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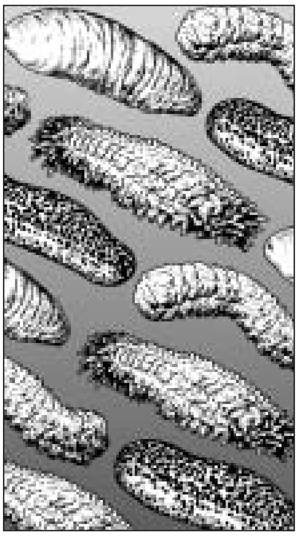

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Editorial

In this 18th issue of the *SPC Beche-de-mer Information Bulletin*, we present several original articles:

J.-F. Hamel and co-authors present the larval development and juvenile growth of the Galapagos sea cucumber *Isostichopus fuscus* (p. 3).

A. Desurmont describes the new series of plastic identification cards, showing 20 different species of sea cucumbers, that the SPC Fisheries Information Section have prepared and produced for the National Fisheries Authority of Papua New Guinea (p. 8).

R. Pitt and N.D.Q. Duy describe experiments conducted in Vietnam to produce sandfish (p. 15).

Jiaxin Chen gives an overview of sea cucumber farming and sea ranching practices in China (p. 18).

Conservation strategies for sea cucumbers are becoming important. A.W. Bruckner and co-authors discuss the CITES Appendix II listing and question whether such a listing would promote sustainable international trade (p. 24).

P. Purwati and J. T. Luong-van present their study of the sexual reproduction in a fissiparous species, *Holothuria leucospilota*, in the tropical waters of Darwin, Australia (p. 33). Their findings have led them to the question: “Does intensive fission prevent recruitment following sexual reproduction, or does failure of sexual recruitment generate intensive fission activity?”

We continue our publication of spawning observations in the wild with one case involving *Pearsonothuria graeffei* described by P. Purwati, and one involving *Stichopus hermanni* described by A. Desurmont (p. 38).

Inside this issue

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Following these original articles, you will find our regular features presenting abstracts, new publications and meetings. A workshop on beche-de-mer was held in the Torres Strait Islands on 28 and 29 May 2002. Its objectives and outputs are presented here (p. 42).

Please note that an important workshop on Advances in Sea Cucumber Aquaculture and Management (ASCAM), organised by the Fishery Department of the Food and Agriculture Organization (FAO), is planned for October 2003 in China. The workshop, which aims at gathering experts from different parts of the world, is expected to last four full days. You will find more information, and the contact details for Mr Alessandro Lovatelli at FAO, on page 44 of this issue.

I remind you that the 11th International Echinoderm Conference will be held at the Ludwig-Maximilians-Universität, Munich, Germany, on 6–10 October 2003. More information can be found at http://www.iec2003.uni-muenchen.de.

Previous issues of the Bulletin are available on the SPC website at http://www.spc.int/coastfish/ in both French and English. I also draw your attention to the very informative Virtual Echinoderm Newsletter. Issue no. 26 is available on the Web at http://www.nmnh.si.edu/iz/echinoderm.

Chantal CONAND

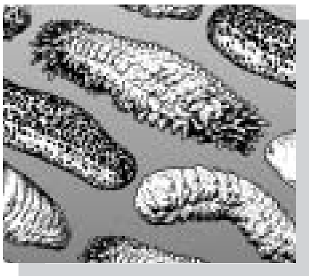
Produced with financial assistance from the European Union.

The views expressed in this Bulletin are those of the authors and are not necessarily shared by the Secretariat of the Pacific Community or the European Union.

PIMRIS is a joint project of five international organisations concerned with fisheries and marine resource development in the Pacific Islands region. The project is executed by the Secretariat of the Pacific Community (SPC), the South Pacific Forum Fisheries Agency (FFA), the University of the South Pacific (USP), the South Pacific Applied Geoscience Commission (SOPAC), and the South Pacific Regional Environment Programme (SPREP). This bulletin is produced by SPC as part of its commitment to PIMRIS. The aim of PIMRIS is to improve the availability of information on marine resources to users in the region, so as to support their rational development and management. PIMRIS activities include: the active collection, cataloguing and archiving of technical documents, especially ephemera ('grey literature'); evaluation, repackaging and dissemination of information; provision of literature searches, question-and-answer services and bibliographic support; and assistance with the development of in-country reference collections and databases on marine resources.

