasolofornirina, C. Conand & Y. Samyin

Source: Bulletin de l'Institut Royal des Sciences Naturelles de Belgique. Biologie. 69: 151–160. (1999).

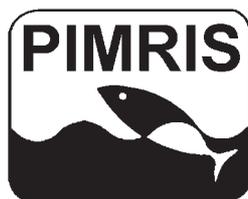
Bohadschia atra sp. nov. from the Western Indian Ocean is described and compared with *Bohadschia subrubra* (Quoy & Gaimard, 1833). *B. subrubra* is redescribed and compared to the new species and related *Bohadschia* species. The shape of the ossicles varies with body size for both species.

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provided by Prof. Dr. Ridzwan Hashim. E-mail: ridzwan@medic.ukm.my

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PIMRIS is a joint project of 5 international organisations concerned with fisheries and marine resource development in the Pacific Islands region. The project is executed by the Secretariat of the Pacific Community (SPC), the South Pacific Forum Fisheries Agency (FFA), the University of the South Pacific (USP), the South Pacific Applied Geoscience Commission (SOPAC), and the South Pacific Regional Environment Programme (SPREP). This bulletin is produced by SPC as part of its commitment to PIMRIS. The aim of PIMRIS is to improve



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