

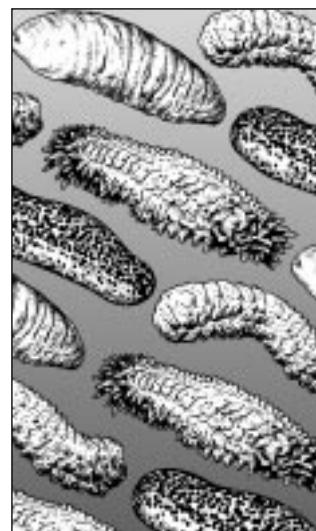


MARINE RESOURCES DIVISION
INFORMATION SECTION

BECHE-DE-MER

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INFORMATION BULLETIN



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NOTE FROM THE EDITOR

Welcome to the ninth *Beche-de-mer Information Bulletin*. This issue contains contributions from the various fields of sea cucumber biology and fishery, arranged as in the previous issues. The number of members is still increasing, and we hope that the new members will contribute to future issues.

Since the last issue, the highlight has been the symposium devoted to echinoderm fisheries and aquaculture during the International Echinoderm Conference, which was held in San Francisco in August 1996. The abstracts are presented here (see p. 26) and the papers will be published in 1997 by the editor A.A. Balkema (Rotterdam). The increase in overexploitation, now spreading to many coastal zones of the tropical East Pacific is one of the issues discussed.

An original approach is also being carried out in a traditional exploitation country—Madagascar—in the context of a regional programme (Commission de l'Océan Indien (COI), GICZ). To achieve sustainable exploitation of this fragile resource, the exporters have decided to organise the profession (see p. 4).

Several contributions update the state of the fisheries, as in Tuvalu (see p. 2), California and Washington State (see p. 11 and 12), Torres Strait reefs (see p. 17),

In the rubrique 'Asexual reproduction by fission' new observations are reported for the first time on the species *Holothuria leucospilota* (see p. 5) which had been previously cited as reproducing only sexually.

A new rubrique on aquaculture could also be prepared (see ICLARM results in the Solomon Islands, p. 3). We are looking forward to your suggestions and contributions.

Chantal Conand

Inside this issue

Beche-de-mer production in Tuvalu
by K. Belhadjali p. 2

A new study of asexual reproduction in holothurians: Fission in *Holothuria leucospilota* populations on Reunion Island in the Indian Ocean
by C. Conand et al. p. 5

A brief survey of the commercial sea cucumber *Isostichopus fuscus* Ludwig, 1875 of the Galapagos Islands, Ecuador
by J. Sonnenholzner p. 12

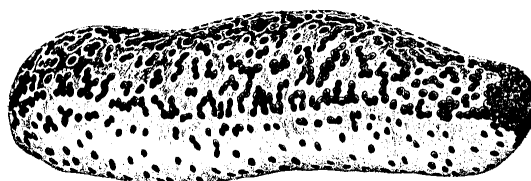
Distribution and abundance of beche-de-mer on Torres Strait reefs
by B. Long & T. Skewes p. 17

Correspondence p. 20

Abstracts, publications, workshops & meetings p. 24



B E C H E - D E - M E R I N F O



Bohadschia argus

Beche-de-mer production in Tuvalu

by Karim Belhadjali

Introduction

Tuvalu is an island chain composed of nine atolls and coral islands, with a total land area of approximately 26 square kilometres, geographically located between 5°30' and 11° South and 176° and 180° East. On declaring its 200 nautical mile Exclusive Economic Zone in 1983, Tuvalu laid claim to marine resources in an area encompassing approximately 757,000 square kilometres. The population of Tuvalu is approximately 9,000 (1991), with 40 per cent of the total population living on the capital Funafuti. The nine islands that form Tuvalu are: Funafuti, Nukufetau, Nui, Niutao, Nanumea, Vaitupu, Nukulaelae, Niulakita and Nanumaga. All of the following islands have lagoons: Nukulaelae, Funafuti, Nukufetau, Nui and Nanumea.

Sea cucumbers are locally known as **funafuna**. There is no name distinction between species, except for the lolly fish *Holothuria (Halodeima) atra*, known locally as **loli**. This absence of differentiation can probably be attributed to the fact that sea cucumbers and their products are not part of the traditional diet of Tuvaluans, and were therefore of little practical interest.

At present, no regulations have been enacted to manage the beche-de-mer industry in Tuvalu, though the *Fisheries Act 1978* gives the Minister for Natural Resources full authority to promote the development of fishing and fisheries in Tuvalu to ensure that fisheries resources are exploited to the full for the benefit of Tuvalu. The Fisheries Department is currently advocating a ban on the use of SCUBA and hookah gear to harvest all sessile organisms, especially beche-de-mer.

Past production

The Fisheries Department received funding from the United Nations Development Program in 1978 to assist the development of the beche-de-mer industry in Tuvalu. In that year, resource surveys for sea cucumbers were conducted in all the islands of Tuvalu with lagoons, but only Funafuti and

Nukufetau were identified as having stocks of commercially-valuable sea cucumbers.

The Tuvalu Fisheries Department, through its extension section, began training fishers in Funafuti and in the outer islands. The Fisheries Department also produced a leaflet in Tuvaluan entitled '**A tupe e mafai o maua mai funafuna**' 'The amount of money you can get from selling beche-de-mer', to encourage and promote the beche-de-mer fishery.

In 1979, the Fisheries Department purchased beche-de-mer from fishers in Nukufetau and sold the product to overseas markets (Anon. 1979). A total of 1.8 metric tonnes of grade 1 (AU\$ 2.00/lb) and grade 2 (AU\$ 3.00/lb) beche-de-mer was sold in Fiji, with a total value of AU\$ 7,100. The Funafuti fishers were not interested in the beche-de-mer industry, despite receiving much encouragement from the Fisheries Department.

In 1980, a total of 805 kg of graded beche-de-mer, worth AU\$ 4,000 was exported to markets in Fiji (Anon. 1980). Production fell sharply in 1981 (90 kg) and in 1982 (198.5 kg) because the fishers in Nukufetau were too busy with other community projects (Anon., 1981; Anon., 1982). In subsequent years, there was no production and export of beche-de-mer in Tuvalu despite efforts to revive interest in the fishery.

Current production

Harvest and export of beche-de-mer to overseas markets resumed again in 1993. A local fisher harvested sea cucumbers in Funafuti and Nukufetau lagoons, and exported processed, graded beche-de-mer to markets in Singapore in Hong Kong. In 1994 and 1995, another local fisher, in a joint venture with a Fiji businessperson, began exporting beche-de-mer to Fiji. Both producers however stopped harvesting in 1995 and have not resumed. The joint venture dissolved due to friction between the two partners. Total export figures and species breakdown are summarised in Table 1.

The main species targeted for export are the white teatfish, *Holothuria (Microthele) fuscogilva*; and the black teatfish, *Holothuria (Microthele) nobilis*, because they are highly valued in the Asian markets (Anon., 1994). The other species that make up a large proportion of the exports are the prickly redfish, *Thelenota ananas*; and elephant trunkfish, *Holothuria (Microthele) fuscopunctata*. Four other species make up around 3 to 13 per cent by weight of the exports and these are the blackfish, *Actinopyga miliaris*, surf redfish, *Actinopyga mauritiana*, brown sandfish, *Bohadschia marmorata/vitiensis*, and leopard (tiger) fish, *Bohadschia argus* (Table 1).

After processing, the product is stored in synthetic fibre bags (onion bags), until a sufficient volume is accumulated, and then shipped to Fiji on the next available cargo ship, usually once or twice a year. Prior to export, the shipments are inspected by the Principal Fisheries Officer, who verifies the grading, quality and quantity of each shipment, and issues the exporter with a certificate. This service is performed voluntarily by each party, and is done to ensure that seafood products from Tuvalu are of the highest quality possible, and therefore command and receive the

highest possible price in overseas markets. Despite a drop in production of 450 kg from 1994 to 1995, the monetary value of the exports rose by approximately US\$ 5,700. This is attributed to the higher prices received for the products in 1995.

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Table 1: Tuvalu beche-de-mer production and species composition

Year	Total (kg)	Value (US\$)	Species composition (%) by weight				
			White teatfish	Black teatfish	Prickly redfish	Elephant trunkfish	Other
1993	871	12,461	52.1	10.6	19.0	13.6	4.6
1994	3,678	40,004	67.4	0.6	14.1	5.1	12.8
1995	3,228	45,737	71.7	0.0	19.5	5.9	2.8

Successful production of juvenile sandfish *Holothuria scabra* by ICLARM in the Solomon Islands

The International Centre for Living Aquatic Resource Management (ICLARM) Coastal Aquaculture Centre (CAC) in the Solomon Islands has a five-year project funded by the Australian Centre for International Agricultural Research (ACIAR) to develop methods for mass rearing of tropical sea cucumbers for the purpose of enhancing wild stocks (see *SPC Beche-de-mer Information Bulletin* no. 8, p. 45).

The project started spawning trials in August this year. A total of 107 *Holothuria scabra* and 69 *Actinopyga mauritiana* broodstock have been collected from the wild and transported to the CAC. We have successfully spawned both species by elevating sea water temperature by 3 to 5°C. Spawning was induced in 16

per cent of *H. scabra* and 33 per cent of *A. mauritiana*. We have reared two batches of *H. scabra* larvae and one of *A. mauritiana*.

We initially fed the larvae a mixture of three types of microalgae—*Chaetoceros muelleri (gracilis)*, *Chaetoceros calcitrans* and *Tetraselmis chunii*— up until settlement, and then a combination of fresh microalgae and a new commercially dried microalgal product, 'Algamac 2000'. In our first trial *H. scabra* larvae were reared in 750-litre fibreglass tanks at around 2 larvae/ml, with about 25 per cent of the larvae surviving to settlement. Water was exchanged by sieving out the larvae every second day until the appearance of doliolaria on Day 10. Then we started 200 per

cent daily exchange of flow-through sea water. The majority of *H. scabra* larvae were at the pentacula stage by Day 14.

From this first trial we produced over 10,000 juvenile *H. scabra*. From Day 40, juveniles were reared in 4,000-litre concrete tanks. At 60-days-old, the juveniles held at the lowest density averaged 23.8 ± 4.7 mm in total length ($n = 50$). Settlement and juvenile rearing on fiberglass plates conditioned with diatoms in the 750-litre tanks produced smaller animals 8.4 ± 3.4 mm ($n = 50$). Reduced growth may have been related to a copepod infestation. The sec-

ond batch of *H. scabra* larvae are now 14-days-old, and undergoing settlement. The *A. mauritiana* larvae are only a week old and still auricularia.

The results to date have been very encouraging, and we look forward to improving survival and growth in subsequent batches. In addition to the larval rearing experiments we have also been collecting data on the reproduction of *H. scabra*, *H. fuscogilva* and *A. mauritiana* in the wild, and also plan to start conducting experiments to determine suitable habitats for the release of hatchery-produced juveniles.

Sea cucumbers in Madagascar: difficulties in the fishery and sustainable management

by C. Conand, N. Galet-Lalande, H. Randriamiarana,
G. Razafintseho & M. de San

History of the fishery

The age and scale of various fisheries were estimated from historical export data. In 1921, for example, the *Bulletin économique de Madagascar* refers to exports of 11 metric tonnes (t) of trepang to China and Mauritius in the third quarter of the year, which would probably give an annual total of 40 t.

G. Petit (1930) presents statistics for the 1920 to 1928 period, when exports varied from 50 to 140 t. The subject of this study merits further research through trade statistics, in order to determine whether historically activity in the fishery fluctuated according to resource availability or for other reasons, and whether the fishery was being exploited on a sustainable basis.

In the south-western region (Tulear), this fishery is an active one: various sources (provincial trade and sea fisheries departments) indicate that exports fluctuated between 10 and 56 t from 1979 to 1986.

Export data from 1987 to 1995 are as follows: 1987: 60 t; 1988: 119 t; 1989: 113 t; 1990: 202 t; 1991: 545 t; 1992: 423 t; 1993: 356 t; 1994: 539 t and 1995: 311 t. The 539 t recorded in 1994 placed trepang in 5th place on the list of national exports in terms of value (2% of the total).

Resource management problems and overfishing

There have been various indications in recent years that the fishery is experiencing difficulties. These indications emerge from various parts of the beche-de-mer trade, which is especially complex (Conand & Byrne, 1994), because of the many stages and par-

ties involved between the fishermen and the foreign consumer.

Fishing on foot would appear to be in decline. Studies currently under way at the Tulear Fisheries and Marine Science Institute will provide more precise data on this development.

Scuba divers are complaining that they now need to dive to increasing depths to harvest holothurians, which is leading to accidents, and also that they are being forced to look for new fishing grounds. The size of specimens of the various species concerned would also appear to be diminishing. With regard to processing, which is either done by the fishers themselves or by traders, techniques could apparently be improved. The processed product often fails to meet the required quality criteria, even with high-commercial-value species. Problems can subsequently arise in the export market.

Prospects for sustainable management

This resource has great social and economic importance for the coastal villages of Madagascar where it is often exploited as a family activity. Research carried out—in Tulear for the south-west region and in Nosy Bé for the north-west region, where the main reef areas are found—will make it possible to assess the state of the resource more accurately.

The Indian Ocean Commission—Commission de l'Océan Indien (COI)—is currently conducting a regional programme on integrated coastal zones management. Madagascar has therefore resolved that the sustainable management of its resources, and in par-

ticular sea cucumbers, is an objective to be achieved and that coordination and integration are necessary; meetings have taken place in the regions to better organise the sea cucumber trade by involving the various parties concerned (meetings were held at Ambanja, Mahajunga and Toliara). The Madagascar National Trepanng Traders Group (ONET) was set up in Antananarivo on 25 September 1996.

The group's objectives are as follows:

- trepanng quality management;
- training of traders and fishers in better resource management; and
- working closely with the administration in the management and exploitation of trepanng.

A new study of asexual reproduction in holothurians: Fission in *Holothuria leucospilota* populations on Reunion Island in the Indian Ocean

by C. Conand¹, C. Morel¹ & R. Mussard¹

Introduction

Holothuria leucospilota is a large, black sea cucumber species, which is found throughout the tropical Indo-Pacific Region. It most often lives near the back reef, in sandy areas where dead coral accumulates (Massin & Doumenc, 1986; Conand, 1989; Ong Che, 1990). This initial study on Reunion Island proved that asexual reproduction through fission does exist, contrary to some previous observations (Britayev, 1992), and that it is even quite common.

The data collected covered information on the species populations and their densities, and on fission and regeneration rates in the different sites within the La Saline reef complex.

This data also allowed observations on the morphology and anatomy of normal individuals, those in fission and those in regeneration. Finally, the chronology of organ development during fission and regeneration was extrapolated from the data.

Material and methods

All specimens of the species *Holothuria leucospilota* found within the 10 m² quadrats set out in the back reef of several sites in the Saint Gilles/La Saline Reef

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were collected, measured and weighted. The process of asexual reproduction in *H. leucospilota* leads to six distinct categories for specimens. The categories as defined for other species, in particular *Holothuria atra* (Conand & De Ridder, 1990; Conand, 1996), were used here for *H. leucospilota*.

- Normal specimens (N) which show no sign of fission.
- Specimens in the process of fission (F) are characterised by a constriction in the anterior part of the body.
- Complete fission of F specimens leads to two new types of specimen:
 - (A) specimens which correspond to the anterior part,
 - (P) specimens which correspond to the posterior part.
- A and P specimens will then regenerate into:

Anterior specimens that are regenerating their posterior part are specimens (Ap).

Posterior specimens that are regenerating their anterior part are specimens (Pa).

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Data on the frequency of occurrence for the different categories of specimens allowed fission figures to be determined (Conand, 1996):

The fission rate (F%) was calculated from A and P specimens using the formula $(A+P)/2T*100$, with T being the total number of specimens.

The regeneration rate (R%) was calculated from Ap and Pa specimens using the formula $(Ap+Pa)/T*100$.

The different types of specimens were collected and dissected in order to analyse the arrangement of internal organs during the various stages of fission and regeneration. Measurements were taken from specimens fixed with Bouin fluid, after relaxation using magnesium chloride.

The different length and weight measurements covered:

Total length, ± 0.5 cm, and the length of the regenerated part, ± 0.1 cm;

Length of the intestine and Polian vesicle, ± 0.5 cm; oral podia;

Total open weight and the weight of the integument, ± 0.5 g.

Weight of the intestine tube and gonads, ± 0.1 g;

The gonadal-somatic ratio was calculated, using the formula $RGS=100*Pg/Pt$, in order to determine the degree of sexual maturity.

Results

Abundance levels

The results first involved density levels, which averaged 0.84 'normal' specimens per sq.m. (variation: 0.09) and 0.12 specimens in regeneration (variation: 0.02) per sq.m. The various categories of specimens, collected at the Trou d'eau site were: N = 87.5%, P = 10.4% and Pa = 2.1%.

The fission rate (F%) at the Trou d'eau site as extrapolated from the figures for the different categories of specimens was 5.2 per cent. The regeneration rate (R%) was 4.3 per cent.

The difference in numbers between P and A specimens suggest that mortality among A specimens is clearly higher than that of P specimen (not a single A specimen was found at this site). In their natural environment, specimens in the process of fission (F) were mostly found under coral heads (*Poritidae*), where they hide in order to protect themselves from possible predators.

Anatomy in the different categories of specimens

'Normal' specimens (N) (Figure 1)

H. leucospilota is a large sea cucumber with an average length of 18 cm and an average total open weight of 245 g at the study site.

Its integument is very thick, i.e. 8 mm. The weight of the integument (muscles included) averages 82 g. Normal specimens are characterised by five pairs of longitudinal muscles which are attached near the peripharyngeal calcareous ring at the mouth and at the cloaca in the posterior area. Each pair of muscles has an average width of 8 mm.

The mouth opens in the anterior part and has twenty oral tentacles. The intestine is filled with sand, dead coral, and other rock debris and has a thin integument. The intestine is divided into three loops. The average length of the intestine of the five specimens studied was 98.4 cm. The transverse vessel joins the first and the second loops. The intestine is attached to the integument by a number of mesenteries. The *rete mirabile* is found within the second loop of the intestine and takes part in intestinal absorption.

Twenty vesicles of oral podia were located around the calcareous ring and provide turgescence to the oral tentacles. The average length of the oral podia in normal specimens was 2.5 cm. The Polian vesicle below the calcareous ring is large in *H. leucospilota* (average length 4.9 cm). *H. leucospilota* is gonochorismal. The gonads were attached along the mesentery by the gonad base, approximately 4.5 cm from the mouth, and had the form of a group of branched tubules.

At maturity, male and female gonads can be differentiated in *H. leucospilota* by their colour, as male gonads are beige, while female gonads are bright pink in colour. For the five individuals specimens studied, weight of the gonads varied between 9 and 32 g, with an average weight of 18.9 g.

The gonadal-somatic ratio was between 12.5 and 33.86. The respiratory organs consisted of two respiratory trees, i.e. the right and left. Each respiratory tree consisted of a trunk with branches, attached very high on the anterior part and opening onto the cloaca. Diffusion of water by means of these organs is a passive phenomena, permitting respiratory exchanges and the elimination of metabolic wastes.

The right respiratory tree was attached to the integument by the mesentery while the left respiratory tree was attached to *rete mirabile*. When this species is attacked, it releases a great number of very fine Cuvierian tubules from its anus. The tubules are normally carried on the base of the respiratory trees (Van den Spiegel, 1994).