PIMRIS

Pacific Islands Marine Resources Information System



new info
beche-de-mer

Larval development and juvenile growth of the Galapagos sea cucumber *Isostichopus fuscus*

Jean-François Hamel[1], Roberto Ycaza Hidalgo[2] and Annie Mercier[1]

Abstract

This study presents preliminary results on the early development and growth of the sea cucumber *Isostichopus fuscus* in land-based installations on the coast of Ecuador. This species has been intensively fished along the mainland and around the Galapagos Islands, where efforts at management have always met strong opposition from local communities. Ecuadorian populations of *I. fuscus* have thus been severely depleted over the past decade. The data presented here show that this species can be reared in captivity, thus providing an alternative to fisheries, or a way to maintain sustainable harvests and eventually contribute to the restoration of the natural populations. Data pooled from three trials indicate that juveniles can be grown to a size of ca 3.5 cm in length in less than three months. They are then fit to be transferred to grow-out ponds or to be released in the field.

Introduction

Isostichopus fuscus (Fig. 1) is a deposit-feeding sea cucumber that is mainly found on reefs and sandy bottoms along the western coast of the Americas, from northern Peru to Baja California, Mexico (Castro 1993; Toral 1996; Sonnenholzner 1997; Gutierrez-Garcia 1999). Like many other commercial species, *I. fuscus* has been widely fished over the past decades to meet the growing demand for beche-de-mer on the major Asian markets. As the waters along mainland Ecuador became depleted, the fisheries shifted to the Galapagos Islands, raising international apprehension over the fate of this unique archipelago, which has been recognised as a national park and marine reserve.

Figure 1. ***Isostichopus fuscus* adults collected along the coast of Ecuador.**

In spite of the worldwide concern, the Galapagos sea cucumber populations became the focus of intensive and poorly managed exploitation in the early 1990s. Since then, governmental attempts at regulating sea cucumber harvests, and banning them in some areas, have met strong opposition from local fishermen in Ecuador. In fact, illegal fish-

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eries have always been a preoccupation and still occur along the mainland, around the Galapagos Islands and elsewhere in the distribution area of *I. fuscus*. Official information on the fisheries and actual total catches are consequently difficult to obtain and remain sparse (Salgado-Castro 1993; Sonnenholzner 1997; Gutierrez-Garcia 1999; Jenkins and Mulliken 1999). Nevertheless, recent data and reports on average capture sizes (Sonnenholzner 1997; Martinez 2001) indicate that *I. fuscus* populations have declined drastically and that natural stocks may irreversibly crash in the near future.

In spite of this alarming situation, a very limited number of studies have been conducted on the reproductive biology, spatial distribution, population structure, growth and survival rate of this species (Herrero-Perezrul 1994; Fajardo-Leon et al. 1995; Toral 1996; Sonnenholzner 1997; Herrero-Perezrul et al. 1999).

Some authors have mentioned that aquaculture and stock enhancement should be investigated as possible solutions to the current *I. fuscus* crisis (Gutierrez-Garcia 1995, 1999; Fajardo-Leon and Velez-Barajas 1996; Jenkins and Mulliken 1999). However, to our knowledge, no results have ever been presented on the captive breeding of the species.

Until recently, aquaculture in Ecuador was largely focused on shrimp. The emergence of white spot disease in 1999–2000 has severely harmed the industry and resulted in the bankruptcy and closing of numerous farms. Consequently, Ecuador now has a lot of shrimp farm infrastructures that could very well be put to use for the development of other species, such as sea cucumbers.

The present paper brings forward preliminary results on the larval development and juvenile growth of *I. fuscus* in land-based nursery systems on the coast of Ecuador. The data show that aquaculture of this species is feasible and that it could potentially be developed as an alternative to fisheries. Then again, it could be used to maintain sustainable harvests and eventually contribute to the restoration of the natural populations. Further research to complement the present work is being conducted on the feeding, growth and reproductive biology of this highly prized sea cucumber, which is a dominant feature of the Ecuadorian marine ecosystem. In time, aquaculture and stock enhancement of *I. fuscus* might provide part of the solution to the Galapagos sea cucumber crisis.

Larval development of *Isostichopus fuscus*

I. fuscus possess oligotrophic, transparent larvae that follow an indirect development, meaning that the larvae need to feed during their pelagic phase and undergo a series of transformations to reach the juvenile stage (Fig. 2, 3 and Table 1). In most trials, the development, settlement and early growth of the juveniles were somewhat asynchronous, and different stages and sizes could be found simultaneously in the culture. Extreme examples were observed in a few tanks where residual auriculariae neighboured 4-mm long juveniles. Table 1 provides a developmental kinetic that is based on the observation of the bulk of the culture, discarding the asynchronous animals.

Ovulation in *I. fuscus* occurs in the gonadal tubule as the oocytes are released (Fig. 2A). Thus, fully mature oocytes (ca 120 µm in diameter) are expulsed di-

Table 1. Development of *Isostichopus fuscus*, from fertilisation to 35-mm long juvenile, at a salinity of 34–35, a temperature between 22 and 29°C, a pH of 8.4–8.5 and an oxygen level varying between 5.4 and 6.1 mg L^{-1}.