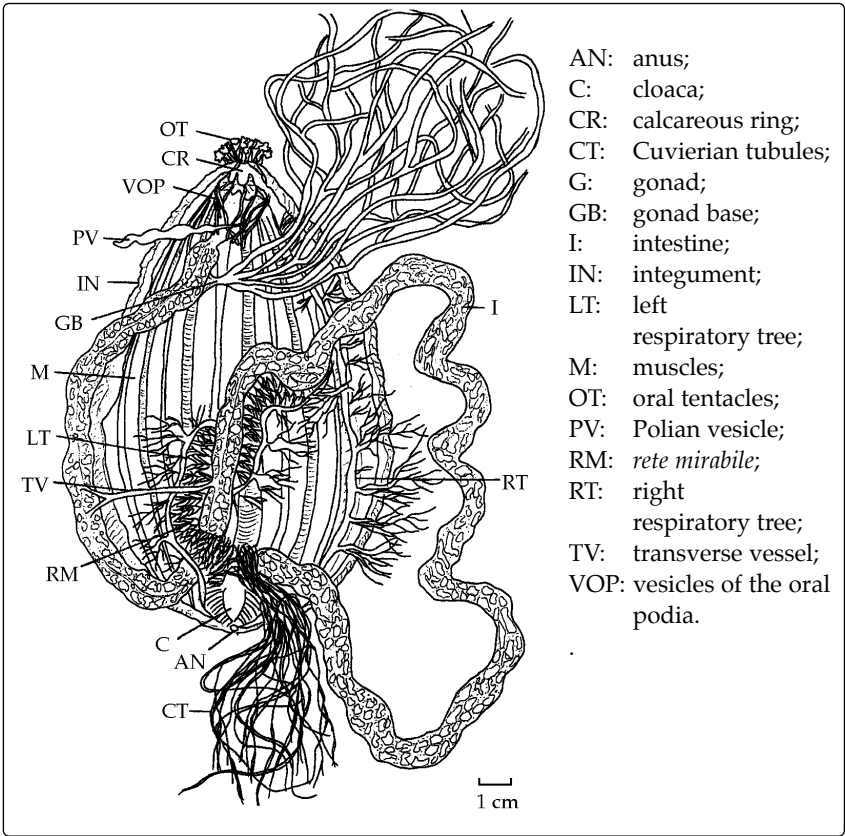


Figure 1: Dissection of an N specimen

Specimens in the process of fission and regeneration

Specimens in the process of fission (F)
(Figure 2)

All these specimens showed constriction in the anterior part of the body. During the early stages of fission, constriction is annular. Ambulacral papillae disappear from the integument at the constriction ring. During advanced stages, constriction leads to a rupture in the integument and organs, thereby separating the sea-cucumber's body into two parts. These two parts are still attached by a thin ventral integument. In certain F specimens, regeneration can begin as early as this stage. In fact, some specimens showed regeneration of the mouth and oral tentacles while the two parts of the specimen in process of fission were still attached. Figure 2 shows the anatomy of an F specimen.

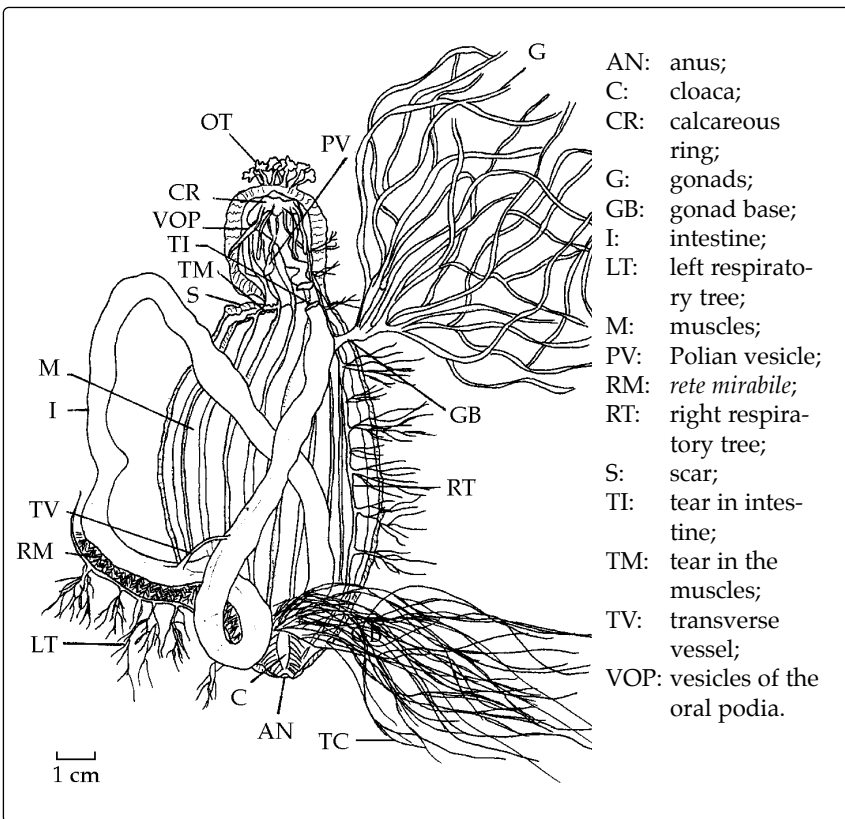


Figure 2: Dissection of a specimen in the process of fission (F)

In *H. leucospilota*, fission took place in the anterior part of the body at about 19 per cent (1/5) of the total length of the specimen. The average thickness of the integument in the anterior half was 8 mm and thinned out near the mouth. The longitudinal muscles were thin and measured on average 2 mm in width in the anterior part. The digestive system was always empty in the anterior part, which may be explained by the fact that the animal no longer feeds during fission. The Polian vesicle averaged 15.8 mm, and this size is much smaller than in normal specimens. The oral podia had the same size as normal specimens.

Only the right respiratory tree was found in the anterior section. It was always located near the calcareous ring and was connected to the integument. The integument wall was thin in the area where fission had occurred, i.e. an average thickness of 2 mm. The muscles were torn apart at the moment of fission. During the initial stages of the fission, the intestine was constricted and during the final stages, it was sundered. In the anterior half, it was attached to the pharyngeal

bulb. Only the right respiratory tree is affected by fission. It breaks in such way that part of it remains in the anterior part, so most of the respiratory tree was located in the posterior section.

The integument on the posterior half was thick, and muscles were much more voluminous than in the anterior part. The major portion of the intestine was found in the posterior region and was filled with fine coarse sand. This sand accumulated during the later stages of fission. Gonads were not always present in specimens undergoing fission. Of the five F specimens studied, only two specimens had gonads. The average weight of the gonads in F specimens was less than the weight of gonads in normal specimens, i.e. 1.3 g.

Anterior specimens (A) (Figure 3)

A specimens corresponded to the anterior part which broke off during fission. The integument formed a more or less closed scar depending on the amount of time which had passed since fission.

On average, A specimens measured 43 mm and had a weight of 9.6 g. The integument had an average thickness of 3 mm, and thinner near the scar (1.5 mm). During the initial stages of regeneration, the scar was open, while in later stages, it was completely closed. There were muscular bands in the area near the scar, while the muscles were attached normally out the calcareous ring. The intestine had an average length of 22.5 mm and weight of 0.11 g and was empty.

In A specimens, the intestine did not show any anal orifice. Only the right respiratory tree was present and was attached to the integument without any sign of regeneration. The Polian vesicle was small (average length: 2 mm) in comparison to that of normal specimens. The oral podia were smaller in size than those of N specimens. As A specimens do not feed, the oral tentacles were not functional and appeared atrophied. The gonad base was visible in P specimens, but gonads were absent in A specimens.

Anterior specimens in the process of regeneration (Ap) (Figure 4)

Ap specimens were characterised by regeneration of the posterior part. The size of the regenerated part depended on the amount of time which had passed since fission. In the Ap specimens studied, the length of the regenerated part varied from 5 to 20 mm. The regenerated integument was thin and could have ambulacral papillae. The average thickness of the regenerated integument was 1 mm. Regeneration of the muscles in the posterior part of Ap specimens began at the muscular band. The regenerated muscles were thinner and were attached to the integument at the cloaca. All Ap

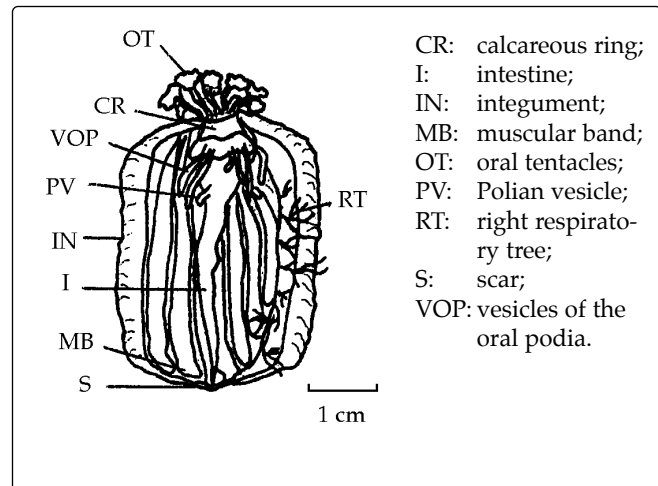


Figure 3: Dissection of an A specimen

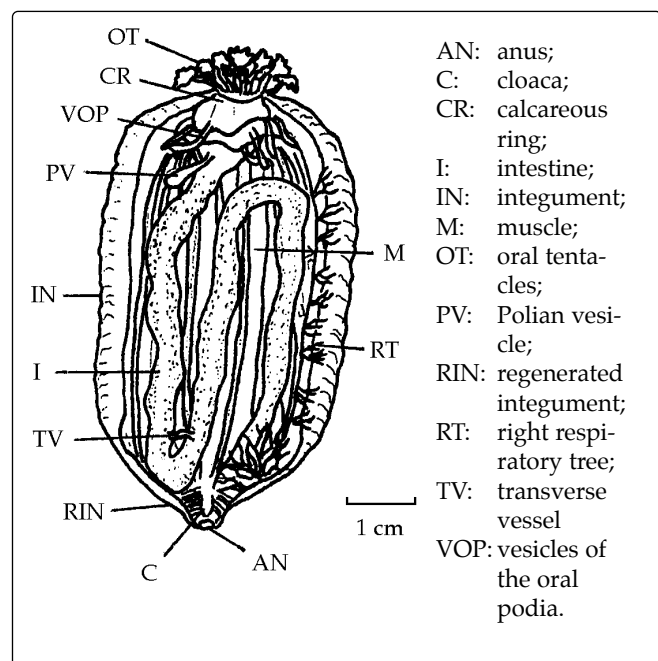


Figure 4: dissection of an Ap specimen

specimens showed some regeneration of the intestine and anus. Regeneration of intestine involved regeneration of the transverse vessel. The intestine appeared to begin to function as soon as the anus had regenerated since after that time it was filled with sand. Complete regeneration resulted in an intestine with three loops and a transverse vessel and which had a cloaca. When fission had taken place quite recently, only the right respiratory tree was found. It was also one of the first organs regenerated and extended as far as at the cloaca. In those instances where a significant amount of regeneration had taken place, the left respiratory tree regenerated on the intestine. The turgescence of oral podia indicated that they were functional. The Cuvierian tubules regenerated as soon as the intestine was fully formed, i.e. even before the cloaca. Gonads did not regenerate in Ap specimens.

Posterior specimens (P) (Figure 5)

P specimens correspond to the posterior part of the sea cucumber after fission. Cicatrisation and internal anatomy depended on the amount of time which had taken place since fission. When fission was recent, the scar was open, leaving the intestine visible. In later stages, it was completely closed but there was no oral orifice.

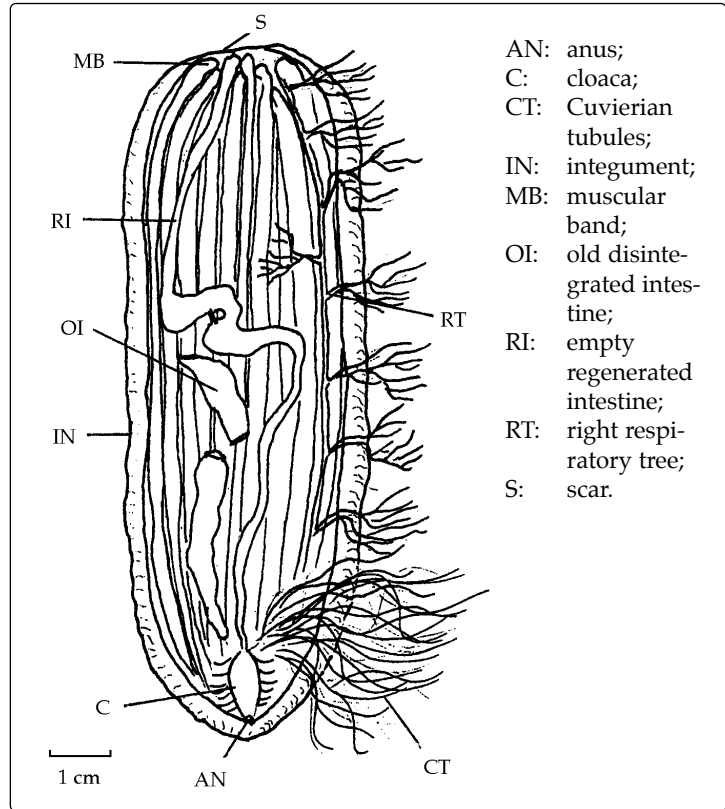
The length of the P specimens observed ranged from 110 to 180 mm, while the total open body weight varied between 89 and 104.5 g. The integument was very thick with an average thickness of 7 mm. Thickness dropped drastically at the scar site; i.e. to 2 mm. In some instances, folding of integument closed off the scar. In P specimens with recently-formed scars, the muscles were torn and formed bands at the end. In all the P specimens studied, the intestine consisted of three loops with a transverse vessel and was open at the scar. When the scar is open, the intestine was in contact with the outside environment. As P specimens do not feed, the intestine was always empty.

In some P specimens, the intestine showed signs of regeneration with a very thin integument, while in other cases, it desintegrated and did not show any signs of regeneration. If the intestine had not become atrophied, the entire *rete mirabile* was present. Both respiratory trees were found in P specimens. The left respiratory tree was not affected by fission and was still linked to the *rete mirabile* whenever the latter was present. The right respiratory tree was broken during fission but could be found in the posterior part. The Polian vesicle was absent in all P specimens. Some specimens had a ring of oral podia at the scar site even when the mouth had not yet formed. Of the five P specimens studied, only one had gonads which were small in size. They were found on a specimen which had just undergone fission. All P specimens had Cuvierian tubules.

Posterior specimen in the process of regeneration (Pa) (Figure 6)

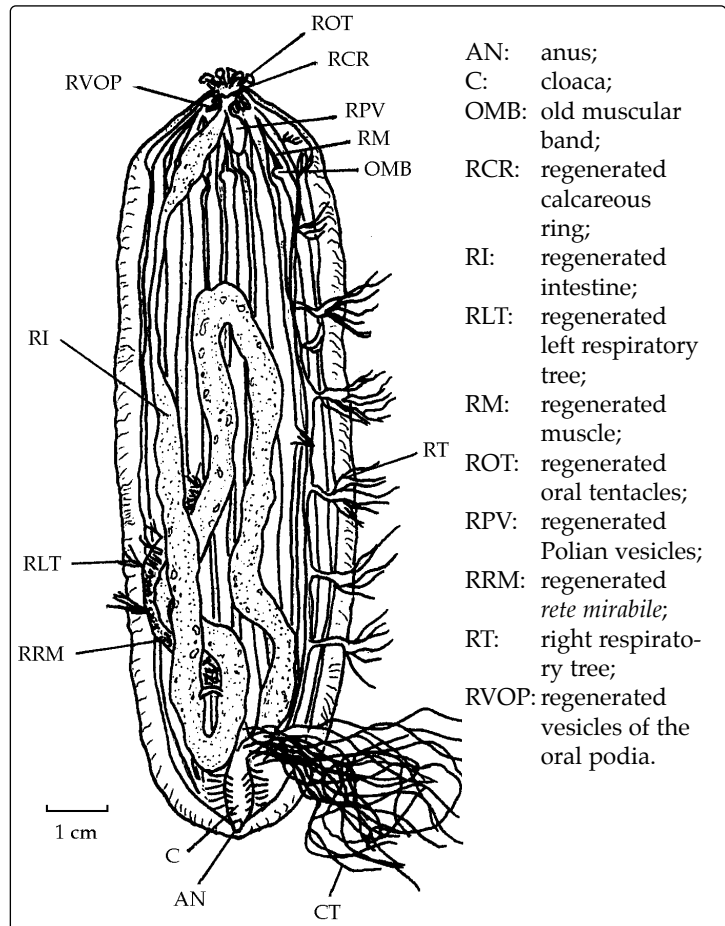
Pa specimens corresponded to P specimens which had regenerated their anterior part, including their mouth and oral tentacles.

The integument had an average thickness of 6 mm, while in the regenerated section, the integument only measured 2 mm. Significant regeneration of the anterior section involved regeneration of the first ambulacral papillae.



- AN: anus;
- C: cloaca;
- CT: Cuvierian tubules;
- IN: integument;
- MB: muscular band;
- OI: old disintegrated intestine;
- RI: empty regenerated intestine;
- RT: right respiratory tree;
- S: scar.

Figure 5: Dissection of a P specimen



- AN: anus;
- C: cloaca;
- OMB: old muscular band;
- RCR: regenerated calcareous ring;
- RI: regenerated intestine;
- RLT: regenerated left respiratory tree;
- RM: regenerated muscle;
- ROT: regenerated oral tentacles;
- RPV: regenerated Polian vesicles;
- RRM: regenerated *rete mirabile*;
- RT: right respiratory tree;
- RVOP: regenerated vesicles of the oral podia.

Figure 6: Dissection of a Pa specimen

One pair of muscles had an average width of 6 mm, while in the regenerated part this width was only 2 mm. In P specimens, regeneration of the muscles in the anterior part began with the muscular bands near the scar. The intestine began regeneration at the mouth which was surrounded by a ring of completely-regenerated oral tentacles.

In all Pa specimens, the intestine was filled with sand. Feeding began as soon as the mouth had been regenerated. Mainly the anterior part of the intestine was regenerated. The oral podia and Polian vesicle were regenerated in Pa specimens and turgescence of the vesicles indicated that they were functional.

Both respiratory trees were present. Only the right respiratory tree regenerated into the anterior area. None of the Pa specimens had gonads. As in P specimens, the Cuvierian tubules were always abundant in Pa specimens, and did not need to be regenerated.

Discussion

Population characteristics

At the Trou d'eau site, *H. leucospilota* density in the back reef was 0.96 specimen per m². In Trois-Chameaux and Planch'Alizés sites, *H. leucospilota* density was respectively 0.5 specimens and 1.2 specimens per m².

Density levels for the species *H. atra* are generally higher and can reach 4 specimens per m² (Conand, 1996). As with *H. atra*, the highest density levels for *H. leucospilota* were observed in the back reef. However, *H. leucospilota* was also found on the reef flat where hydrodynamics are strongest.

In the Trou d'eau site, although actual numbers were low, taking into account all A, P, Ap and Pa specimens, 12.5 per cent of the total specimens were a result of asexual reproduction.

The fission rate ($F\% = (A+P)/2T \times 100$) was 5.2 per cent for *H. leucospilota* at the Trou d'eau site, which is low compared to *H. atra* whose fission rate in the back reef is 20 per cent (Conand, 1996). Data on fission rates for *H. atra* (Conand, 1996) depend on the area of the reef which is studied.

The regeneration rate ($R\% = (Ap+Pa)T \times 100$) was 4.3 per cent for *H. leucospilota*, while it is 10.6 per cent for *H. atra*. In *H. leucospilota*, the regeneration rate was lower than the fission rate, which indicates some mortality of specimens after fission.

The percentage of Pa specimens (20%) was clearly higher than that of Ap specimens (0%), and this corroborates Doty's hypothesis for *H. atra* (1977), i.e. that the mortality of Ap specimens is higher than the mortality of the Pa specimens.

Fission and regeneration results / comparison to *H. atra*

In *H. leucospilota*, fission occurs much farther back on the body than it does in *H. atra*. Fission in *H. leucospilota* occurs at 19 per cent of the total length while for *H. atra* it occurs at 45 per cent of the total length (Conand & De Ridder, 1990). Fission may be controlled by different factors. Hydrodynamics, immersion, temperatures, salinity, solar radiation and desiccation may be responsible for fission in *H. atra* (Doty, 1977; Conand & De Ridder, 1990).

In the La Saline Reef, man-made changes like eutrophication of the water or sea cucumbers being stepped on may be possible catalysts for fission (Conand, 1996). *H. leucospilota*'s intestine is empty above the fission point but is filled with sand in the posterior part. The right respiratory tree is affected by the constriction with the largest part of this tree found in the future P specimens, and only a fragment remaining in the anterior part.

The same phenomena was observed in *H. atra* (Conand, 1996). Specimens in the process of fission (F) do not always have gonads. When they do, the gonad base is situated after fission in the posterior part in *H. leucospilota* while it is found in the anterior part in *H. atra*. Only P specimens of *H. leucospilota* have gonads, whereas in *H. atra*, it is the A specimens which have them.

After fission, A and P specimens are characterised by a scar located in the posterior part of the A specimens and in the anterior of the P specimens. The intestines of A and P specimens are always empty as they do not feed. Muscles formed bands near the scars and regeneration begins from these bands.

As for regeneration, the length of the part regenerated depends on the amount of time which has occurred since fission. The thickness of the regenerated integument is always less than that of normal integument. As with *H. atra*, *H. leucospilota* can show ambulacral papillae on the integument if the regenerated part is significant.

Regenerated muscles are thin and fine and converge either towards the anus (in Ap specimens) or the mouth (in Pa specimens). The intestine of *H. leucospilota* seems to regenerate and begin normal functioning rather quickly as is the case with *H. atra*. In any case, complete regeneration leads to the appearance of a mouth, three intestinal loops, a transverse vessel and anus.

The first stage in the regeneration of digestive organs in Ap specimens is regeneration of the anus. Next the intestine lengthens to form three intestinal loops. Regeneration of the transverse vessel connecting the first loop to the third one occurs rather early. The *rete*

mirabile regenerates on the second intestinal loop. As soon as the anus is open, the intestine becomes functional. The defence organs develop after regeneration of the cloaca. The right respiratory tree regenerates from a fragment of the respiratory organ found in A specimens. The left respiratory tree develops later.

In Pa specimens, regeneration first involves the anterior part of the intestine. The oral podia develop very early before perforation of the mouth. When the mouth has formed, it is surrounded by a ring of oral tentacles. The Polian vesicle forms. The old intestine from P specimens disintegrates and disappears.

Pa specimens then regenerate an intestine with three folds, a transverse vessel and a *rete mirabile*. Pa specimens which have oral tentacles and a functional digestive system can feed. The right respiratory tree is maintained and only regenerates the anterior part in Pa specimen. Defence organs show no signs of regeneration.

H. leucospilota is gonochorismal. All the specimens collected in February had gonads. As the gonadal-somat-

ic ratio was high (22.6), sexual reproduction can take place at this time of the year. Specimens in the process of fission collected at that time of the year also had mature gonads, so during periods of sexual reproduction asexual reproduction can also take place.

Conclusion

This study has proven the existence of fission in *H. leucospilota*. The chronology of the regeneration of organs has been established. Fission for *H. atra* has been the object of more serious and detailed studies on the fission and regeneration rates than has been the case for *H. leucospilota*.

It would be interesting to analyse the role of asexual reproduction in population dynamics for this species and to know if environmental factors play a role in the fission rate.

Is asexual reproduction in this species determined by specific factors, in particular, environmental disturbances which occur frequently in the reefs of Reunion Island?



Fishery in Washington State

by Alex Bradbury

The commercial dive fishery for *Parastichopus californicus* in Washington State, USA, underwent management changes in 1993 following court decisions granting Indian treaty tribes the right to take half of the harvestable resource.

The former management policy of rotating fishing areas such that each area was fished only once every four years had to be abolished in 1994 to allow treaty tribes to harvest annually within their traditional fishing areas. Quotas were reduced roughly one-quarter in each area to accommodate the yearly fishery.

Following this change in management practices, logbook data from non-Indian divers has been monitored to detect shifts in either catch-per-unit-effort (CPUE) or mean harvest depth. Three seasons have elapsed since the management shift to yearly quotas: 1994, 1995 and 1996.

Mean CPUE and its variance is derived from log normalised diver logbook data and is reported as kg of split, eviscerated, and drained sea cucumber per hour

of diving. For the 1994, 1995 and 1996 fishing seasons, CPUE has been 66 kg, 64 kg, and 61 kg per diver-hour, respectively. There was no statistically-significant difference between these CPUEs for the last three seasons (coefficient of variation or CV for the three means was 2.2%, 1.9% and 1.9% respectively).

Mean harvest depth for the 1994, 1995 and 1996 fishing seasons was 15.7 m, 16.4 m and 14.6 m, respectively.

This preliminary analysis suggests that there have been no significant changes in either mean catch rate or mean harvest depth thus far following the shift from rotational area management to yearly statewide fishing in all areas. However, Washington Department of Fish and Wildlife will continue to monitor these and other fishery-dependent indicators to determine if current harvest levels are sustainable.

Underwater video surveys of sea cucumber density will be performed again in the summer of 1997 throughout the most important fishing area, the San Juan Islands.

Fishery in California in 1995

by Kristine Barsky

In 1995, 590,000 lbs of California (*Parastichopus californicus*) and warty (*P. parvimensis*) sea cucumber worth US\$ 463,290 were landed in the state of California. This was 9 per cent less than the 646,000 lbs landed in 1994. Eighty per cent of the sea cucumbers were taken by trawl, and the remaining 20 per cent were harvested by divers. Almost all of the landings were made in southern California (south of Pt. Conception).

Only 78 of the 116 fishermen possessing sea cucumber permits made landings in 1995. The average ex-vessel price for both sea cucumber species, regardless of the

way it was harvested, was US\$ 0.70/lb. The price ranged between US\$ 0.20 and US\$ 1.00/lb.

Landings for the first half of 1996 totaled 368,000 lbs, greater than the 3-year average of 213,000 lbs for the same period. Since summer and fall are normally the time of peak trawl activity, landings this year will probably exceed last year's.

Legislation is pending that will affect the way in which the sea cucumber fishery will be regulated in the next fishing season.

A brief survey of the commercial sea cucumber *Isostichopus fuscus* (Ludwig, 1875) of the Galapagos Islands, Ecuador

by J. Sonnenholzner¹

Introduction

The sea cucumber fishery was originally located along the continental Ecuadorian coast in 1988. Four years later this fishery was centered mainly on the western side of the Galapagos archipelago (Aguilar et al., 1993). Traditional fishing in the Galapagos Islands is relatively undeveloped and there has never been any traditional fishing of sea cucumbers (Conand, 1995). Giant sea cucumbers *Isostichopus fuscus* are caught by artisanal fishermen, and this fishery has developed without any control around the Galapagos Islands during the last eight years (De Paco et al., 1993). Ecuador's General Fisheries Direction has reported that ten companies are exporting dried sea cucumbers and the data shows that sea cucumber fishery was less than 0.04 t (fresh total weight) from 1983 to 1988 and 50.3 t from 1989 to 1995.

The highest catch (30 t) was reported in 1995. These products are all exported, 66.7 per cent to the U.S. and 33.3 per cent to Taiwan. The maximum value paid per kg/net in Ecuador is US\$ 30.00. The aim of this paper is to contribute briefly with biological and ecological information on the giant commercial sea cucumber *I. fuscus* in the western side of the archipelago area where they were intensively fished.

Location and distribution

The Galapagos Islands are volcanic islands located 570 miles (960 km) off the continental Ecuadorian coast and are composed of thirteen large islands, six small islands and forty-two islets (Anon, 1992). Fernandina and Isabela islands are characterised by vertical drop-offs that fall dramatically and have mixed bottoms of rocks and sand with dispersed coral communities. The eastern side of the Fernandina Island has semi-exposed and protected areas (Wellington, 1975).

Isostichopus fuscus is limited to the west American coasts (Deichmann, 1958) and it is distributed in the western zone of the Galapagos Islands. It is the most commonly found sea cucumber species in shallow waters (<20 m) (Wellington, 1975).

Field procedures

In April 1993, individuals (n = 200) from rocky reefs, boulders and broken coral rubble from depths of 0 to 24 m on the eastern side of the Fernandina Island were collected in five stations covering a sampling zone, 17.30 km along the Bolivar Channel from Punta Mangle (0°25' S, 91°23' W) to Punta Espinoza

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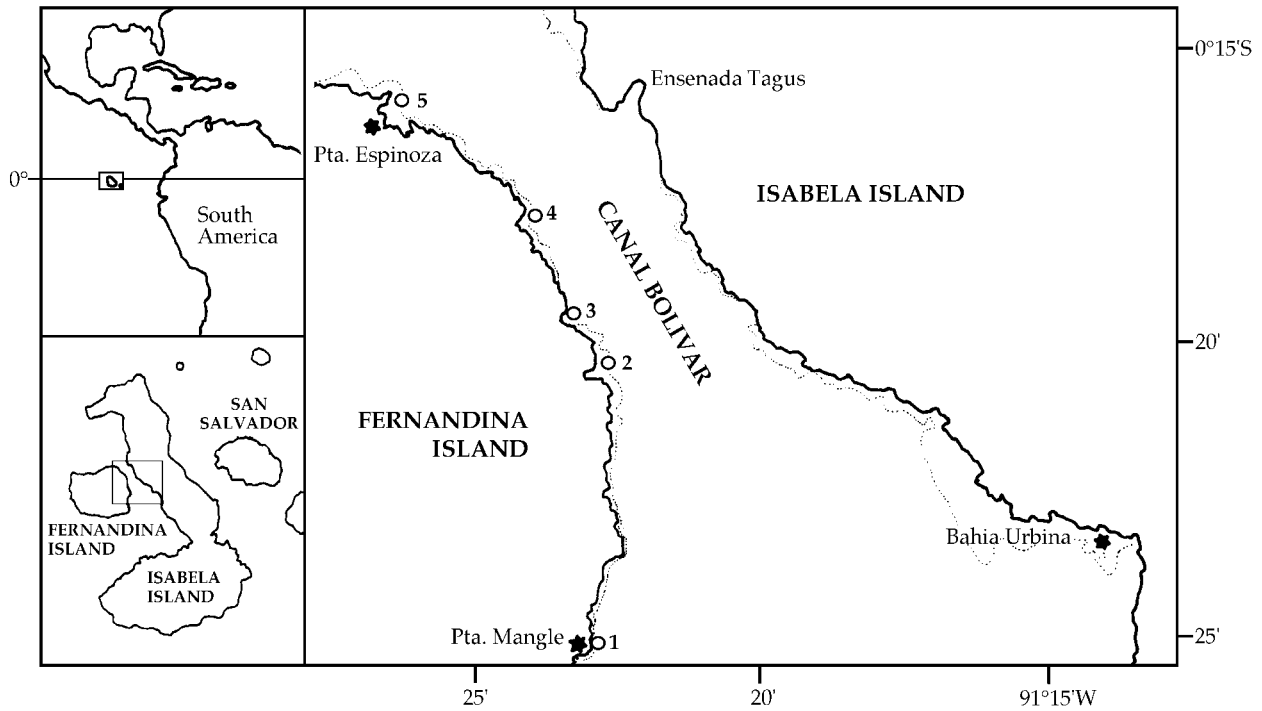


Figure 1: Study area, east coast of the Fernandina Island (Narborough), covering a sampling zone of five stations from Punta Mangle (0°25'S, 91°23'W) to Punta Espinoza (0°15'S, 91°26'W), in the Bolivar Channel

Table 1: Sampling of *Isostichopus fuscus* on the 5 stations along the eastern coast of Fernandina Island

Sampling site	Location	Station no.	No. of ind.	Depth	Size (cm)	Mean size (cm)	Wet weight (g)	Mean wet weight (g)
Pta. Mangle	0°25'S 91°23'W	1	20	5-12	10-30	25	110-295	205
Pto. Galvez	0°20'S 91°23'W	2	75	1-15	7-32	20	100-410	350
		3	15	10-24	15-25	17	190-300	270
Diag. Tagus Cove	0°17'S 91°24'W	4	55	3-18	8-30	20	210-290	290
Pta. Espinoza	0°15'S 91°26'W	5	35	5-19	10-21	20	160-295	270

(0°15' S, 91°26' W) (Figure 1). Samples were put in plastic trays with sea water and the allometric parameters were measured.

Parameters of *I. fuscus*

Table 1 shows five sites, number of samples, size and wet weight intervals and averages sampled, respectively. The average size of the individuals was 20 cm and the interval of the wet weight was 100-410 g, with an average of 271 g. 37.5 per cent of the individuals collected were found in the Stations 2 and 4; these two

stations had the greatest size and wet weight intervals of all the stations sampled along the Bolivar Channel. The specimens are cylindrical, tough and flexible with thick flanks, flat underside and convex upper side. The smooth skin is covered on the top and sides with numerous warts (see Figure 2a on next page). There are numerous large tube feet in three rows on the underside. The mouth is directed downwards (Figure 2b). The buccal tentacles are shaped like shields. The body surface is brownish, with the warts darker. The colour may change to dark brown depending on the colour of the substrate.

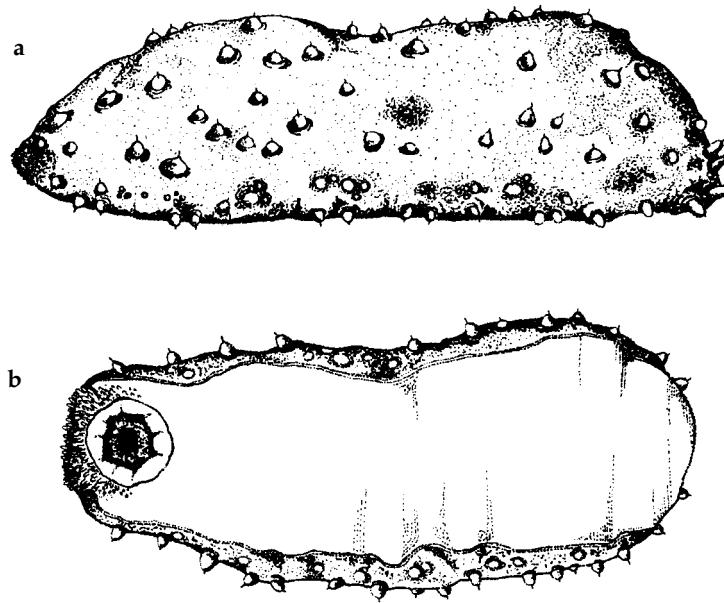


Figure 2: *Isostichopus fuscus*
(a) lateral view; (b) ventral view

Discussion and conclusion

Isostichopus fuscus was found most abundantly between 5 and 18 m on the non-exposed coasts on the eastern side of Fernandina Island as in Stations 2 and 4 (see Table 1), which are characterised by an abundant presence of boulders and broken coral rubble on the bottom. Several individuals were found on sand at the base of the large boulders at the edge of reef flat.

The lack of biological and ecological information on the sea cucumbers of the Galapagos Islands has limited comprehension of the real situation of the stocks of this fragile marine invertebrate.

The consequences of overfishing have been reported in the Solomon Islands, Cook and Fiji Islands (Richmond & Martinez, 1993), Baja California, Mexico (Castro, 1995) and Costa Rica (Anon, 1994).

The Ecuadorian government still does not have any legislation to restrict the exploitation of this marine resource. Sitwell (1993) mentioned that the enormous increase in catch rates of sea cucumbers in Galapagos could lead to a collapse of the fishery in the whole archipelago in a period of three or four years (Stone, 1995; Langreth, 1995; Gibbs, 1995).

Acknowledgments

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News from Ecuador

Fishers demanding the release of eight fishers, gaoled for illegally collecting sea cucumbers, took over Galápagos National Park offices on the islands of Isabela in January 1996; this is the second revolt relating to the issue of sea cucumber fishing in four months, and one-year on from a similar invasion in January 1995 (*TRAFFIC Bulletin* 15(2):58).

In this latest incident, Galápagos Congressman Eduardo Veliz reportedly was responsible for rallying the support of fishers who, armed with machetes, threatened to destroy the building unless their gaoled colleagues were released; when they learned that the majority of their colleagues had escaped, the siege was brought to an end after 12 hours. National Parks staff were not harmed. The incident was sparked by the seizure and subsequent incineration of 80,000 sea

cucumbers by officials. Eight of a group of some 30 fishermen were arrested; the rest fled.

On June 1996, over 30 000 sea cucumbers and 32 shark fins were seized in various islands of the archipelago during an operation jointly undertaken by the navy and the Galápagos National Parks Service; six people were detained and four boats and diving equipment seized. The sea cucumbers were incinerated.

Galápagos National Parks Press Release, February 1996; Charles Darwin Foundation, Inc., in litt., 7 February 1996; *El Universo* (Ecuador), 22 June 1996; *Hoy* (Ecuador), 20 June 1996.

Source: *TRAFFIC Bulletin* vol.16 no.2 (1996)

Survey of commercially-valued sea cucumbers in the Saipan Lagoon, CNMI

by Roy T. Tsuda ¹

In 1985, Dueñas & Swavelly, Inc. in association with Pacific Basin Environmental Consultants, Inc. prepared a Saipan Lagoon Use Management Plan for the Coastal Resources Management Office (CRMO) of the Commonwealth of the Northern Mariana Islands. In its 1996 update of this plan, one of the tasks assigned to Dueñas & Associates, Inc. (formerly Dueñas & Swavelly, Inc.) by the CNMI CRMO was to conduct a resurvey of the sea cucumber resources and to document any changes in population as compared with Ravi Chandran's 1988 Master of Science Thesis in Biology from the University of Guam entitled *The dis-*

tribution and abundance of holothurians in Saipan Lagoon, Mariana Islands.

The sea cucumber survey was conducted from 21 to 25 October 1996 by Roy T. Tsuda of Dueñas & Associates, Inc. (also Professor Emeritus of Marine Biology, University of Guam Marine Laboratory) and Michael S. Trianni of the CNMI Division of Fish and Wildlife, with the assistance of Steven S. Amesbury (Professor of Marine Biology) of the University of Guam Marine Laboratory and Patrick G. Bryan of the CNMI Division of Fish and Wildlife, who were con-

¹ Ph.D., Chief Environmental Services, Dueñas & Associates, Inc.

ducting the fish census at the same time. Sincere appreciation is extended to both Robert H. Richmond and Barry D. Smith of the University of Guam Marine Laboratory for their tutelage to R.T. Tsuda on sea cucumber identification and ecology prior to the October 1996 survey.

The 1996 sea cucumber survey (Figure 1) was conducted in waters ranging from 0.3 to 7 metres deep (MLLW) at 20 of the 22 habitats within the Saipan Lagoon described and quantified by Steven S. Amesbury, Dennis R. Lassuy, Robert F. Myers and Vaughan Tyndzik in *A survey of the fish resources of Saipan Lagoon* (University of Guam Marine Laboratory, Technical Report No. 52, March 1979). The habitats included sea-grass and macroalgal beds and patches, sandy areas, patch reefs, fringing reefs, barrier reefs and shallow harbor areas within the 30.7 km² Saipan Lagoon. The 1996 survey included similar habitats to six of the seven stations sampled by R. Chandran in 1988.