Stage	Time
Fertilisation	0
Elevation of the fertilisation envelope	4 min
Expulsion of the first polar body	7 min
Expulsion of the second polar body	9 min
2-cell	52 min
4-cell	70 min
8-cell	95 min
16-cell	124 min
32-cell	140 min
Blastula	3 h
Early gastrula	6 h
Hatching	10 h
Late gastrula (elongation)	14 h
Early auricularia	1–2 d
Auricularia	3–15 d
Late auricularia (early metamorphosis)	16–18 d
Doliolaria	19–24 d
Early pentactula	21–26 d
Settlement (metamorphosis completed)	22–27 d
Juvenile, 1 mm	28 d *
Juvenile, 2 mm	30 d
Juvenile, 3 mm	32 d
Juvenile, 4 mm	38 d
Juvenile, 5 mm	40 d
Juvenile, 8 mm	44 d
Juvenile, 10 mm	47 d
Juvenile, 15 mm	51 d
Juvenile, 20 mm	56 d
Juvenile, 25 mm	63 d
Juvenile, 30 mm	69 d
Juvenile, 35 mm	72 d

* For the juvenile stages, the time indicated corresponds to the first noteworthy observations of a particular size in the tanks.

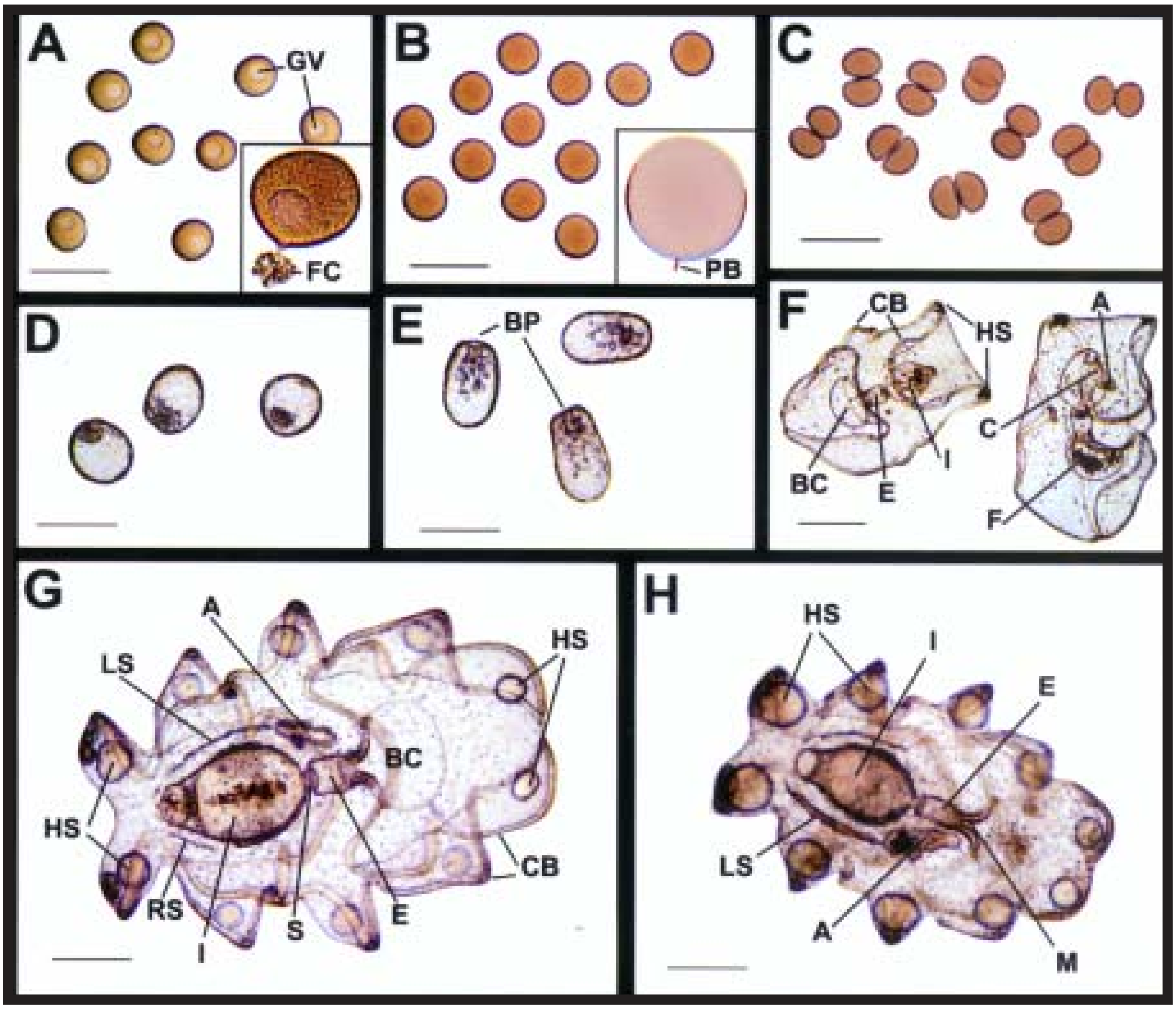

Figure 2. **Early development of the sea cucumber *Isostichopus fuscus*.**

The bars represent 200 µm. A. Oocytes collected surgically from a mature gonad. The germinal vesicle (GV) is clearly visible. The insert shows a close-up of an ovulating oocyte with the follicular cells (FC) still attached to it. B. Fully mature, newly fertilised eggs with clear germinal vesicle breakdown. The insert shows the expulsion of the two polar bodies (PB). C. 2-cell stage. D. Newly hatched gastrula. E. Elongated gastrula with visible blastopores (BP). F. Early auricularia on which the ciliary bands (CB), hyaline spheres (HS), buccal cavity (BC), oesophagus (E), intestine (I), cloaca (C) and anus (A) are identifiable. Food items (F) are present in the buccal cavity. G. Ventral view of a fully developed auricularia showing the left somatocoel (LS), axohydrocoel (A), hyaline spheres (HS), ciliary bands (CB), buccal cavity (BC), oesophagus (E), sphincter (S), intestine (I) and the right somatocoel (RS). H. Dorsal view of a metamorphosing auricularia. With a noticeable decrease in size, the buccal cavity disappears and the hyaline spheres (HS) are pulled closer together. The mouth (M), intestine (I), oesophagus (E), left somatocoel (LS) and axohydrocoel (A) are clearly visible.