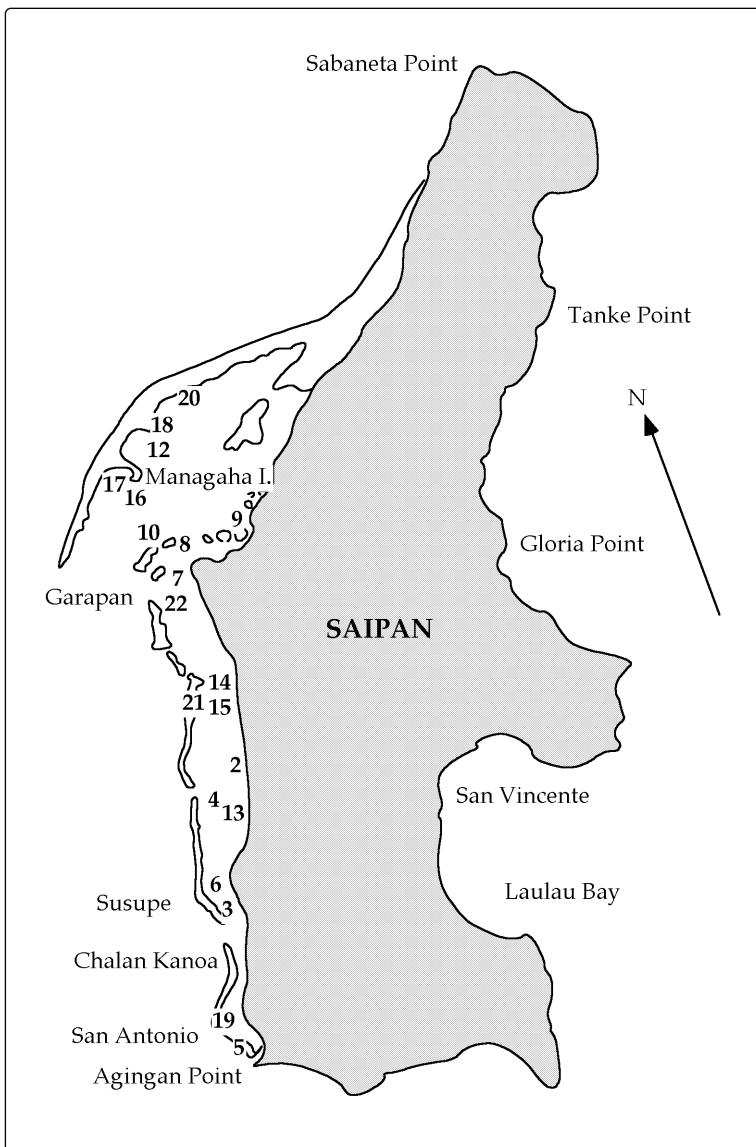


Figure 1: Map of Saipan showing the 20 stations used for the survey

R. Chandran based his 1988 counts on one set of four 10-metre long by 1-metre wide transects (i.e., area of 40 m²) in five sites and two sets of transects (i.e., area of 80 m²) in two sites. In 1996, the species composition and density were obtained from four 100 m² circles, i.e., rotating a 5.64-metre long polypropylene rope around the weighted end, per habitat, as described by Steven S. Amesbury and Alexander M. Kerr in a workshop paper 'Data collection methods for beche-de-mer resource management in Micronesia' included in the *Results of the Workshop, A Regional Management Plan for a Sustainable Sea Cucumber Fishery for Micronesia*, 3-5 March 1993, edited by R.H. Richmond.

R. Chandran quantified only four edible sea cucumbers, i.e., *Holothuria (Halodeima) atra*, *Stichopus chloronotus*, *Bohadschia marmorata* and *Actinopyga echinites*. The 1996 survey quantified these four species, plus four additional species, i.e., *Actinopyga mauritiana*, *Actinopyga miliaris*, *Bohadschia argus* and *Holothuria (Halodeima) edulis*. Two *Holothuria (Microthele) axiologa* were found in waters 4 to 7 m deep in the harbor and around a patch reef outside of the 100 m² circles. The estimated population size of each species of commercially-valued sea cucumber was derived by multiplying the mean density per square metre in each habitat by the square metre area of the applicable habitat and totaling the products of each applicable habitat. R. Chandran's density data were, likewise, used in the same manner, i.e., total number of each sea cucumber species divided by total area quantified at seven sites (360 m²) within the Saipan Lagoon, i.e., 30.7 km² instead of 51.8 km², so that the estimated sea cucumber populations for 1988 and 1996 could be compared.

Whereas R. Chandran's 1988 revised estimated sea cucumber populations appear high, the recent October 1996 estimates may be underestimations of the number of sea cucumber species within the Saipan Lagoon. The 1996 population estimates of *Actinopyga echinites* at 29,238 vs. Chandran's 583,244, *Holothuria atra* at 8,186,527 vs. Chandran's 154,160,000 and *Stichopus chloronotus* at 146,575 vs. Chandran's 2,455,766 were approximately 17 to 20 times less than that estimated for the same species in 1988. In the case of *Bohadschia marmorata*, the 1996 population estimate of 30,671 was nearly 100 times less than Chandran's 1988 estimate of 3,020,225 for Saipan Lagoon. The 1996 survey recorded only 6 individuals of *Bohadschia marmorata* during the entire

survey period. Chandran's 1988 revised estimated populations of 3.0 million and 0.6 million, respectively, were based on 46 *B. marmorata* in one of seven sites and 7 *A. echinites* in two of seven sites.

The most abundant commercially-valued sea cucumber in the Saipan Lagoon, i.e., excluding *Holothuria atra*, is *Stichopus chloronotus* with a 1996 estimated population of 146,600, with the majority of the individuals present on the lagoon slope of the barrier reef flat and on the barrier reef. One 100 m² circle consisted of 14 small individuals, with a mean length of 11 cm, or an estimated population of 384,000 individuals within the 2.74 km² of one of the barrier reef habitats. Chandran's 1988 revised estimates of 2.4 million (i.e., 0.080 per 1 m²) seems high, since he only observed 29 individuals in his seven sites; the 1996 survey documented 42 individuals in 8 of the 20 habitats.

The 1996 population estimate of approximately 20,000 *Actinopyga mauritiana* (surf redfish) in the Saipan Lagoon seems plausible, since this species is mainly found on the seaward reef margin and slope in the surf zone. A total of 15 *A. mauritiana* was

counted in one of the 20 habitats, i.e., the edge of the leeward fringing reef off Managaha Island. Only one specimen each of *Holothuna axiologa* and *Holothuria edulis* was found in the lagoon.

The one specimen of *H. edulis* allowed a projection of approximately 900 individuals inhabiting the lagoon; R. Chandran never encountered this species in the Saipan Lagoon during his extended studies.

Since the specimen of *H. axiologa* was found outside of the sampling circle, a population estimate was not prepared. The low estimate of 5,317 *Actinopyga miliaris* encountered in the Saipan Lagoon may be attributed to mistaken identification while counting *Holothuria atra*. The population estimate for *Bohadschia argus* at approximately 6,000 also seems low.

Future surveys should target four species within the Saipan Lagoon, i.e., *Stichopus chloronotus*, *Actinopyga echinites*, *Bohadschia marmorata* and *Bohadschia argus*. Population counts of *Actinopyga mauritiana* can be obtained from the commercial harvesters when they initiate harvesting within the confines of the lagoon.

Distribution and abundance of beche-de-mer on Torres Strait reefs

by Brian Long & Timothy Skewes¹

Introduction

Beche-de-mer is once again an important fishery in Torres Strait after a 50-year lull. Historically it has been a very valuable fishery with annual catches earlier this century sometimes greater than 500 t, and continued to be a prominent fishery up until the Second World War (Shelley, 1985). Torres Strait, a shallow stretch of treacherous reef-studded water situated between Australia and Papua New Guinea, was a wild frontier for pearl and beche-de-mer fishing entrepreneurs at the turn of the last century. This spirit is still evident in the recent gold rush for beche-de-mer in Torres Strait which started on the reefs on the Papua New Guinea side of the border in the early 1990s and has since spread to the reefs on the Australian side (Queensland Fisheries Management Authority (QFMA), personal communication).

One consequence of the enthusiastic fishing has been the recent closure of the beche-de-mer fisheries on both sides of the border because of concerns of over-

fishing (Lokani et al., 1996; QFMA, pers. comm.). Currently, beche-de-mer is a very important fishery on the PNG side of Torres Strait with catches reaching 192 t dry weight (approximately 3,000 t wet-weight) in 1991 (Lokani, 1996). With the renewed interest on the Australian side between 1,200 to 1,400 t wet-weight of beche-de-mer were collected in 1995 (QFMA, pers. comm.). The fishery at the turn of the last century was based on black and white teatfish (*Holothuria nobilis* and *H. fuscogilva*) whereas the fishery now is mainly sandfish, *H. scabra*. Over the last couple of years there has been, however, an increasing number of lower valued species such as *Actinopyga* spp. reported in the catch.

Although research on the PNG side of Torres Strait has shed some light on the stock in PNG waters (Lokani et al., 1996), very little is known about the distribution and abundance of beche-de-mer in Australian waters of Torres Strait. The CSIRO Division of Fisheries recently conducted a survey of the marine resources of Torres Strait reefs on behalf of

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the Australian Fisheries Management Authority (AFMA) to map reef habitats and quantify commercial resources. One of the resources sampled during the survey was beche-de-mer.

Torres Strait

Torres Strait has more than 585 reefs ranging in size from 975 m² to 165 km² covering a total area of 2,426 km². Torres Strait has a wide range of benthic shallow water habitats on the reefs and inter reefal areas which are structured by a diverse array of inter-related environmental factors such as water turbidity, sediment composition, freshwater discharge, strong tidal currents and complex bathymetry (Long & Taranto, 1997; Long et al., 1996a).

There are significant patterns in the spatial distribution of substrate types: live coral, soft sediment, rubble, consolidated rubble, pavement and boulders on the tops of the reefs in Torres Strait. The percentage cover of live coral on the reef top, averaged by reef, decreased significantly from the south-east to the north-west corner of Torres Strait whereas seagrass cover on the reefs showed a significant increase (Long et al., 1996b).

Field Survey

The large and conspicuous holothurians on the reefs in Torres Strait were surveyed in February 1995, November 1995 and February 1996. A total of 1,272 sites were sampled on the tops of 46 reefs and 374 sites were sampled along the edge of 44 of these reefs. On the reef top, the primary sampling unit was a 700 m x 700 m square and we subsampled this area with a 20 m x 2 m transect. A grid of potential sample sites centred in the squares were superimposed on all reefs in Torres Strait. For each day's sampling, 50 sites were randomly selected from the complete list of sites and a team of three divers used a small dinghy fitted with a Global Positioning System receiver (GPS) to locate the sites in the field.

At each site on the reef top a diver laid out a 20 m transect line and swam along the line collecting all holothurians within a metre either side of the transect line and placing them in a nylon-mesh divers bag. All holothurians were returned to the surface and individually weighed in the dinghy. For each transect the percentage cover of live coral, seagrass and algae and the relative proportions of the dominant taxa were also estimated. Other variables measured at each site were the percentage cover of the dominant sessile megabenthos and the percentage cover of sand, rubble, consolidated rubble, boulders (>0.5 m) and hard smooth coralline algal.

Consolidated rubble was distinguished from pavement by the presence of reticulated crevices and holes in the substrate. The vertical structure of each site was

described as low (0 to 0.5 m), moderate (0.5 to 1 m) or high (>1 m).

On the reef edge, sites were sampled at regular intervals along the edge of the reef. At each site a 4 m wide transect orientated perpendicular to the reef was sampled down the reef slope to the base of the reef or to a depth of 15 m, whichever came first. When sampled this way the average transect length for the reef edge sites in Torres Strait was 40 m. The sites along the edge of the reef were sampled with the same techniques used for the reef top except that information was recorded for every 10 m interval along the transect.

Holothurian distribution and abundance

A total of 2,287 holothurians from 12 commercial species were identified and counted during the survey: three species of high-commercial value (see Conand, 1990), *Holothuria scabra*, *H. nobilis* and *H. fuscogilva*; two species of medium commercial value, *Actinopyga miliaris* and *A. echinites*; and seven species of low commercial value, *Holothuria atra*, *H. edulis*, *H. axiologa*, *Stichopus chloronotus*, *S. variegatus*, *Bohadschia argus* and *B. marmorata*.

The regional distribution of most commercially important species showed strong spatial patterns in Torres Strait. The current target species, *Holothuria scabra*, was only found in central Torres Strait, with highest abundances recorded on the Warrior reefs (Fig. 1).

In contrast, both *H. nobilis* (black teatfish) and *H. fuscogilva*, the other two species with high value, were found in the north-eastern part of Torres Strait. However, whereas *H. nobilis* had a wide distribution and were mainly found on the tops of the reefs in this area, *H. fuscogilva* had a very narrow distribution and were mainly found along the edge of the reef (Figs. 2 & 3). *Holothuria atra*, the most abundant species, was widely distributed throughout Torres Strait (Fig. 4).

At a habitat scale there were significant correlations between holothurian abundance and characteristics of the habitats such as substratum type and seagrass cover. The abundance of *Holothuria scabra* increased significantly with increase in the percentage cover of seagrass ($P < 0.001$).

In contrast, *H. nobilis* were more abundant in areas with higher percentage cover of live coral and coralline algal pavement ($P < 0.01$). *H. fuscogilva* were more abundant at deeper than shallower sites ($P < 0.05$). *H. atra* were significantly more abundant in shallow water ($P < 0.001$) with high cover of soft sediment ($P < 0.001$) and low cover of live coral ($P < 0.001$). The abundance of most of the remaining species were also significantly correlated with one or more of the habitat variables measured.

Holothuria scabra fishery

The current beche-de-mer fishery in Torres Strait occurs mainly on the Warrior Reef complex and is based almost exclusively on *H. scabra*. Size frequency of the population on the Australian side of the border suggested that the breeding year classes (larger than 18 cm total length, 2-years old and older) were heavily depleted whereas the recruiting year class (one-year old) was relatively abundant (Fig. 5a). Fisheries managers were advised that the recruiting year class needed to be protected from over-exploitation to allow the juvenile *H. scabra* to grow to legal size (18 cm) in the latter half of 1996 to spawn in the 1996/97 summer (Long et al., 1996c). On the basis of this information and catch statistics the Australian Fisheries Management Authority imposed a minimum size limit of 18 cm and a total allowable catch of 260 t.

In contrast, new recruits (one-year old) of *H. scabra* were noticeably absent on the Warrior reefs in Papua New Guinean waters (Fig. 4). This fishery has been closed for most of the last four years (Lokani, 1996). The lack of a conspicuous recruiting year class during the present survey means that this fishery will require close monitoring and management for a sustainable recovery. The focus of future research will be on the *H. scabra* stock on the Warrior Reefs as this is the commercially important species now fished. The depleted breeding year classes sampled during the survey indicates that there is a chance that there will be weak larval settlement to the fishery during the summer of 1995/96. This could be assessed by a survey of the recruiting year class (one-year olds) in early 1997 and this information would shed some light on the stock recruitment relationship which could be used for management arrangements in 1997. If a weak

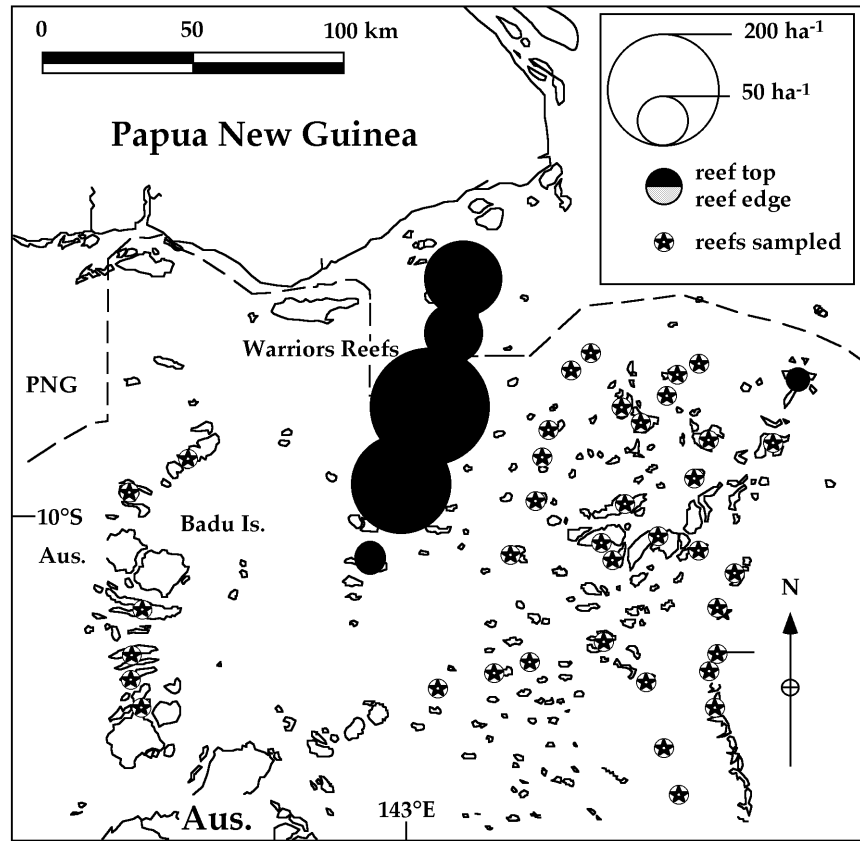


Figure 1: Pie bubble plot of abundance of *Holothuria scabra* (ha^{-1}) sampled on the top of the reefs in Torres Strait (dotted line: international border)

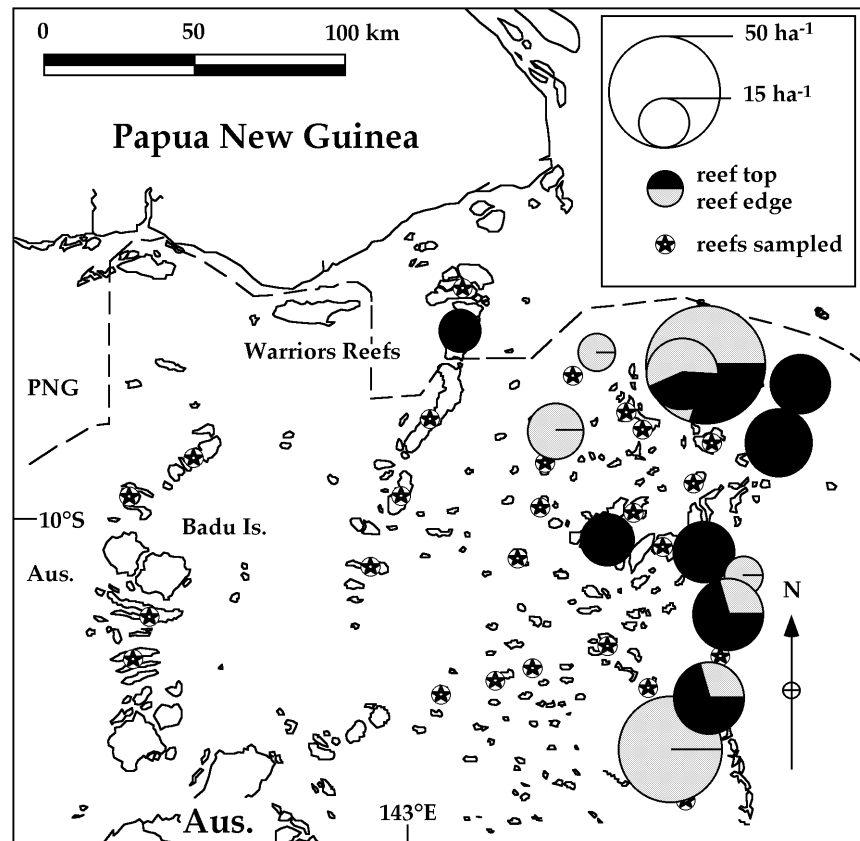


Figure 2: Pie bubble plot of abundance of *Holothuria nobilis* (ha^{-1})

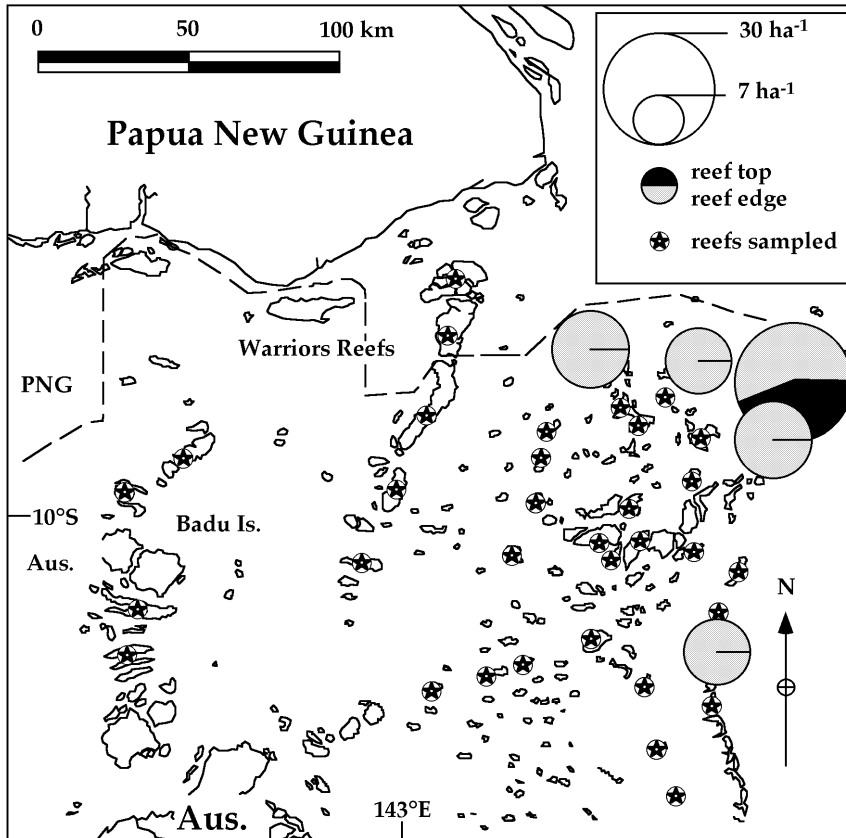


Figure 3: Pie bubble plot of abundance of *Holothuria fuscogilva* (ha^{-1})

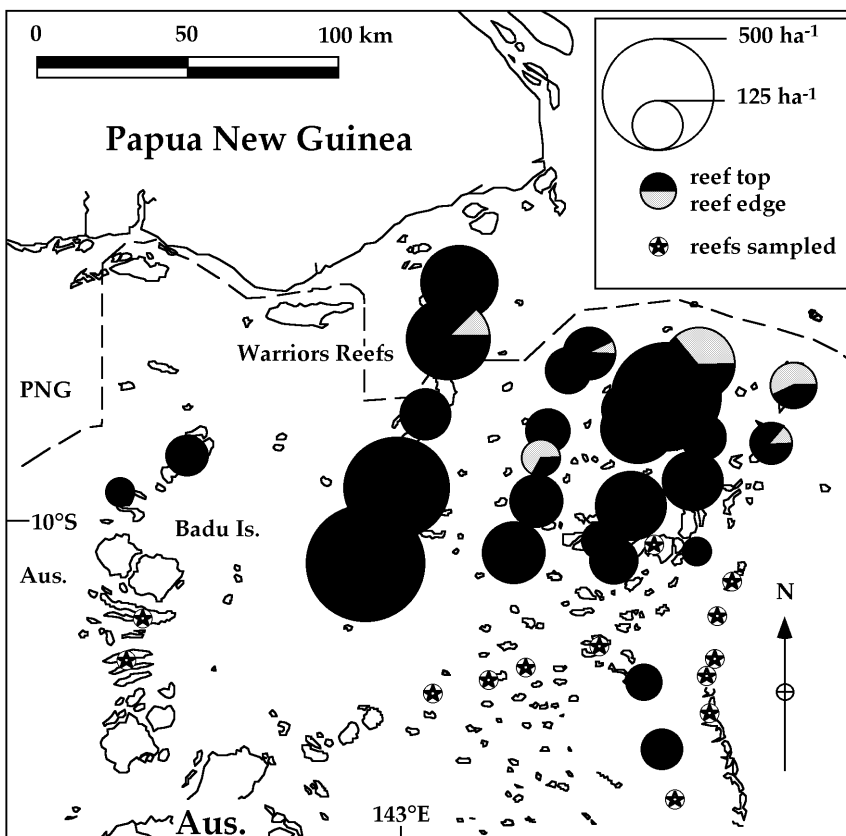


Figure 4: Pie bubble plot of abundance of *Holothuria atra* (ha^{-1})

recruitment results from this years breeding stock, then further measures such as a lower total allowable catch (TAC) and/or closed seasons may need to be taken to protect the breeding stock in 1997.

Potential new fishery for beche-de-mer in Eastern Torres Strait

The preliminary results of this survey indicates that there are substantial resources of beche-de-mer on the unfished reefs of Eastern Torres Strait principally made up of high-value *Holothuria nobilis*, *H. fuscogilva* and medium-value *Actinopyga miliaris* and *A. echinites*. This resource may provide an important future beche-de-mer fishery for Torres Strait. At present we do not have enough information about the stock to provide useful fishery advice and a full survey is required to assist fisheries managers to develop plans for sustainable exploitation of this resource.

Conclusions

Although the survey did not specifically target beche-de-mer the results have provided valuable ecological and fisheries information for this resource at both the regional and habitat-level spatial scale. There were large scale regional patterns in the distribution and abundance of many of the holothurians sampled in Torres Strait during the survey. A striking example of this was the absence or very low abundance of holothurians on most of the reefs in western Torres Strait whereas holothurians were abundant on the reefs of eastern and central Torres Strait. Only one individual of *Bohadschia argus* was collected from more than 400 sites on the 12 reefs sampled in western Torres Strait between the Australian mainland and Badu Island.

Furthermore, low abundances only of *Holothuria atra* were sampled on the reefs north of Badu Island. We cannot explain this dif-

ference in terms of habitat alone as the reefs in western Torres Strait are similar in many respects (e.g. percentage cover of seagrass) to the Warrior reefs—reefs which do have high abundance of holothurians.

Moreover, the correlations between habitat characteristics such as seagrass cover and substrate type and holothurian abundance, although significant, were generally low (Pearson's $R < 0.3$). Thus factors other than habitat type are also important for explaining the regional patterns in distribution and abundance. One hypothesis being investigated is that the differences are due in part to the relationship between larval source, supply and delivery (supply side ecology) and the complex tidal hydrological system experienced in Torres Strait (Skewes & Long, in prep.).

The significant correlations of most species of holothurians and habitat variables do, however, match up with research findings elsewhere. In Torres Strait, *Holothuria scabra* was found mainly on the Warrior reefs that are influenced by terrigenous sediments carried into Torres Strait by large rivers on the adjacent Papua New Guinea mainland. *H. scabra* have been shown to prefer reef flat areas with a high terrigenous influence (Conand, 1990).

Also, *H. nobilis* in Torres Strait had a wider distribution and a shallower mean water depth than *H. fuscogilva*; a finding also reported for other areas by Conand (1990). Moreover, *H. fuscogilva* was found on reefs at the eastern edge of Torres Strait in an area under the oceanic influence of the Coral Sea. *H. fuscogilva* in particular is usually found in reef passes that have a high oceanic influence (Conand & Chardy, 1985; Conand, 1990).

In both Torres Strait (this study) and other tropical reef systems, *H. atra* has a widespread distribution (Conand 1990). The survey of the Warrior reefs of Torres Strait also provided very useful information for fisheries managers. The results indicated that there were important differences in the size structure of the population of *H. scabra* fished on the Australian versus the Papua New Guinean sides of the border on the Warrior reefs. These differences are most easily explained in terms of differences in fishing pressure; Papua New Guinea has been fishing beche-de-mer on the Warrior reefs for a longer period than Australia. There is little evidence today that the fishery has recovered despite the extensive closure periods on the Papua New Guinea side over the last four years.

The information from the survey is being used by fisheries managers to prevent a similar occurrence in the Australian fishery. Without these data the managers may not have been able to halt the rapid decline of beche-de-mer stocks from over-fishing using catch statistics alone, as shown by what happened on the Papua New Guinea side of the border and in other tropical nations (Conand, 1990).

The broad scale patterns of distribution of many species of commercially important holothurians combined with the significant correlation of abundance with characteristics of the main habitats of Torres Strait reefs provides powerful information for designing cost-effective sampling programmes to estimate the standing stock of beche-de-mer in Torres Strait.

Stratification of the reef top based on reef and dense seagrass habitat for the Warrior reef complex improved the precision of the estimate of the abundance of *Holothuria scabra* (sandfish) by 38 per cent, because there was a significant difference in the abundance of *H. scabra* between reefs, and also because there was a significant correlation between the abundance of *H. scabra* and the percentage cover of seagrass (Long et al., 1996c).

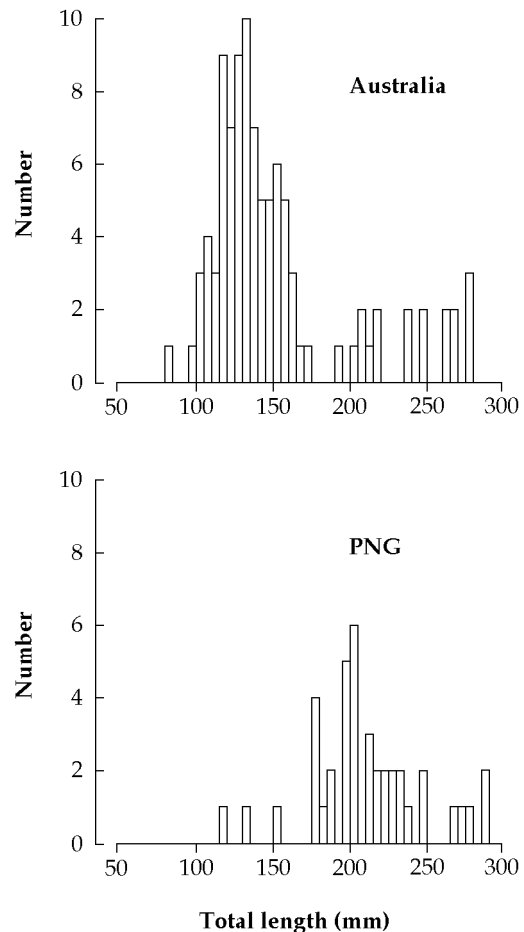


Figure 5: Length frequency distributions for the sandfish *Holothuria scabra* collected in Australian waters and Papua New Guinea (PNG) waters on the Warrior Reef complex. Total lengths were derived from wet weight using a biometric relationship total weight versus total length, given by Conand (1990).

Acknowledgments

This study was funded by the Australian and Queensland Fisheries Management Authorities. We thank D. Dennis and D. Milton from CSIRO; P. Polon, B. Karre and C. Evans from PNG NFA; and I. Baxter for their valuable assistance in the field.

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Total catch by species of beche de mer for the Queensland east coast fishery, July 1995 - June 1996

Information given by the Queensland Government and sent by Robert Lowden, President of the East Coast Beche-de-mer Industry Association (QECBIA). Please note that this information does not include the Torres Strait, 10°41'S to the Papua New Guinea border.

Month	Black teatfish	Sandfish	White teatfish	Prickly redfish	Black lolly	Deep water redfish	Other	Total (kg)
Jul. 95	5,346	3,810	32	556	0	0	64	9,808
Aug. 95	6,294	3,659	32	556	0	0	54	10,595
Sep. 95	7,809	3,433	33	558	0	0	55	11,888
Oct. 95	9,518	1,511	90	378	66	0	235	11,798
Nov. 95	24,544	3,270	43	605	88	13	455	29,018
Dec. 95	6,434	1,117	80	1,179	0	14	186	9,010
Jan. 96	14,294	3,474	0	114	0	9	0	17,891
Feb. 96	23,329	4,729	25	1,546	0	0	741	30,370
Mar. 96	22,373	935	230	492	0	13	405	24,448
Apr. 96	25,036	7,798	188	3,192	0	23	725	36,962
May 96	13,483	8,081	69	397	0	36	180	2,246
Jun. 96	15,451	5,779	1	0	0	0	0	21,231
Total (kg)	173,911	47,596	823	9,573	154	108	3,100	235,265

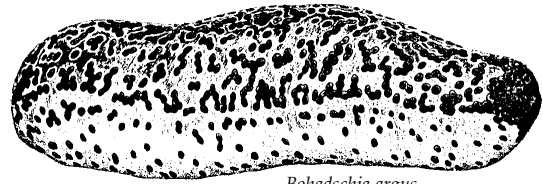
Honk Kong imports of beche-de-mer, January - March 1996

The followings table shows imports of dried/salted or in brine beche-de-mer by Hong Kong for the period January to March 1996. Quantities are in metric tonnes (t) and all values are in Hong Kong dollars.

Country	Quantity (t)	Value (1,000 HK\$)
USA	1.1	135
Canada	10.5	1,441
France	1.9	256
Mozambique	23.0	480
Taiwan	15.7	597
Indonesia	452.9	17,782
Philippines	214.4	4,707
Korea, Rep	4.0	251
Japan	6.6	6,640
China	2.1	1,546
Vietnam	11.4	116
Sri Lanka	5.3	778
Malaysia	1.5	263
Singapore	138.7	9,894
Madagascar	40.3	4,242
South Africa	6.6	285
Kenya	7.4	250
Mauritius	2.7	448
Tanzania	73.8	1,679
US Oceania	17.3	1,132
Australia & Oceania	21.0	2,964
Kiribati	3.8	765
Tonga	3.9	744
W. Samoa	3.2	180
Australia	10.4	2,404
Solomon Is.	30.5	1,528
Fiji	66.2	7,279
New Zealand	3.9	460
Vanuatu	5.6	310
Papua New Guinea	84.9	4,559
Others	0.4	18
Total	335.0	74,133

Source: *Infofish Trade News* 11/96, 17/6/96

B E C H E - D E - M E R
CORRESPONDENCE



Bohadschia argus

Correspondence from Beche-de-mer
Special Interest group members

compiled by Chantal Conand

From Andrew Morgan 06/06/96

You might also be interested to know that I am doing a Masters degree at the University of Queensland on a local species of sea cucumber. This is funded by a fisheries company from Northern Queensland and aims to set up a successful hatchery and growout system for *Holothuria scabra*, the sandfish. My research last summer was successful in getting spawn and pro-

ducing larvae. In the coming summer we aim to produce juveniles and quantify various parameters affecting the culture of this animal.

Rather than sea-ranch juveniles I am considering polyculture and waste-water drain growout in conjunction with prawns and finfish here at the centre.

From Brian Long 13/03/96

I am a research scientist at the Commonwealth Scientific Industrial Research organisation (CSIRO) Australia and we have recently completed a biological survey of the reefs in Torres Strait, northern Australia. As part of the survey we collected infor-

mation on the distribution and abundance of beche-de-mer. We have recently finished a preliminary stock assessment of the beche-de-mer resources of Torres Strait for the Queensland Fisheries Management Authority.

From Mark Baine 02/10/96

I currently undertake fisheries research with the International Centre for Island Technology (ICIT), Heriot-Watt University, Scotland. We were recently awarded Darwin Initiative funding to undertake a 3

year research project entitled 'The taxonomy, life history and conservation of Malaysian holothurians'. This research has begun.

From Randell B. Dietrich, Pres. 3/09/96

R.B. Dietrich Co., 224 Sullivan Street, Ste. A-52, New York, N.Y. 10012, Tel: 212 673-5568, Fax: 212 260-9502, e-mail: dietrich@mail.idt.net

We are an import-export trading company dealing extensively with the Far East (China, Korea, Indonesia, etc.).

Currently several of our clients are interested in the purchase of sea cucumbers, also known as: various forms of beche-de-mer; teat fish (*Microthele nobilis*);

black fish (*Actinopyga miliaris*); deep-water red fish (*A. echinites*); surf red fish (*A. mauritiana*); stone fish (*A. lecanora*), leopard (tiger) fish (*Bohadschia argus*), chalky fish (*Bohadschia marmorata marmorata*); brown sandfish (*Bohadschia marmorata vitiensis*); lolly fish (*Halodeima alra*); *Stichopus variegatus*, etc. . .

We would be interested in the purchase of farm-raised fish if they exist. If you are aware of other suppliers that are capable of producing beche-de-mer in quan-

tity, we would appreciate hearing from you. We are interested in about 4 t a month, on a regular basis. If available, they should be a minimum of 3 inches long after drying. We would like to purchase them dried and smoked.

Alternatively, if you are aware of any suppliers anywhere else in the world, preferably in the cooler waters of South America or Australia/New Zealand, we would be most grateful.

From Clarissa Marte

Southeast Asian Fisheries Development Center, Aquaculture Department (AQD), Philippines

Thank you for the *Beche-de-mer Information Bulletin* (April 1996) which I received for the first time. The information contained in this issue was most interesting, particularly since I know very little about holothurians and their fishery. I do know that they are being fished heavily in the Philippines, but there is scanty information on the state of the resource. In reefs or seagrass beds where I have visited, there are hardly any holothurians left.

We encounter only small individuals, and only very rarely large ones of commercial importance. I am interested to look at the culture potential of these animals and would like to know if there is information on the possibility/feasibility of using these animals in polyculture with fish in marine cages. While marine

fish cage culture is still not commonly practiced in the Philippines, this is one area that will rapidly develop in the near future now that areas for land-based culture are near saturation.

One of the environmental effects of net-cage culture is the accumulation of organically-rich sediments from uneaten feeds and fecal material below the fish cage.

I would like to look at the feasibility of stocking juvenile beche-de-mer in areas below or close to the fish cages so that they are able to feed on the organic materials in the sediments. May I request for information on this and other areas such as biology, reproduction and ecology of commercially important species that may be found in the Philippines.

From S. Battaglione

Iclarm, Solomon Islands 13/11/96

In August, I visited Indonesia and saw the cage culture of wild-caught juvenile *Holothuria scabra* in Sulawesi and hatchery production in Bali. The Indonesian Central Research Institute for Fisheries have produced small experimental batches of *Holothuria scabra* juveniles. They do not appear to be as progressed as the Indian researchers. The bottleneck in production is in the nursery culture of 10–20 mm juveniles where they experience problems with fungal infections.

I visited Japan in September and was very impressed with the research into the hatchery production of the temperate species *Stichopus japonicus*. In particular, I believe the development of mass production techniques by Dr Shiro Ito at the Saga Prefectural Sea

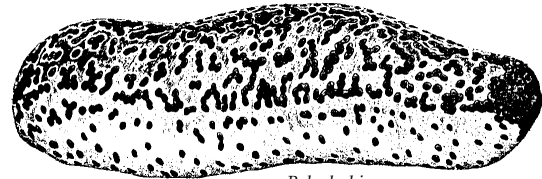
Farming Center and Mr Yanagisawa at the Aichi Prefectural Center to be highly relevant to what we are trying to achieve in the Solomon Islands with stock enhancement.

Last year in Japan, 11 Sea Farming Centres released a total of 2,557,000 sea cucumbers, average size 9 mm (range 1–120 mm). In 1996 the Saga produced 366,000 sea cucumbers (mean 15 mm, range 10–20 mm) and released 215,000, the remainder being sold to other Prefectures for release at 5.5 ¥/sea cucumber. Production has risen from 150,000 in 1992, peaking at 500 000 in 1995.

I also had the pleasure of meeting Maria Byrne this week when she visited the CAC.

B E C H E - D E - M E R

Abstracts, publications, workshops & meetings

*Bohadschia argus*

9th INTERNATIONAL ECHINODERM CONFERENCE San Francisco, August 1996

Abstracts on holothurians compiled by C. Conand

1. Holothurian fisheries

Stock assessment of the commercial sea cucumber *Parastichopus californicus* in the San Juan Islands, Washington State, USA

by A. Bradbury¹, W. Palsson² & R. Pacunski²

¹ Washington Department of Fish and Wildlife, Point Whitney Shellfish Laboratory, 1000 Point Whitney Road, Brinnon, WA 98320, USA

² Washington Department of Fish and Wildlife, Olympia, WA, USA

Although the sea cucumber *Parastichopus californicus* has been commercially exploited in the eastern Pacific since the 1970s, stock assessment has been hampered by a lack of life history data typically used in age- or size-structured models. Likewise, the lack of a long time series of catch-effort data reflecting 'equilibrium' conditions has precluded the use of many classic surplus production models. We present a simple surplus production model for *Parastichopus* which relies on a time series of catch and biomass estimates in the San Juan Islands. Harvestable biomass was estimated in two consecutive years with an underwater video method, systematically sampling along the shoreline at depths up to 40 m. Additional biomass estimates were made using dive survey data and a Leslie declining catch-per-effort technique. An independent dive survey biomass estimate which related observed declines in sea cucumber density to known catch came within 10 per cent of the corresponding video estimate. We fit a Schaefer surplus production model to these biomass estimates and the known catch during a 5-year period. Model predictions of maximum sustainable yield (MSY) ranged from 12–35 per cent of the unfished biomass per year. The best fits using video data estimated MSY between 12–14 per cent of the unfished biomass. We suggest a cautious application of these harvest rates, due in part to the relatively low precision of the video density estimates (CVs 30%). In future surveys, our results suggest that more efficient substrate-based stratification and increased sample size may improve precision, and that validation of video counts by divers may reduce bias. Despite these limitations, video has advantages over traditional dive surveys, including safety, increased depth range, economy, increased sample size, and the ability to survey several species simultaneously.