rectly in the water column at the metaphase-I of meiosis, after the germinal vesicle breakdown.

The development of *I. fuscus* is initiated with the elevation of the fertilisation envelope, roughly 4 minutes after fertilisation. The expulsion of the first polar body occurs ca 3 minutes later (Fig. 2B). The second polar body follows rapidly within ca 2 min. The first cleavage is equal, radial and holoblastic and divides the cell into two equal hemispheric blastomeres (Fig. 2C). The second cleavage again occurs along the animal-vegetal axis, yielding more spherical blastomeres. Embryos hatch from the fertilisation envelope as early gastrulae, ca 10 h after fertilisation (Fig. 2D). These early gastrulae swim with the help of cilia covering their entire surface; they elongate into full-size gastrulae after ca 14 h (Fig. 2E). Auricularia larvae begin to appear ca 24 h after fertilisation; they constitute the first feeding stage. Growing auriculariae can be observed during the next two weeks of culture (Fig. 2F, Table 1). At this stage, they begin to accumulate hyaline spheres. The oesophagus, the sphincter, the intestine, the cloaca as well as the anus are clearly visible. After 16–18 days, the auricularia reaches its maximum size of 1.1–1.3 mm; it has left and right somatocoels, as well as an axohydrocoel (Fig. 2G).

In the following hours, many auriculariae initiate the transformation that will lead to the doliolaria stage (Fig. 2H). In the course of this process, the larvae shrink down to nearly 50 per cent of their initial size, the buccal ciliated cavity disappears and the hyaline spheres are pressed closer together (Fig. 3A). The doliolaria stage is reached ca 19–24 days after fertilisation (Fig. 3B, Table 1) as the larvae stop feeding and the cilia are aligned in five distinct crowns along their cylindrical body. At this time, the movement of the primary tentacles can be observed through the translucent body wall. The somatocoel is also visible. A few days later, the doliolaria transforms into an early pentactula pos-