Review of recent developments in the Baja California, Mexico, *Isostichopus fuscus*, *Holothuria impatiens*, and *Parastichopus parvimensis* fisheries

by L.R.S. Castro, Semarnap-Inp, B.C., Mexico

Along the Pacific coast of Mexico, only Baja has a permanent holothurian fishery producing the highest catches, and also has a program for its study. Exploitation started in 1988 with *I. fuscus* (subtropical), in 1989 with *P. parvimensis* (temperate) and in 1994 with *H. impatiens* (subtropical). The annual catches (metric tonnes live weight) for both coasts through 1988–1996, east-west are: 730–, 553–57, 568–470, 1038–553, 960–613, 465–450, 479–727, 203–734,

40–160. Although a small fishery, it is economically significant, being one of the few sources for jobs on the east side. In the west, it helps economic survival during closure of the more profitable red sea urchin season and complements profits from abalone, top shell and keyhole limpet harvests. Holothurian exports include gutted dried whole, boiled semi-frozen skin, raw fresh muscle, and gutted whole in brine. Yields are 4–6%, 12%, 7–12% and 15% respectively. Prices are variable, influenced by devaluation, introduction of Central American markets and organisations of international traders. Our studies started in 1990 and became systematic in 1994. Drops in CPUE from 2000 kg/diver/boat to 150 kg along with drastic increases in number of permits, actual dive depth above 20 m and absence of virgin stocks below 20 m indicates overfishing. After 1990, yield fluctuations are probably stock-related. Understanding of population growth and stock size is poor, but we suggest an arbitrary quota of 500 t and closure of some areas to assure spawning stock for recruitment. The reproductive cycle shows latitudinal differences: *Parastichopus* spawns in late spring in the north and in the summer further south. Four-month seasonal closures are needed: September – December in the east, April – July in the west. Diving surveys of randomly drawn quadrats show these densities (per m²): east, 1990–1.46, 1991–0.38, 1992–0.09, 1993–0.14, 1996–0.075 and 0.08 for *H. impatiens*; west, 1996–0.03. This spring, submarine video was also taken. Correlation indices of total and gutted-drained measures and size frequency distributions are presented.

Overexploitation in the present world sea cucumber fisheries and perspectives in mariculture

by C. Conand

Laboratoire d'écologie marine, Univ. La Réunion, France

Holothurians are traditionally fished for human consumption in many tropical and temperate Pacific countries. Despite their very long-standing history, they are presently overexploited in most countries. Western Atlantic fisheries, both temperate and tropical, are generally more recent. Following the last review by Conand and Byrne (1993), the present trends are analysed from catches and trade statistics. A few case studies are also presented from recent experiences in tropical islands and mainland countries (Indonesia, New Caledonia, Madagascar, etc.). They show that during recent years, signs of overexploitation have increased, in relation to the present high commercial value of this product. The frequency of the conflicts for resource use, both at national level and between nations, is also increasing. It is probably the right time to draw attention at the international level (international organisations, conservation agencies), to those species whose taxonomy, biology and ecology are still poorly known. Mariculture projects for stock enhancement and/or for growth, are being conducted in several countries. They show promise, but the circulation of the information concerning their results is still very limited and scattered, and should be encouraged.

A review of the status of echinoderm fisheries in Australia and New Zealand

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Echinoderm fisheries are a small component of total fisheries production in both Australia and New Zealand and a small component of the world's echinoderm fisheries. Echinoderm fisheries are segregated largely on a temperate and tropical basis, with sea urchins fished in southern states of Australia and in New Zealand and holothurians in the tropical waters of northern Australia. Holothurians are an insignificant catch in temperate waters, although there is an exploratory interest in *Stichopus mollis* in New Zealand and some southern Australian states. Sea urchins are generally regarded as being under-exploited in both Australia and New Zealand with low value and variable quality inhibiting fishery development. There is some interest in post-harvest conditioning to improve quality in both Australia and New Zealand. Sea urchin species exploited are

Heliocidaris erythrogramma, *H. uberculata* and *Centrostephanus rodgersii* in southern Australia, and *Evichinus chloroticus* in New Zealand. Holothurian species fished commercially in Australia are principally *Holothuria scabra*, *Holothuria nobilis* and *Thelenota ananas*. *Holothuria atra*, *Holothuria fuscogilva* and *Actinopyga echinites* are also collected. There has been substantial recent interest in the beche-de-mer fishery in Queensland, Western Australia and the Northern Territory and rapid expansion in Queensland in particular with concerns of over-exploitation of stocks in the Torres Straits. This paper presents a summary of catch and value statistics for echinoderm fisheries in each Australian state and New Zealand along with an assessment of the current status of fisheries, management arrangements and the likely factors affecting future development of the fisheries.

Response of sea cucumber populations to a conservative harvest strategy in southeast Alaska, USA

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Sea cucumber (*Parastichopus californicus*) populations have shown mixed responses to conservative management in Southeast Alaska in the past six years. The Alaska Department of Fish and Game has conducted a very conservative fishery since 1990 with harvest rates of about 5 per cent per year. All local populations are surveyed prior to fisheries conducted on a three-year rotational basis. Of 28 local populations that have been surveyed at least twice, only 4 have had significant changes in densities. Survey biomass data indicate that several areas have had marked decreases in average mass but stable or slightly increasing densities, suggesting recruitment events into the fishery. Given the highly conservative nature of the management programme in Southeast Alaska, these results have implications for sustainable sea cucumber fisheries in general.

Population and reproductive biology of the sea cucumber *Isostichopus fuscus* in the Galapagos Islands

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The commercial exploitation of the sea cucumber *Isostichopus fuscus* in the Galapagos Islands, and the lack of studies of its ecology and reproductive biology, created the need for a long-term study to understand and manage this species. Between 1993 and 1996, six censuses were completed in seven sites of the Bolivar Channel (between the Isabela and Fernandina islands). Twenty-five to thirty individuals were collected monthly from the Fernandina and Santa Cruz islands to determine their reproductive timing. The population density around Fernandina decreased more than 50 per cent from the original census in 1993. The size structure of the population was relatively stable, with lengths from 8 to 35 cm and no smaller size classes were found. The minimum length and drained weight of individuals with mature gonads was 16 cm and 150 g. The peaks of reproductive maturity were found from November to March. The absence of juveniles in the study sites suggests different habitat preferences between juveniles and adults. Censuses demonstrated that population density levels are declining and that present levels will not allow sustainable fisheries in this area. This study will provide baseline data for the conservation and management of *I. fuscus* in the Galapagos.

Resource evaluation of the sea cucumber (*Stichopus mollis*) in an environmentally sensitive region of New Zealand

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A number of companies have located overseas markets for products derived from the New Zealand sea cucumber, *Stichopus mollis*. In late 1990, one company was granted a special permit to harvest by SCUBA up to 74 t green weight of *S. mollis* from the fiords of south eastern New Zealand to evaluate the potential of this fishery. This

proved to be a controversial initiative because it was not preceded by a resource assessment, and because the fiords are unique marine habitats surrounded by pristine catchments comprising a national park and world heritage area. In this paper we present the results of a resource evaluation conducted in four of the fiords during the course of the experimental harvesting operation. *S. mollis* was found on a great variety of substrata and was uniformly distributed throughout the fiords (but avoided the low salinity surface layer when present) at densities in the range of 1–2 individuals/10 m².

Mean catch per unit effort (CPUE) for this virgin stock was about 52 kg/diver-hour (SD=18) which equates to about 1 kg, (or four animals), per minute. Crude projections of green weight biomass, in depths of 0–20 m, ranged from 860 kg/km of coastline in Doubtful Sound to over 2000 kg/km of coastline in Charles Sound (mean of 1574 kg/km of coastline for the four fiords surveyed). On this basis, the total projected biomass in the all of the fiords approximates 1950 t in the 0–20 m strip surveyed. Potential impacts of such a fishery in the fiords include incidental damage to other organisms, particularly black coral, which is a protected species, and alteration of energy flow, particularly along detrital pathways.

Growth and reproduction of the commercial sea cucumber *Parastichopus parvimensis* in Baja California, Mexico

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The somatic growth and reproductive cycle of the commercially exploited sea cucumber *P. parvimensis* were analysed. The individuals were collected monthly between June 1993 and December 1994 at Todos Santos Islands (Baja California, Mexico), 15 m deep; transported to the lab in plastic bags in sea water with menthol crystals to relax them. Biometrical analysis was performed on: total length; total drained wet weight; body wall wet weight; length and weight of the digestive tract; gonad wet weight and external diameter of the calcareous crown. The average length was 23.2 ± 6.2 cm; total wet weight 147.8 ± 82.3 g, and gutted drained wet weight 125.6 ± 66.0 g. The calcareous ring was not adequate for measuring. *Parastichopus parvimensis* seems to be dioecious and iteroparous, with annual synchronic reproductive cycle reaching its maximum gonad index in April, for both male and females. Size at maturity was 160 g approximately (body wall wet weight), with no external sexual dimorphism. *P. parvimensis* showed a progressive atrophy of the visceral organs, with a complete disappearance by the end of October, thus getting into a cryptic habitat and hiding in holes and crevices. During this period, the body wall weight was reduced about 30 per cent. The gradual recovery of the digestive tract was completed within the next 2–4 weeks. In December the sea cucumbers showed themselves again and formation of gonads began, which (after the reproductive event) were gradually absorbed, and sea cucumbers remained sexually undetermined until the end of the year. A recruitment was observed between June and July. Two years of growth, referred to the wet weight of the body wall, were reconstructed and parameters of the von Bertalanffy growth function, with the inclusion of an oscillatory element, were obtained. It is important to point out that in the study area since 1991, *P. parvimensis* has been intensely harvested and populations around the islands seriously depleted.

Sea cucumber fisheries in Venezuela

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Before the 90s, sea cucumber fisheries in Venezuela were unknown, therefore no regulations existed. Biological and ecological studies on Venezuelan holothurids are very few; only some works on physiological aspects of two species, *Isostichopus badionotus* and *Holothuria mexicana* are available. Records of sea cucumber fisheries began in 1991–1992, when illegal catches were confiscated. These catches were made in the Mochima National Park area, northeastern Venezuela. No species, number of specimens or weight were reported. In 1993, despite the lack of knowledge in Venezuela, the Venezuelan Fisheries and Aquaculture Office Service of the Ministry of Agriculture issued the first commercial fisheries licence. One-year licences were issued to four boats to catch 200 kg/week, in the surrounding areas of Cubagua Island, northeastern Venezuela. These licences were suspended because no technical reports on the activity were submitted. In 1994, four new licences for commercial exploitation were authorised. This time two scientific institutions—Escuela de Ciencias Aplicadas del Mar, ECAM (Universidad de Oriente) and Estacion de Investigaciones Marinas (Fundacion La Salle)—agreed to submit technical reports on

captures, required for the development of management plans, regulations and authorising new licences. The fisheries area authorised were the neighbouring waters of Cubagua and Coche Islands, northeastern Venezuela.

Report from ECAM showed that fishing effort was concentrated on only two species: *I. badionotus* and *H. mexicana*. The average density (specimens per 1000 m²) was 93 and 69 for *I. badionotus*, and 14 and 17 for *H. mexicana*, in Coche and Cubagua islands, respectively. Both species were captured above a depth of 15 m. Total dry weight captures reported by two companies in approximately 5 months were 3.825 kg (with 8 boats) and 1.922 kg (with 4 boats).

In 1995, another illegal catch of 930 kg was confiscated in Los Roques National Park, northern Venezuela. In all these activities, legal or illegal, Asiatic entrepreneurs were involved. Studies and control policy on this resource are necessary to evaluate the possibility of its rational exploitation and to avoid natural populations' reduction or eradication.

2. Holothurian biology

Variation in alanine transport among sibling lecithotrophic larvae of holothuroid and asteroid echinoderms

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Variation in development rate (e.g., time to metamorphic competence) among sibling larvae has been reported, but inter-individual differences in physiological processes has received comparatively little attention. All echinoderm larvae tested have a physiological capacity to assimilate dissolved organic materials (DOM) from seawater. Lecithotrophic larvae of holothuroid and asteroid echinoderms are sufficiently large to allow measurement of DOM transport in individuals and to determine variation among sibling larvae. Larvae of *Cucumaria miniata*, *Psolus chitonoides*, and *Solaster stimpsoni* (30–45 individuals) were added to 15 ml of seawater (9–9.5°C) and 14C-alanine was added to produce a concentration of 50–70 nM. At regular time intervals, 3–5 larvae were transferred to 200 ml of seawater, each was removed and placed in a separate tube, the residual seawater removed, and the radioactivity measured.

All larvae tested assimilated alanine from solution, but the worst rates varied among and within species. For *C. miniata* doliolaria and pentactula larvae, transport rates averaged 0.0195 ± 0.00129 pmol ala/larva-min (\pm standard deviation, n = 4 experiments). Transport rates of individual larvae varied and the r² of the regression line for each experiment was <0.70. When individual values were averaged per sampling time, the r² of the regression equations increased to >0.90. For both *Psolus* and *Solaster* there was less variation in transport rate among individuals. The transport rate of *Psolus* pentactulae was 0.021 pmol/ala larva-min (r² = 0.86) and rates of alanine transport by *Solaster* brachiolariae were 0.054 and 0.049 pmol ala/larva-min (r² of the regression lines were 0.82 and 0.92 respectively).

Observed differences among larvae are not a consequence of sample contamination or label absorption and represent true variation among individuals. The functional consequences of variation in the ability to remove DOM from seawater remain unknown, but these results indicate that there can be significant variation among individuals.

A taxonomic revision of some west coast cucumariid brooders

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Five nominal species of cucumariid sea cucumbers in the northeastern Pacific brood their young. In this paper the taxonomy of *Cucumaria lubrica* Clark, *Cucumaria curata* Cowles, *Pseudocnus astigmatus* (Wells), *Cucumaria pseudocurata* Deichmann, and *Cucumaria vegae* Théel, is revised, based on morphology and results from a study of mitochondrial DNA. The identity of *C. lubrica* is clarified and *P. astigmatus* is reduced to a junior synonym. The geographic range of *C. curata* is extended to British Columbia. *Cucumaria pseudocurata* and *C. vegae* are closely related and may be synonymous. DNA evidence suggests that brooding arose twice within this group of species.

The simulated deep-sea holothurian

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The deposit feeding activities of many deep-sea holothurians make these animals important modifiers of the deep-sea sediment surface, either through mixing or repackaging and redistribution of material. The scale of the bioturbations will be greatly influenced by, among other factors, the population density, individuals' speed and search strategy of members of such fauna. We used computer simulations to investigate the range and sensitivity of areal coverage times to the ranging strategy assumed by a holothurian. Data for components of actual behaviour for the elaspod holothurian *Oneirophanta mutabilis* were drawn from time-lapse photography taken at a 4844 m sounding, (Porcupine Abyssal Plain, N.E. Atlantic). An individual *O. mutabilis* appeared in a sequence of 113 frames at one minute intervals, moving at an overall mean speed of 129 cm.hr⁻¹ (SD 68.3, range 18.9–333 cm.hr⁻¹) equivalent to 7.9 body lengths per hour. By assuming a systematic ranging strategy, a theoretical density of 15.63 indiv.10⁻³m⁻² would take a minimum of around 20.8 days to cover half the sediment area. At its most inefficient, employing a purely random ranging strategy simulation, the same density of *O. mutabilis* would take a maximum of around 32 y to cover the same half sediment area. An intermediate simulation incorporating observed distributions of speed and angles of turn, designed to emulate actual ranging behaviour, gave a half area coverage time of 16 y. These simulations reveal the sensitivity of areal coverage time estimates to the ranging strategy of the holothurian.

New records of the lagoon reef holothurians of Puerto Morelos, Quintana Roo, Mexico

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The holothurians of Puerto Morelos, Quintana Roo, Mexico, have never been made the object of investigation, although there are some reports for the general area of the Caribbean. Puerto Morelos is located at 21°00'N and 87°00'W. This area is influenced by the Yucatan Current. The specimens were collected on the lagoon reef, at 1–8 m depth, and obtained by SCUBA diving. The holothurians were found in different habitats. This contribution is based upon the collections made by the Instituto de Ciencias del Mar y Limnología, UNAM, and it is part of a more generalised project scheduled for 1995 to 1998. A total of 16 species were identified, of which 5 are recorded for the first time from Mexican waters (*Pseudothyone belli*, *Holothuria* [*Cystipus*] *pseudofossor*, *Synaptula hydriformis*, *Isostichopus macroparentheses* and *Epitomapta roseola*). The holothurians were classified as follows: 3 orders, 5 families and 9 genera. The family Holothuriidae was the most abundant. The nature of the holothurian fauna of Puerto Morelos was compared to other similar areas in the Atlantic Ocean.

Determining the nature of stiffness alteration in holothurian dermis using dynamic mechanical analysis

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Pieces of dermis from *Parastichopus parvimensis* were subjected to oscillatory shear strain. The dynamic storage and loss moduli were calculated and compared for tissues that were in stiff and compliant states. Tissues exhibited an increasing ratio of storage to loss modulus as they became more stiff, suggesting an increase in the prevalence of elastic linkages within the dermis. Extracts of the cellular contents within the dermis were obtained by subjecting the dermis to freezing followed by thawing. Outer and inner regions of the dermis were used to make two separate extractions. Tissues exposed to these solutions became compliant in the outer dermis extract, and stiff in the inner dermis extract. They did so in the absence of extracellular Ca²⁺. Based on the two parameters measured, these mechanical states were similar to those found in tissues that were taken directly from the animal and were exposed only to artificial seawater. This suggests that the stiffening and softening caused by the extracts is due to a physiologically relevant mechanism.

Microfibrils from sea cucumber dermis belong to the Fibrillin family, and their long-range elasticity is a crucial component of mutable collagenous tissues

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Microfibrils (10–14 nm diameter) are abundant in the dermis of the sea cucumber *Cucumaria frondosa*, where they form an extensive network that surrounds and penetrates bundles of collagen fibrils. This network has been purified by extracting the tissue sequentially with 6M guanidine HCl and bacterial collagenase, which extracts everything except the microfibrils. Tensile testing of this network shows it to have a linear force-extension relationship up to almost 3 times its initial length, at which strain the network breaks. The network has an elastic modulus of about 2×10^5 N/m², which decreases markedly after reduction and alkylation. The breaking strength and strain however are unaffected by disulfide reduction. Rotary shadowed images of the microfibrils of this network reveal structures identical to fibrillin microfibrils from vertebrates.

The amino acid composition of the purified network gives it a high probability of being in the fibrillin family when compared with the SwissProt database. The network also strongly reacts with an antiserum to mammalian fibrillin microfibrils. The network was not found to possess any of the commonly found lysyl oxidase-mediated crosslinks such as hydroxyproline, pyridinoline, desmosine, or isodesmosine, nor did it contain dityrosine or trityrosine. It does possess large amounts of the transglutaminase-derived epsilon-(gamma-glutamyl) lysine crosslink, which has also been found in mammalian fibrillin microfibrils. This microfibrillar network with long-range linear elasticity is crucial to the function of mutable collagenous tissues because it surrounds and retains the dissociated collagen fibrils in organised proximity. It also is likely to contribute an elastic restoring force which helps tissues (which lack muscle) to recoil. The elastic microfibrils must be considered as a necessary mechanical contributor when models of mutable collagenous tissues are developed.

Non-collagenous proteins modulate the stiffness of sea cucumber dermis in vivo and interactions between isolated collagen fibrils *in vitro*

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Separate but intact native collagen fibrils, isolated from frozen and thawed inner dermis of *Cucumaria frondosa* by extensive washing in artificial sea water, aggregate in the presence of a purified fibril-binding glycoprotein also from the dermis. This novel glycoprotein, named 'stiparin', is a flexible molecule about 125 nm long with a monomer molecular weight of $\approx 375,000$ (Matrix Biology, in press). Stiparin is the most abundant soluble protein in the dermis. Previous work has shown that experimental plasticisation of inner dermis caused by calcium chelation is due to inhibition of Ca²⁺-dependent cellular processes; and that stiffening of the dermis caused by cell lysis in the presence of a calcium chelator is due to release of an organic stiffening factor (J. Exp. Biol. 198:1951 [1995]). This factor has now been purified from freeze-thaw extracts of inner dermis: it is a protein with a monomer molecular weight of $\approx 38,000$ (Bull. MDIBL, in press). In contrast to the inner dermis, outer dermis is plasticised by cell lysis. A protein has been purified from frozen and thawed outer dermis that, in the presence of either Ca²⁺ or a Ca²⁺-chelator, plasticises specimens of inner dermis.

This protein has a monomer molecular weight of $\approx 10,000$ (Bull. MDIBL, in press). Extracts containing the plasticising protein block the stiparin-dependent aggregation of collagen fibrils *in vitro*. Extracts containing stiffening protein inhibit this action of plasticizing protein. The following molecular model is suggested by these data: (1) collagen fibrils, which, in the absence of stiparin, are prevented from associating, perhaps by sulfate groups on surface glycosaminoglycans (Comp. Biochem. Physiol. 112A:463 [1995]); (2) stiparin, which binds to fibrils and causes them to associate; (3) plasticiser, which inhibits action of stiparin; and (4) stiffener, which blocks the action of plasticiser. Plasticiser and stiffener are postulated to be secretory products, since they are only obtained from dermis in which cells were lysed. The rate at which each is secreted would determine the plasticiser/stiffener molar ratio in the dermis. This, in turn, would determine dermis stiffness by regulating stiparin-mediated collagen fibril interactions.

Seasonality in asexual reproduction of three tropical aspidochirotid holothurians and the respiration of their fission products

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Asexual reproduction by fission was monitored over a 16-month period in populations of *Holothuria* (*Halodeima*) *atra*, *H. (Halodeima) edulis* and *Stichopus chloronotus* on four reefs in the Great Barrier Reef, Australia. Fission by *S. Chloronotus* occurred exclusively between May and August with a peak of 21 per cent freshly divided animals in the population in June. *H. atra* showed a similar pattern also with a peak in June (26%). However, very few (<1%) individuals divided throughout the year. In *H. edulis*, asexual reproduction only occurred between February and May with a maximum proportion of 17 per cent divided individuals in March.

Respiration rates of intact individuals and recently (<2 weeks) divided individuals were measured for all three species in data-logging respirometers. For all species, power functions were fitted to describe biomass-specific oxygen consumption rates for intact individuals, and for anterior and posterior sections. There were no differences in biomass-specific respiration rates between the two fission products of all species. In *H. atra*, the respiration rate of fission products was on the same level as that of intact individuals. Compared to intact individuals, fission products of *H. edulis* and *S. chloronotus* showed a 32–47 per cent and 50 per cent decrease in respiration rate, respectively. Dissections of the two *Holothuria* species revealed that most of the intestines, including the respiration organs (water lungs) were retained in the posterior sections after fissions. In contrast, *S. chloronotus* lost the complete gut, including its respiration organs, during the fission process. Hence, both sections of *S. chloronotus* and the anterior sections of *H. atra* and *H. edulis* are able to sustain a considerable proportion of the respiration rate of complete individuals without their water lungs, presumably by respiration via the body wall and uptake of water into the body cavity.

Phagocytosis of sea cucumber amoebocytes: a flow cytometric study

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The present study was designed to document the quantitative aspects of phagocytosis by amoebocytes in the black sea cucumber, *Holothuria leucospilota*, using the flow cytometric method. The percentage of phagocytic cells, the number of ingested fluorescence latex beads per cell and the total number of beads ingested were quantified simultaneously at different bead/cell ratios (5, 10, 25, 50, 100 and 200). It was found that 96 per cent of amoebocytes were functionally phagocytic and the percentage of phagocytic cells as well as total number of ingested beads were positively correlated with bead/cell ratio. Within 2 hours, 3 million beads were ingested by 0.5 million amoebocytes, indicating the high efficiency of the amoebocytes to cleanse foreign particles. This study, the first quantitative analysis of phagocytosis in echinoderms by a flow cytometric method, provides new insight into the defence mechanism of sea cucumbers. Of the 50 million coelomocytes in an adult animal, about half of them are amoebocytes.

Reproduction and development of the apodous holothurian *Chiridota rotifera* (Pourtales, 1851), in the laboratory

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Chiridota rotifera is a small apodous holothurian occurring in coarse sand, at the intertidal zone in Sao Sebastiao, Sao Paulo State, Brazil (23°49'S and 45°25'W). An attempt to rear these animals in the laboratory has been conducted since 1993. Individuals of *C. rotifera* 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 sea water. Some cups contained only one individual, whereas others contained a pair, or up to ten animals. They were kept in constant temperature chambers at 22°C in the dark. *C. rotifera* are viviparous, brooding their young in the coelom. Until April 1996, 2231 individuals were born in cups containing between two and four animals, but none of the isolated individuals

reproduced. The first generation raised in the laboratory produced 1631 new holothurians, which later on produced 528 newborn, which constituted the second generation produced under laboratory conditions. A third generation began to be born in March 1996, amounting to 72 specimens up to date. The initial 304 young born in the laboratory died, but since November 1994 only 43 of 1927 born individuals were lost. Of the remaining animals, 1691 were released in their natural environment, and 193 were kept for studies. The average length of the newborn animals was 5.9 mm (SD = 1.6; n = 500), ranging from 1.2 to 12.5 mm. Some of the animals born and kept in the laboratory reproduced when they were almost 6 months old. The number of newborn per brood varied from only one up to 84 animals. Although the ambient temperature was held constant, most of the animals were born from October to February, the warmest months in the Southern Hemisphere. This may show a tendency for these animals to reproduce in the summer.

Spatial and temporal distribution of feeding of Aspirochirotida (Holothuroidea) on Heron Island, Great Barrier Reef

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Aspidochirotida are distributed throughout the reef flat of Heron Island, contributing 34–44 g wet weight of biomass per square metre. On the reef flat, feeding by *Holothuria edulis* and *Stichopus chloronotus* is concentrated on sediments 0–5 cm from coral outcroppings, while *H. atra* and *H. leucospilota* feed at 9–15 cm from coral outcroppings. Reef flat sediments actively fed upon by Aspidochirotida do not differ significantly ($p > 0.05$) in total organics, chlorophyll a, or phaeophytin from sediments not being fed upon. Spatial variation in the apparent food quality of sediment is low and probably does not contribute to the distribution of Aspidochirotida on the reef flat. In the lagoon, Aspidochirotida are highly aggregated around the bases of coral patch reefs, where their biomass can reach 210–220 g wet weight per square metre. Biomass of Aspidochirotida approaches 0 beyond 15 m from coral patch reefs. Sediments at the bases of coral patch reefs in the lagoon do not differ in total organics, chlorophyll a, or phaeophytin from sediments at 20 m distance. However, sediments at the bases of coral patch reefs contain significantly more protein and are significantly skewed toward the coarser grain sizes (ϕ -1.5 to 1.5). This suggests either that Aspidochirotida in the lagoon aggregate in areas of higher quality sediment, or that intense feeding by Aspidochirotida alters the composition of sediment near coral patch reefs. Most Aspidochirotida feed continuously. *H. atra*, *H. edulis*, *H. leucospilota* and *Stichopus variegatus* do not exhibit any circadian rhythm in feeding or the passage of sediment through the gut, whereas *S. chloronotus* demonstrates a clear circadian rhythm, extending oral tentacles more frequently and passing more sediment in the afternoon and evening than in the morning. The aggregated spatial distribution of Aspidochirotida, and the spatial separation of some species, is not driven by resource availability and niche partitioning, but rather by some other factor, such as the availability of shelter.

Effect of diet on growth and larval development of the sea cucumber *Holothuria nobilis* in Guam (poster)

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The effects of diet on larval growth, development, and survival of the economically valuable sea cucumber *Holothuria nobilis* (Selenka) was studied under laboratory conditions. Adult sea cucumbers were collected from the reefs of Guam and induced to spawn in the laboratory. Two sets of experiments were conducted at different times, each with a duration of 30 days. Larvae were raised on the following diets: 0.45 mm filtered seawater (unfed), natural seawater, and cultured algae including Tahitian (T-) *Isochrysis*, *Pavlova salina*, and a mixed culture of T-*Isochrysis* and *P. salina*. Five 1-litre replicate glass bottles were used for each diet, and larvae were raised at a larval density of 1000/bottle. Larval length at the secondary auricularia stage was largest for larvae that were raised on the T-*Isochrysis* and natural seawater diets, and significantly smaller for the unfed larvae.

Larval development was initially fastest for larvae raised on natural seawater, with 78 per cent of the individuals reaching the secondary auricularia stage within one week. However, from week two until the end of week four, development was slower for larvae raised on the natural seawater and T-*Isochrysis* diets compared to those on the

unfed treatment. Unfed larvae had faster development than the larvae of any of the other treatments; with 37 per cent larvae reaching the doliolaria stage by week four.

Larval survival was very low on the mixed diet treatment with a mean survival of 1.4% compared to 52% and 26% for T- *Isochrysis* fed and unfed larvae. Results indicate that diet has a major influence on growth, development, and survival of *H. nobilis* larvae, but other factors may also affect the ability of larvae to complete metamorphosis.

Characteristics of a population of *Holothuria floridana* (Echinodermata: Holothuroidea) in the Florida keys (poster)

by C.M. Pomory, T.W. Foret, S. Hill & J.M. Lawrence

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In March 1996, a survey of the population from seagrass beds in a small channel between the west Content Keys was done along two 170 m transects, 9 m and 25 m from shore. The habitat in each square metre was classified as algal/sand (mainly *Halimaeda incrassata*), sparse grass or thick grass (mainly *Thalassia testudinum*), and the number of *H. floridana* counted. Nineteen sediment samples were collected from the combined transects for grain size analysis. Fifteen individuals were haphazardly selected for analysis of gut sediment grain size and proximate analysis of the body wall. The 9 m transect contained 27 individuals, and the 25 m transect contained 93 individuals. Of the total population (173 mm mean length) 13 per cent was found in algal/sand, 28 per cent in sparse grass and 59 per cent in thick grass. None of the individuals were regenerating. The frequency distributions between transects and between habitats were significantly different from an equal probability distribution (G-test, $p < 0.05$). Sediment grain size distribution from the transects was 10.3% $<149 \mu\text{m}$, 28.5% $149-297 \mu\text{m}$, 30% $297-595 \mu\text{m}$, 5.6% $595-841 \mu\text{m}$ and 25.6% $>841 \mu\text{m}$, not significantly different from the gut contents except for the smallest size fraction of 18% (ANOVA, $p < 0.01$). The body wall (78 g mean wet weight) contained 86% water. On a dry weight (11 g mean) basis, it was 21% ash, 46% NaOH-soluble protein, 3% lipid, 3% carbohydrate and 27% insoluble material, probably structural proteins; equivalent to 15.6 kJ/g dry weight, 19.7 kJ/g ash-free dry weight and 60 kJ/m². The occurrence of large individuals primarily in dense seagrass beds may be related to the baffling effect of the grass blades that would cause the accumulation of fine particles, or to the provision of cover.

A review of the holothurian family Gephyrothuriidae

by P. Mark O'Loughlin

Museum of Victoria, Melbourne, Australia

The family Gephyrothuriidae Koehler & Vaney, 1905 was erected for the monotypic genus *Gephyrothuria* Koehler & Vaney. H.L. Clark (1907) added a second monotypic genus *Himasthlephora*, which Hérouard (1923) synonymised with *Gephyrothuria*. Heding (1935, 1940) added an initially monotypic genus *Molpadiodemas*, subsequently referred three synallactid species to *Molpadiodemas*, and included in the Gephyrothuriidae the genera *Pseudostichopus* Théel, *Trachostichopus* Heding, *Filithuria* Koehler & Vaney, *Plicastichopus* Heding, *Paroriza* Hérouard, *Platystichopus* Heding and *Benthothuria* Perrier. Djakonov (1952) added a monotypic genus *Peristichopus*, and Hansen (1956) referred a monotypic genus *Hadalothuria* to the Gephyrothuriidae. F.W.E. Rowe (in Rowe & Gates, 1995) followed Heding (1940), but synonymised *Trachostichopus* Heding and *Plicastichopus* Heding with *Meseres* Ludwig, including *Meseres* in the Gephyrothuriidae. Hansen (1956), Pawson (1982), Thandar (1992) and Gilliland (1993) did not follow Heding (1940), and by inference restricted the family to the genera *Gephyrothuria* Koehler & Vaney and *Hadalothuria* Hansen. Based principally on the systematic significance of tentacle form at order and family level, the family is restricted herein to *Gephyrothuria* Koehler & Vaney, *Molpadiodemas* Heding and *Hadalothuria* Hansen, genera which have digitate tentacles. *Molpadiodemas* is restricted to the species *M. acaudum* Heding, which has digitate tentacles. In the current absence of adequate morphological and molecular evidence on which to base further higher taxa, the excluded genera with predominantly peltate tentacles are at this stage referred to the family Synallactidae from which many of them were transferred by Heding (1940) without reference to tentacle form. Based on an examination of material in good condition taken off eastern Australia and held in the Australian Museum and Museum of Victoria, and on direct comparison with syntypes of *Gephyrothuria glauca* (H.L. Clark) held in the Museum of Comparative Zoology at Harvard, *Gephyrothuria glauca* (H.J. Clark, 1907) and *G. europeensis* Hérouard, 1923 are synonymised with *Gephyrothuria alcocki* Koehler & Vaney, 1905.

Elasipod holothurians from the continental slope of Australia

by P. Mark O'Loughlin

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Based on Australian Museum material, Rowe and Gates (1995) recorded six bathyal elasipod holothurian species for the continental slope off eastern Australia—*Oneirophanta mutabilis* Théel, *Laetmogone violacea* Théel, *L. maculata* (Théel), *L. fimbriata* (Sluiter), *Pannychia moseleyi* Théel and *Benthodytes lingua* Perrier. Six additional elasipod species are reported herein for further material collected from the slope off southeastern Australia and held in the Museum of Victoria—*Deima validum validum* Théel, *Benthogone rosea* Koehler, *Peniagone vitrea* Théel, *Amperima furcata* (Hérouard), *Elpidia theeli* Hansen and a *Peniagone* Théel species. The Museum of Victoria material also includes numerous specimens of *Laetmogone violacea* Théel, *L. maculata* Théel and *Pannychia moseleyi* Théel. The *Peniagone* species is characterised by having typically seven pairs of pedicels on the posterior half of the body; two pairs of anterior dorsal radial papillae posterior to the velum; a body four times as long as broad; and very spinous ossicles with distinct stem, four arms and four apophyses, dorsal ossicles with arms strongly downturned and ventral ones with arms slightly downturned.

These features are shared most closely with *P. challengeri* Théel from south of Australia, and *P. papillata* Hansen from the eastern Pacific. Of the six species reported by Rowe & Gates (1995), *Benthodytes lingua* Perrier was previously known only from the north and south Atlantic and *Oneirophanta mutabilis* Théel was known from the deep-abyssal zone. Of the six species reported herein *Amperinma furcata* (Hérouard) was previously known only from the northeastern Atlantic, *Peniagone vitrea* Théel is reported for the first time from the western Pacific, and both *Deima validum validum* Théel and *Elpidia theeli* Hansen were previously known in this region from the abyssal depths of the Tasman Sea. The remaining five species were known from bathyal depths in this region of eastern Australia, the Tasman Sea and New Zealand. In addition to these eastern Australian records, *Benthodytes sanguinolenta* Théel is represented in the Museum of Victoria collections by two specimens from the continental slope off central Western Australia. Thirteen elasipod species are recorded for the continental slope of Australia.

A new dendrochirote holothuroid from deep waters of the west coast of South Africa

by A.S. Thandar

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The order Dendrochirotida of the class Holothuroidea is well represented in southern Africa where approximately 50 species have so far been recorded. Deep-water dredgings undertaken by the South African Museum have brought to light several specimens of a new species, referable to the cucumariid genus *Paracucumaria*. This genus was erected by Panning (1949) to accommodate the type species, *Cucumaria mauritanica* Hérouard, *C. hyndmani* Thompson, *C. tricolor* Sluiter, *C. glaberrima* Semper and *C. parva* Ohshima. The latter three species have long been transferred to other genera. However, in 1971, in his re-assessment of certain cucumariid genera, Panning concluded that *P. hyndmani* should be referred to *Panningia*, a genus erected by Cherbonnier (1957) for some east Atlantic forms.

However, unaware of *P. thallasae*, described by Cherbonnier in 1969, Panning concluded that the genus *Paracucumaria* had become monotypic, represented by the type of species which possesses, in addition to the smooth plates of the body wall, baskets in the anal region. Since then, one other species, namely *P. deridderae* Massin, 1993, has been described. To the three species is now added a fourth species taken from deep waters off the west coast of South Africa. This species was originally suspected to be a *Trachythyone* and described as *T. parva* by Thandar (1991). The new species differs from others in the genus *Paracucumaria* by the equal size of the tentacles, the distribution of the pedicels, the form of the radial plates and the presence of large, multi-ocular, smooth plates in the general body wall and cup-like baskets, usually in the anal region. It is noteworthy that, like the Rhopalodinidae, the genus *Paracucumaria* is limited in its distribution to the west coast of Africa and appears to be allied to *Trachythyone* and *Leptopentacta*. However, it is doubtful whether *P. deridderae* really belongs to this genus as Massin illustrates mostly knobbed spinous plates from the body wall of his species and makes no mention of anal spicules.

Other abstracts and publications

compiled by C. Conand

Commercial fishing and organic composition of *Isostichopus fuscus* Ludwig, 1875 from the Galapagos Islands

by J. Sonnenholzner¹, N. Camba¹ and J. M. Lawrence²

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² University of South Florida, Tampa, Florida.

The sea cucumbers from the continental coasts of Ecuador and the Galapagos Islands have been fished without any control for approximately eight years. This commercial species, *Isostichopus fuscus*, is distributed in the western zone of the Galapagos Islands and the central Ecuadorian coast, particularly between La Plata Island, 9 miles from the coast of Manabi coast, and Ayangue Beach on the Guayas coast. It is the sea cucumber most commonly found in shallow waters. The proximate composition of the body wall was measured for specimens collected on April 1993 at the eastern coast of the Fernandina Island along the Bolivar Channel from Punta Mangle (0°25'S, 91°23'W) to Punta Espinoza (0°15'S, 91°26'W). The concentrations of ash (1.0–1.5%), protein (2–4%), fat (3.1–3.6%) and carbohydrates (<1%) were all low as the water content was high (93.5%). Carbonate and chloride concentrations were very low (<1%). The body wall of *I. fuscus* is not a high-quantity protein food source.

Species and size related trends in asexual propagation of commercially important species of tropical sea cucumbers (Holothuroidea)

by Norman Reichenbach, Yoosuf Nishar and Ahamed Saeed

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In: Journal of the World Aquaculture Society. December 1996. 27 (4).