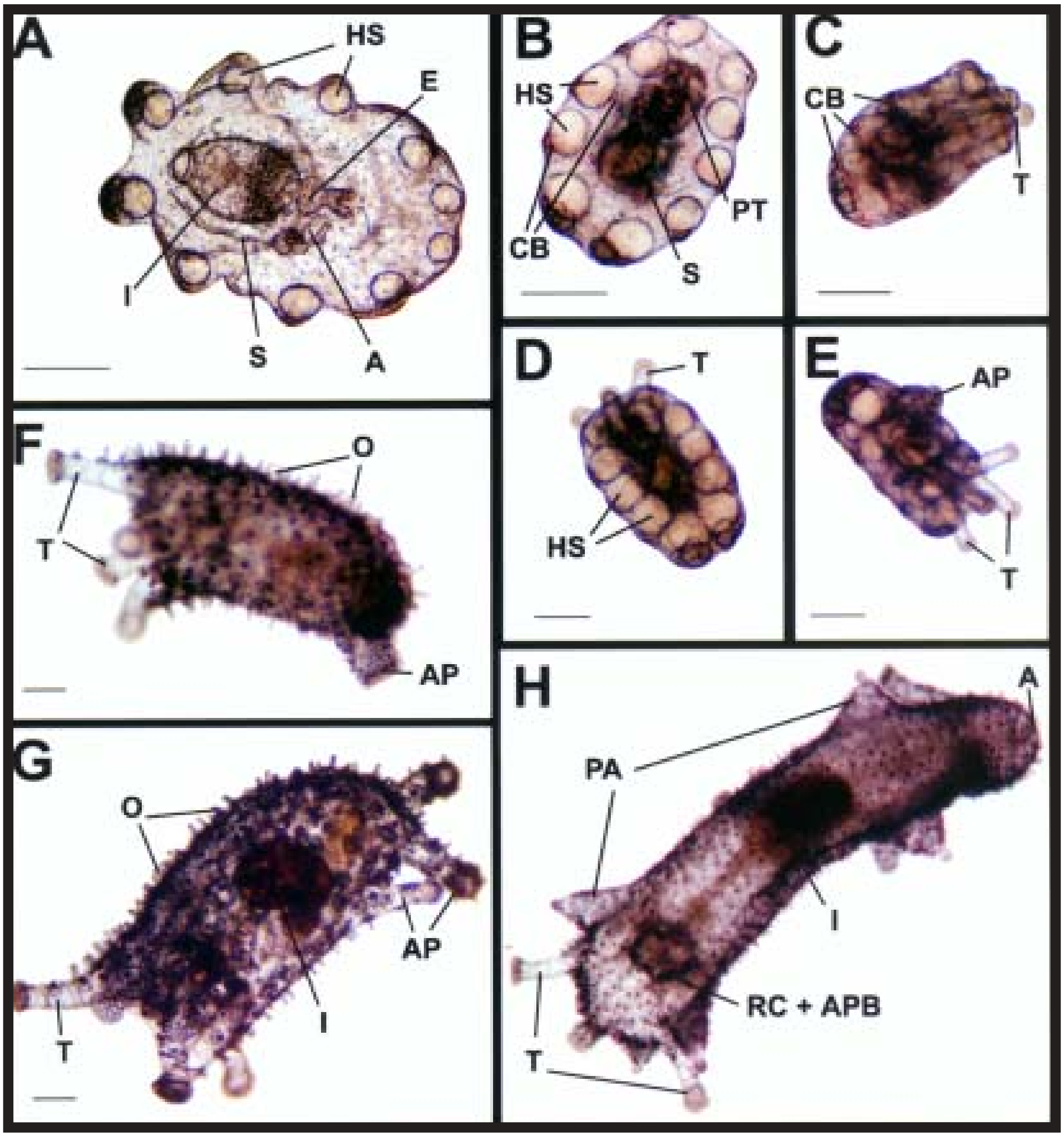

Figure 3. Late development of the sea cucumber *Isostichopus fuscus*.

The bars represent 200 µm. A. Late metamorphosing auricularia, showing the hyaline spheres (HS), oesophagus (E), intestine (I), somatocoel (S) and axohydrocoel (A). B. Fully developed doliolaria with hyaline spheres (HS), primary tentacles (PT), ciliary bands (CB) and somatocoel (S). C. Early pentactula with 5 tentacles (T) and the still visible ciliary bands (CB). D. Dorsal view of newly settled pentactula with tentacles (T) and hyaline spheres (HS). E. Ventral view of newly settled pentactula showing the first ambulacral podia (AP) and the 5 buccal tentacles (T). F. Early juvenile, measuring 1.5 mm in length, with tentacles (T), ambulacral podia (AP) and ossicles (O). The hyaline spheres have disappeared. G. A 2-mm long juvenile with 5 tentacles (T) and 3 pairs of ambulacral podia (AP). The intestine (I) and ossicles (O) are visible. H. A 3-mm long juvenile showing the tentacles (T), papillae (PA), intestine (I), anus (A) and the ring canal and aquapharyngeal bulb (RC + APB).

sessing five buccal tentacles (Fig. 3C). At this stage, the larvae remain close to the substrate, successively going through swimming and settling phases. Definitive settlement, with the complete loss of cilia, completion of metamorphosis and emergence of the two first ambulacral podia, occurs ca 22–27 days after fertilisation (Fig. 3D, E).

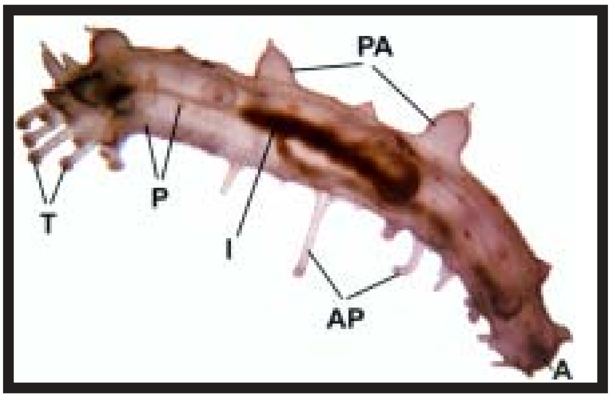

Figure 4. Juvenile sea cucumber *Isostichopus fuscus* measuring 1.5 cm in length and showing the tentacles (T), early body wall pigments (P), intestine (I), ambulacral podia (AP), anus (A) and papillae (PA).

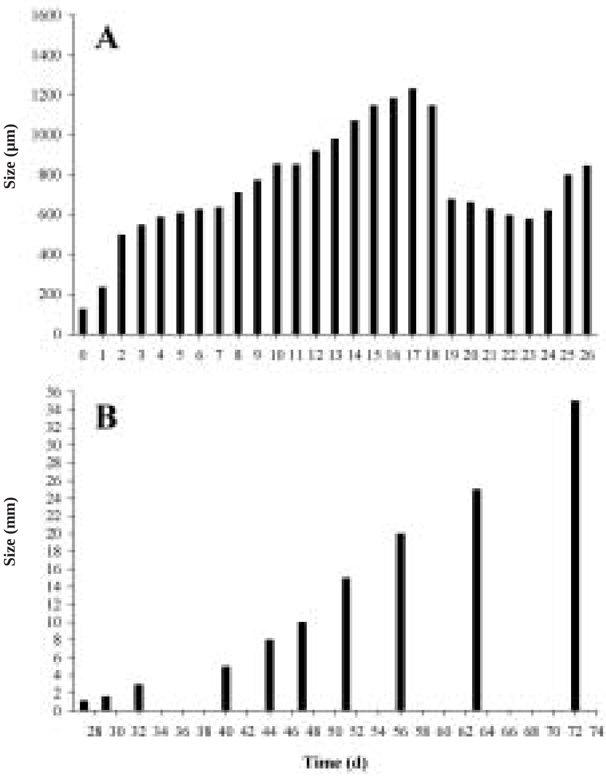

Figure 5. Average growth of the larvae (A) and juveniles (B) of the sea cucumber *Isostichopus fuscus*. Note that the x axis in B is a prolongation of the one in A, with a slightly different scale, and that size is expressed in µm in A and in mm in B.

Juvenile growth of *Isostichopus fuscus*

Although the first settled juveniles can be observed as early as day 22, a majority of juveniles measuring 1–1.5 mm in length are generally recorded in the tanks after 28 days of culture (Fig. 3F, Table 1). They reach ca 2–3 mm only a few days later (Fig. 3G, H), and 5 mm after ca 40 days. The juveniles continue to grow at a rate of ca 0.5–1.0 mm per day for the next 3–4 weeks. When they are ca 5 mm in length, the juveniles start to accumulate reddish-brown pigments. In 8-mm long juveniles, the tip of the tentacles becomes ramified. After 52 days of culture, the juveniles are 1.5–1.8 cm long and 4 mm wide (Fig. 4). They possess several papillae and an elongated intestine that already exhibits strong peristaltic movements. The body wall becomes more opaque as the ossicle density and the tegument thickness increase. When the juveniles reach ca 2 cm in length, the whitish coloration that characterises the early stages of life is gradually replaced by a brownish tinge similar to the one observed in adults. After approximately 72 days of culture, the juveniles are ca 3.5 cm long and 1 cm wide and are ready to be released in outdoor ponds, or in the field, to complete their growth.

Acknowledgements

We would like to acknowledge the hard work and technical assistance of Jorge Jaramillo, Jose Pico, Pedro Gonsaby and Maricela Garcia during the course of this work.

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Papua New Guinea sea cucumber and beche-de-mer identification cards

Aymeric Desurmont[1]

Introduction

Since September 2001, the Papua New Guinea beche-de-mer fishery has been governed by the National Beche-de-mer Fishery Management Plan. Management measures include regulations on access, size and catch limits, storage and export. To facilitate the monitoring of this fishery and enforcement of the regulations, the National Fisheries Authority (NFA) decided to produce a booklet showing the different sea cucumber species traded in the region. They approached the Secretariat of the Pacific Community (SPC) Marine Resources Division Information Section to seek their assistance for this project.

During the last 19 years, SPC has published several versions of a sea cucumber identification guide: *Bêche-de-mer of the South Pacific Islands* (1975); *Bêche-de-mer of the tropical Pacific* (1979); and *Sea cucumbers and beche-de-mer of the tropical Pacific – A handbook for fishers* (1984). This last edition presents pictures, in full colour, of 15 holothurian species and their corresponding beche-de-mer (dried) product. Thousands of copies of have been distributed through the Pacific, and copies of the last edition are still regularly sent upon request. Unfortunately, it is now almost out of print and some of the information it contains is out of date: several species that were not listed as of commercial value in 1994 are now traded and some of the species that were categorised as low value in the handbook have since "climbed the ladder". The handbook was not fully adapted to NFA needs, so it was decided to produce a new sea cucumber identification guide, specially designed for PNG.