Juveniles of four species of tropical sea cucumbers of moderate to high commercial value were studied to determine their potential for being propagated asexually by evaluating their survival and regeneration times after being forced to undergo transverse fission. The species were *Holothuria fuscogilva*, *H. nobilis*, *Actinopyga mauritiana*, and *Stichopus variegatus*. Rubber bands placed midbody on the sea cucumbers provided an effective yet simple technique to induce fission. Posterior parts of animals had similar or higher survivorship and shorter regeneration times relative to the anterior parts. Combining this information with that collected earlier on adults indicated that smaller animals (both anterior and posterior parts) had higher survivorship (up to 100%) and shorter regeneration times (as fast as 41 days) relative to adult animals of the same species. Using per cent weight retained after processing into beche-de-mer a rough measure of body wall thickness, and size of the animal relative to the adult weight, a multiple regression equation was calculated to predict per cent survival and regeneration times for both anterior and posterior parts. The equation illustrated that small, thin-walled species would have the highest survivorship and shortest regeneration times. As the per cent weight retained increased, as would be the case with more thick-walled species, and as the animal approached the adult weight, survivorship declined and the regeneration time increased.

Conservation of sea cucumbers

by D.B. James

Central Marine Fisheries Research Institute, Cochin – 682 014

In: N.G. Menon and C.S.G. Pillai (eds.) Marine bio-diversity, conservation and management, Central Marine Fisheries Research Institute, Cochin. 80–88.

Over the years there has been a decrease in the landings of sea cucumbers all over the Gulf of Mannar and Palk Bay along with a drop in the size of the specimens collected. The catch per unit of effort has also significantly fallen in the recent years. All these factors point to over-exploitation of the sea cucumbers and need for their conservation.

Culture of sea cucumber

by D.B. James
Central Marine Fisheries Research Institute, Cochin – 682 014

In: Bull. Cent. Mar. Fish. Res. Inst. 48: 120–126. 1996.

'Deep-water redfish', a new resource for the Indian beche-de-mer industry

by D.B. James & M. Badrudeen
Central Marine Fisheries Research Institute, Cochin – 682 014

In: Mar. Fish Inform Service. 137: 6–8. 1995.

Taxonomic studies of the species of *Holothuria* (Linnaeus, 1767) from the seas around India

In: Journal, Bombay Nat. Hist. Society. 92(1): 43–62. 1995.

Part 1, by D.B. James

In this paper earlier attempts made to revise the genus *Holothuria* Linnaeus, 1767 are given in detail. Of the 26 species known under the genus *Holothuria* from Indian seas, 18 species have been collected by me. These have been described in detail with full synonymy, notes on habits and remarks with figures and photographs. Keys have been provided for all the species known from the Indian seas.

Part 2, by D.B. James

Holothuria (*Mertensiothuria*) *leucospilota* (Brandt) (Pl. 2, A; 3, A–C).

Stichopus (*Gymnochirota*) *leucospilota* Brandt, 1835, p. 51.

Holothuria vagabunda Bell, 1886, p. 28: Mergui Archipelago; Bell, 1887a, p.140: Andaman Island; Bell, 1888, p. 389: Tuticorin (Gulf of Mannar); Thurston, 1894, p. 11.5: Tuticorin (Gulf of Mannar); Pearson, 1903, p.201: Ceylon (Sri Lanka); Koehler & Vaney, 1908, p. 17: Andaman Island; Laccadives (Lakshadweep).

Holothuria leucospilota A.M. Clark & Davies, 1966, p. 603: Maldives; James, 1969, p. 62; Gulf of Mannar, Arabian Sea, Andamans, Laccadives (Lakshadweep); James, 1982, p. 5; Tikader & Das, p. 99: Andaman & Nicobar Islands; James, 1987, p. 110: Hut Bay (Little Andamans).

Holothuria (*Mertensiothuria*) *leucospilota* James, 1982, p. 92: Goa (West coast of India); Soota, Mukhopadhyay & Samanta, 1983, p. 511: Trinket, Nancowry Harbour, Sound Island (Andaman & Nicobar Islands); Mukhopadhyay & Samanta, 1983, p. 305: Lakshadweep; Price & Reid, 1985, p. 4: Galle (Sri Lanka); James, 1986a, p. 585: Lakshadweep-Maldives, Sri Lanka, Gulf of Mannar, Palk Bay, Andaman-Nicobar Islands; James, 1989, p. 127: Chetlat, Kiltan, Kadmat, Amini, Androth, Kavaratti, Minicoy (Lakshadweep).

Morphology of the Pentactulae of holothurian *Cucumaria japonica* (*Dendrochirota*, *Holothuroidea*) at different developmental stages

by I. Yu. Dolmatov, N.D. Mokretsova
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The morphology of the pentactulae of holothurian *Cucumaria japonica* at different stages was studied. One and a half months after fertilisation, the architectonics of pentactulae is similar to that of adult holothurians. Five tentacles, 5 radial ambulacral canals, the Polian vesicle and the stone canal are present. The nervous system consists of a nerve ring, tentacular nerves and radial nerve cords. The longitudinal muscles are developed at the ventral radius.

The gut consists of several parts. Gonads and respiratory trees are absent in pentactulae of all the studied ages. In the process of metamorphosis, the most important changes take place in the digestive tract and in the stone canal. In 4-month old pentactulae, the stone canal loses its connection with external environment and the dydropore is shut. The madreporite arises as an outgrowth of the wall of stone canal just above the coelomic epithelium. At this period (1.5 to 4 months), the gut passes through three phases of development. These phases are correlated with functional changes in the digestive system and the changes of feeding mode of pentactulae.

Screening for antibacterial agents in three species of sea cucumbers from coastal areas of Sabah

by B.H. Ridzwan, M. A. Kaswandi, Y. Azman and M. Fuad.

Department of Biomedical Sciences, Faculty of Allied Health Science, Universiti Kebangsaan Malaysia, 50300 Jalan Raja Muda Abdul Aziz, Kuala Lumpur, Malaysia.

In: Gen. Pharmac. vol. 26, no. 7, 1539–1543. 1995.

Asexual reproduction by fission in *Holothuria atra*: variability of some parameters in populations from the tropical Indo-Pacific

by Chantal Conand.

Laboratoire d'Écologie Marine, La Réunion

In: Oceanologica Acta, vol. 19, no. 3–4. 1996.

Holothuria atra is the most common aspidochirotid holothurian on tropical Indo-Pacific reefs. Asexual reproduction by transverse fission, followed by regeneration, has been studied at Reunion Island (Indian Ocean) and compared with different populations of the Indo-Pacific zone, thus permitting a better identification of the most significant parameters and a better understanding of this reproductive strategy.

At Reunion Island, the species is studied at two stations on the same fringing reef: 1) on the back-reef where the fission rate is high (20% of the population), the individuals small (generally weighing less than 150 g) and the population density high (4/m²); and 2) on the reef front, where fission is extremely rare, the mean size of the individuals larger (up to 300 g) and the density low (0.01/m²). Different categories of individuals, fissioning (F), after fission, anterior and posterior parts (A and P), and regenerating (Ap and Pa) have been identified from external observations.

Dissection has demonstrated the unequal allocation of organs during fission and the variability of the regenerative states, mostly in the anterior part. Concerning fission, the position of the split in an individual is in the anterior half (at 44% of the total length). The monthly incidence of fission is higher from October to January and in June-July. Fission does not result in an increase in the density of the population.

The monthly rates of regenerating individuals originating from anterior (3.7%) and posterior (6.1%) parts suggest that survival is higher in the latter instance. The occurrence of asexual reproduction in various populations of this species is discussed in relation to the ecology and the parameters of the populations considered. On the back-reef studied at Reunion Island, the population is subtidal and emersion cannot explain fission. Anthropogenic disturbances are possible triggers of this phenomenon.

Ultrastructural organisation of contractile systems in the Holothurian *Eupentacta fraudatrix*

by I. Yu. Dolmatov.

Institute of Marine Biology, Far East Division, Russian Academy of Sciences, Valdivostok, 690041.

In: Russian Journal of Marine Biology, Vol. 21, No. 2. 1995. 119–123. Original Russian text copyright (1995) by Biologiya Morya, Dolmatov.

Morphology of the contractile systems of the holothurian *Eupentacta fraudatrix* are examined using transmission electron microscopy techniques. The largest muscles are the longitudinal muscle bands and the retractor. They

have a similar structure and consist of separate muscle bundles surrounded by connective tissue. Each bundle is composed of 8 to 20 cells and is surrounded by a basal lamina; myocytes anchor the latter by means of hemidesmosomes. The muscle cells are polarised; myofibrils are located in the peripheral basal part of a cell, and the nucleus and cytoplasm with organoids are located in the apical part in the center of a bundle. The muscles of the body wall, gut, and respiratory trees are represented by folded coelomic epithelium composed of epithelio-muscle cells. It is concluded that the formation of myoepithelial folds represents an intermediate stage in the evolution of muscles as three-dimensional systems.

Muscle ultrastructure and growth of the pentactula of the holothurian *Eupentacta fraudatrix*

by I. Yu. Dolmatov.

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In: Russian Journal of Marine Biology, Vol. 21, No. 1. 1995. 64–68.

The Morphology and growth of longitudinal muscle bands (LMB) in one-year old holothurians *Eupentacta fraudatrix* was examined by transmission electron microscopy. The LMBs are covered by a flattened ciliated coelomic epithelium and consist of muscle bundles encircled by connective tissue. A basal lamina separates each bundle from the extracellular matrix. New muscle bundles arise from a coelomic epithelium. Myofibrils begin to form in the processes of some coelomic epithelium cells (myoblasts). The amount of myofibrils gradually increased and the cell groups deepen into the connective tissue of muscle. At the same time, young myocytes form their own basal lamina. This results in a formation of a new line of muscle bundles just under the epithelium. A conclusion is made that the histogenesis processes in both development and growth of holothurian muscles are identical, at least during the first years of life.

Muscle regeneration in the holothurian *Stichopus japonicus*

by Igor Yu Dolmatov, Marina G. Eliseikina, Alexander A. Bulgakov, Talia T. Ginanova, Nina E. Lamash & Valadimir Korchagin.

In: Roux's Arch. Dev. Biol. 1996.

The regeneration of longitudinal muscle bands (LMBs) in the sea cucumber *Stichopus japonicus* was studied using light and electron microscopic and immunocytochemical methods. Previous investigations of holothurian organs showed the presence of some cytoskeletal proteins which were specific for LMBs only. One of them, the 98 kDa protein, was isolated by means of SDS electrophoresis and used as an antigen to obtain polyclonal antibodies. When tested on paraffin sections of sea cucumber organs, the antibodies were shown to interact only with coelomic epithelial cells covering the LMBs. The antibodies were used to study LMB regeneration after transverse cutting. During regeneration no signs of myocyte dedifferentiation or mitotic division were observed. In the wound region, damaged myocytes degenerated and muscle bundles desintegrated. However, the coelomic epithelial cells dedifferentiated and began to invade the LMB. Just beneath the surface these cells formed clusters (muscle bundle rudiments). The number and size of clusters gradually increased, the cells lengthened and developed contractile filaments. These observations suggest that new muscles arise from coelomic epithelial cells covering LMBs. The migration of coelomic epithelial cells into the damaged LMBs and their myogenic transformation are the basic mechanism of holothurian muscle regeneration.

On a *Psolus* species encountered in Kraternaya Bight (Ushishir Island, the Kurile Islands)

by A.V. Smirnov

Zool. Inst., Russ. Acad. Sci., St. Petersburg 199034, Russia.

In: Biologiya Morya (Vladivostok), 21 (1). 1995. 83–84.

The paper deals with species identification and distribution of a holothurian, *Psolus* sp., from Kraternaya Bight of Yankicha Island (the Kuriles).

Two new holothurians (Echinodermata: Holothuroidea) from an anchialine lagoon of an uplifted atoll, Kakaban Island, East Kalimantan, Indonesia

by C. Massin & T. Tomascik.

Dep. Invertebrates, Royal Belgian Inst. Nat. Sc., 29 rue Vautier, 1000 Brussels, Belgium.

In: Raffles Bulletin of Zoology 44(1). 1996. 157–172.

Two new species of holothurians, *Holothuria (Lessonothuria) cavans* (Holothuriidae) and *Synaptula spinifera* (Synaptidae) are described from an anchialine lagoon on the raised atoll island of Kakaban, East Kalimantan, Indonesia.

Morphology of the pentactulae of holothurian *Cucumaria japonica* (Dendrochirota, Holothurioidea) at different developmental stages

by I. Yu Dolmatov & M.D. Mokretspva.

Inst. Mar. Biol., Far East Div., Russ. Acad. Sci., Vladivostok 690041, Russia.

In: Zoologicheskii Zhurnal, 71(1). 1995. 83–91.

Ultrastructural characteristics of the digestive epithelium in *Cucumaria japonica*

by M.G. Eliseikina & N.L. Leibson.

Inst. Mar. Biol., Far East Div., Russ. Acad. Sci., Vladivostok 690041, Russia.

In: Biologiya Morya (Vladivostok), 22(2). 1996. 102–109.

Effect of compounds elevating cyclic nucleotide levels on dithiothreitol-induced oocyte maturation in the holothurian *Stichopus japonicus*

by E.M. Karaseva & Yu S. Khotimchenko.

Lab. Cellular Physiol. Pharmacol., Inst. Marine Biol., Far East Branch, Russian Acad. Sci., Vladivostok 690041, Russia.

In: Comparative biochemistry and physiology C pharmacology toxicology and endocrinology, 111(3). 1995. 441–444.

Muscle repair in the holothurian *Eupentacta fraudatrix* is realised through transdifferentiation of the coelomic epithelium cells

by I. Yu. Dolmatov, M.G. Eliseikina & T.T. Ginanova.

Institute of Marine Biology, Far-Eastern Branch of the Russian Academy of Sciences, Vladivostok, 6990041 Russia. Received 17 September 1994.

In: Biology Bulletin, Vol. 22, No. 4. 1995. 409–414

Regeneration of longitudinal muscle bands in the holothurian *Eupentacta fraudatrix* was studied using light and electron microscopy. It has been shown that new muscle bundles are formed from the coelomic epithelium cells. Migration and submergence of the coelomic epithelium cells in the connective tissue and their myogenic differentiation are the main mechanisms underlying muscle repair in these animals.

No mitotic activity was observed in the regenerate tissues. A conclusion was drawn that multipotency and liability of differentiation of the coelomic epithelium is its primary property, which was preserved, which was preserved during evolution in the Celomata with respect to asexual reproduction and regeneration.

Growth estimates by the size distribution of sea cucumber, *Stichopus japonicus* Selenka, in the artificial pools in Toyosaki, Minamikayabe-chou, southern Hokkaido

by Hiroshi Hoschikawa, Kazuhiro Takahashi, Yukihiro Konno & Tooru Miyagawa.

In: Sci. Rep. Hokkaido Fish. Exp. Stn. 46,7–14. (1995).

The size distribution of a sea cucumber, *Stichopus japonicus* Selenka, was investigated in the artificial intertidal pools and rocky subtidal area in Toyosaki, Minamikayabe-chou, southern Hokkaido. The density of juveniles was higher in the intertidal pools (6.67/0.25 m²) than the rocky subtidal (0.33/0.25 m²). The body weights of 1⁺ and 2⁺ in October were estimated as ca. 10g, and ca. 40g, respectively.

Marine species collected by women in Palau, Micronesia

by Elizabeth Matthews¹ & Evelyn Oiterong²

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² Division of Marine Resources Koror, Palau

In: Micronesica 281: 77–90. 1995.

Women in Palau, Micronesia regularly collect sea cucumbers, molluscs, urchins, crabs, and reef fish from shallow nearshore areas according to a survey of 54 Palauan women. This article describes the most common methods Palauan women utilise to collect marine species for subsistence and local commercial purposes. Of the women interviewed, most collect invertebrates by reef gleaning. Some women collect mangrove clams, commercially their most important species. Some women catch land crabs, coconut crabs or mangrove crabs. Many women use handlines to catch reef fish. Few women use spearguns or nets to catch fish. There is some concern among the women that several of the invertebrates they collect are harder to find now than they were in the recent past. In particular, the women are concerned about the status of stocks of giant clams, short-spined urchins, mangrove clams, and a species of swimming crab that is collected for subsistence use.

Fishery dynamics, ecology and management of beche-de-mer at the Warrior Reef, Torres Strait protected zone, Papua New Guinea

by Paul Lokani.

Master of Science thesis, December 1995. Dipl. Fish. Tech., BSc (PNGUT). James Cook University

An artisanal fishery for sea cucumbers at the Warrior Reef commenced in 1990 but was closed in 1993 as a result of over-exploitation of the target species *Holothuria scabra*. To assist in the appropriate management of the fishery when re-opened, a study was conducted to (i) document and analyse existing fisheries data, (ii) describe patterns of distribution and abundance of common sea cucumber species found on the reef flat, (iii) determine the reproductive biology of *H. scabra* and (iv) describe patterns of movement for *H. scabra*.

Analysis of fisheries records over four years (1990–1993) indicates peak catches of *H. scabra* in 1991–1992, which subsequently declined, with the fishery shifting to several less valuable species. Fishing did not appear to be size selective. As sites were fished out, exploitation moved further afield until the fishery was closed. The rapid depletion of populations during intensive fishing and a depletion experiment provided estimates of the total exploitable stock using the Leslie model. Application of Gulland's surplus production model resulted in extremely low estimates of maximum sustainable yield (2.96 kg per hectare per year) of 49 t for the whole reef.

The distribution and abundance of sea cucumbers that occupy the reef flat at the Warrior Reef are unknown. Using visual census techniques, patterns of distribution and abundance were tested at two reefs, three zones and thirty sites. The mean density was not different among reefs and zones but was significantly different among sites for *H. scabra* which was found to comprise from 10 to 30 per cent of the individuals found at each zone. Two other dominant species were *Holothuria atra* and *Bohaschia similis* which, together with *H. scabra*, comprised from 50 to 90 per cent of the individuals in each zone. Species richness ranged from 12 to 14 per zone and remained about the same in the two reefs. Sizes encountered on the reef flat were smaller than those exploited by the fishery and were significantly different among the zones. Abundance of *H. scabra* monitored on permanent transects on May, September and March 1994 and June 1995 was not significant but species diver-

sity was significantly reduced. The presence of only one high value species, *H. scabra*, on the reef flat would continue to place pressure on this species.

Reproduction of *H. scabra* was studied over a one-year period using histological techniques to determine the reproductive cycle and size at first sexual maturity for possible inclusion into a biologically-oriented management regime. There was a seasonality in spawning, from November to January, which is consistent with other studies carried out in Papua New Guinea. Size at first sexual maturity was estimated to be 14 cm and is consistent with other studies carried out in Papua New Guinea. Observations on spawning found that males tended to spawn earlier than females. A continuous stream of spermatozoa was standard for males but females released oocytes in cycles of about 5 minutes.

Movement is an important consideration in sea cucumber biology and management. The burrowing behaviour and directional movement were investigated in *H. scabra*. Burrowing behaviour was significantly different between high and low tide but was suspected to have been caused by spawning rather than tide. Movement was not random. Water appears important as a hydrodynamic fluid which is used in locomotion by *H. scabra*.

Three management regimes based on this study were recommended for implementation in management. These are a closed season during the spawning season from November to January, a variable Total Allowable Catch of 49 tonnes based on the estimated Maximum Sustainable Yield, and a size limit of 21 cm which is set above the size at first sexual maturity of 14 cm because it is economically desirable and biologically acceptable.

Balkema books on echinoderms:

Echinoderm research 1995 – Proceedings of the fourth European colloquium, London, 10–13 April 1995. 1996. 25 cm, 360 p., Hfl. 230 / \$ 145.00 / £ 94.

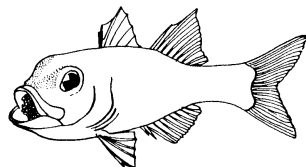
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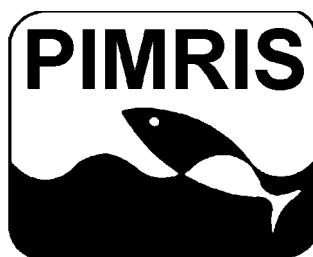
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