An identification guide is mostly used in the field, so it has to be easy to carry around and waterproof. Therefore, instead of a handbook, we decided to make a set of pocket-size (95 x 135 mm) cards printed on plastic (as in credit cards) and bound together by a plastic pin. Each card presents one species of sea cucumber, with a full-colour underwater picture of the live animal on one side and two pictures (ventral and dorsal views) of the corresponding dried product (beche-de-mer) on the other side (Fig. 1). It also contains some basic information on the species (preferred habitat and depth, average sizes) and a short description of the dried product. The complete set contains 24 cards, presenting 20 different species, giving some basic information on beche-de-mer processing and listing the main regulations pertaining to the beche-

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Figure 1.
Both sides of one sea cucumber identification card (scaled at 2/3)

de-mer fishery in PNG. As the fishery regulation information is presented on a separate card, it will always be possible to print a replacement card if the regulations change.

We present below the information given in this new set of identification cards.

Amberfish[2]

Thelenota anax

Habitat: Reef slopes, outer lagoon and near passes, on hard bottoms, large rubble and sand patches.
Depth range: 10–30 m
Average length: 55 cm
Average weight: 3.5 kg
Body thickness: 15 mm

Processed appearance:
- Long shape with a rectangular cross-section.
- Upperside rough covered with irregular warts.
- Underside grainy.
- Entire body different shades of brown.
- Small cut across mouth, or one single long cut in the underside for large specimens.
- Common size: 15–20 cm.[3]

Blackfish

Actinopyga miliaris

Habitat: Reef flats of fringing and lagoon-islet reefs; never found on barrier reefs.
Depth range: 0–10 m
Average length: 25 cm
Average weight: 0.4 kg
Body thickness: 6 mm

Processed appearance:
- Roughly oval shape with a round cross-section.
- Entire body surface smooth and black.
- No cuts.
- Common size: 10–12 cm.

Black teatfish

Holothuria (Microthele) nobilis

Habitat: Reef flats, slopes and shallow seagrass beds.
Depth range: 0–20 m
Average length: 37 cm
Average weight: 1.7 kg
Body thickness: 12 mm

Processed appearance:
- Flat and chunky shape with obvious teats along

2. The English common names are the ones used in the PNG National Beche-de-mer Fishery Management Plan. They are also the names most commonly used in the PNG trade.
3. The average sizes given for dried products are consistent with the minimum size regulations in PNG. They are the sizes that a fishery enforcement officer should come across.

each side.
- Surface powdery, smooth to slightly wrinkled.
- Powdery cover greyish-brown, but skin underneath black.
- One single long straight cut in the upperside.
- Common size: 18–24 cm.

Brown sandfish
Bohadschia vitiensis

Habitat: Coastal lagoons and inner reef flats, often burrowed in sandy-muddy bottoms.
Depth range: 0–20 m
Average length: 32 cm
Average weight: 1.2 kg
Body thickness: 7 mm

Processed appearance:
- Cylindrical shape with an arched upperside and a flat underside.
- Upperside slightly wrinkled, brown to brown-black.
- Underside grainy, brown to brown-black.
- No cuts or small cut across mouth.
- Common size: 12–15 cm.

Chalkfish
Bohadschia similis

Habitat: Coastal lagoons and inner reef flats, often burrowed in sandy-muddy bottoms.
Depth range: 0–3 m
Average length: 18 cm
Average weight: 0.3 kg
Body thickness: 4 mm

Processed appearance:
- Bent, narrow cylindrical shape, slightly flattened underside.
- Upperside granular, light beige (chalky).
- Underside smooth, black with brown marks.
- No cuts or small cut across mouth.
- Common size: 7–9 cm.

Curryfish
Stichopus hermanni

Habitat: Seagrass beds, rubble and sandy-muddy bottoms.
Depth range: 0–25 m
Average length: 35 cm
Average weight: 1.0 kg
Body thickness: 8 mm

Processed appearance:
- Long shape with a rectangular cross-section.
- Upperside wrinkled or deeply ridged with small black bumps.
- Underside smoother.
- Entire body different shades of beige to brown.
- No cuts or small cut across mouth.
- Common size: 12–18 cm.

Deep-water redfish
Actinopyga echinites

Habitat: Reef flats of fringing and lagoon-islet reefs, seagrass beds, rubble reef flats and compact flats.
Depth range: 0–12 m
Average length: 20 cm
Average weight: 0.3 kg
Body thickness: 7 mm

Processed appearance:
- Oval shape, with arched upperside and flat underside.
- Upperside rough and slightly ridged, grey-brown.
- Underside granular, grey-brown.
- No cuts.
- Common size: 15–18 cm.

Dragonfish
Stichopus horrens

Habitat: Rubble or hidden in reef flats.
Depth range: 0–15 m
Average length: 20 cm
Average weight: 0.2 kg
Body thickness: 2 mm

Processed appearance:
- Narrow shape with a squarish cross-section.
- Upperside knobbly, black-brown to brown.
- Underside smoother with two rows of tiny bumps, black-brown to brown.
- No cuts or small cut across mouth.
- Common size: 8–12 cm.

Elephant trunkfish
Holothuria (Microthele) fuscopunctata

Habitat: Reef slopes and shallow seagrass beds.
Depth range: 0–25 m
Average length: 36 cm
Average weight: 1.5 kg
Body thickness: 10 mm

Processed appearance:
- Long cylindrical shape with an arched upperside and a flat underside.
- Upperside with deep grooves, of different shades of light brown to beige with tiny black spots.
- Underside smoother, of different shades of light brown to beige with tiny black spots.
- Small cut across mouth or one single long cut in the underside on large specimens.
- Common size: 20–25 cm.

Flowerfish
Pearsonothuria graeffei

Habitat: Reef slopes, close to the coast. Abundant on bottoms of mixed corals and calcareous red algae.

Depth range: 0–25 m
Average length: 35 cm
Average weight: 0.7 kg
Body thickness: 4 mm

Processed appearance:
- Narrow shape with a rectangular cross-section.
- Upperside rough, black to black-brown.
- Underside grainy, black to black-brown.
- No cuts or small cut across mouth.
- Common size: 15–20 cm.

Greenfish
Stichopus chloronotus

Habitat: Reef flats and upper slopes, mostly on hard substrates.

Depth range: 0–15 m
Average length: 18 cm
Average weight: 0.1 kg
Body thickness: 2 mm

Processed appearance:
- Narrow shape with a squarish cross-section.
- Each of the four edges covered with pointy warts.
- Entire body light greenish brown.
- No cuts or small cut across mouth.
- Common size: 10–12 cm.

Lollyfish
Holothuria (Halodeima) atra

Habitat: Inner and outer reef flats and back reefs or shallow coastal lagoons. Abundant on sandy-muddy grounds with rubble or coral patches and in seagrass beds.

Depth range: 0–20 m
Average length: 20 cm
Average weight: 0.2 kg
Body thickness: 4 mm

Processed appearance:
- Narrow cylindrical shape.
- Entire body surface smooth and black.
- No cuts or small cut across mouth.
- Common size: 15–20 cm.

Pinkfish
Holothuria (Halodeima) edulis

Habitat: Inner reef flats of fringing and lagoon-islet reefs, and shallow coastal lagoons, sandy-muddy grounds with rubble or coral patches.

Depth range: 0–30 m
Average length: 20 cm
Average weight: 0.2 kg
Body thickness: 3 mm

Processed appearance:
- Narrow cylindrical shape, slightly flattened underside.
- Upperside with small wrinkles, dark brown.
- Underside smoother, light to medium brown.
- No cuts or small cut across mouth.
- Common size: 10–14 cm.

Prickly redfish
Thelenota ananas

Habitat: Reef slopes and near passes, on hard bottoms with large rubble and coral patches.

Depth range: 0–25 m
Average length: 45 cm
Average weight: 2.5 kg
Body thickness: 15 mm

Processed appearance:
- Long shape with a squarish cross-section.
- Upperside covered with spikes, brown to black-brown.
- Underside granular, lighter brown.
- Small cut across mouth, or one single long cut in the underside of large specimens.
- Common size: 20–25 cm.

Sandfish
Holothuria (Metriatyla) scabra

Habitat: Inner reef flats of fringing reefs, lagoon-islet reefs, coastal areas affected by sediments, and near mangroves.

Depth range: 0–10 m
Average length: 22 cm
Average weight: 0.3 kg
Body thickness: 6 mm

Note: The golden sandfish (*H. scabra* var. *versicolor*) is also present in PNG waters, but the two species are not differentiated by traders.

Processed appearance:
- Cylindrical shape with an arched upperside and a flat underside.
- Upperside with grooves across entire body, black-brown to black.
- Underside smooth, amber-brown.
- No cuts or small cut across mouth. No smoky smell.
- Common size: 10–12 cm.

Snakefish
Holothuria (Acanthotrapeza) coluber

Habitat: Inner and outer reef flats and back reefs or shallow coastal lagoons. Abundant on sandy-muddy grounds with rubble or coral patches and in seagrass beds.

Depth range: 0–15 m
Average length: 40 cm
Average weight: 0.3 kg
Body thickness: 4 mm

Processed appearance:
- Long irregular skinny shape, clearly tapered at one end.
- Brown body covered with tiny white bumps.
- Small cut across mouth and / or in the middle of body.
- Common size: 18–25 cm.

Stonefish
Actinopyga lecanora

Habitat: Hard substrates. Nocturnal species. In daytime, found under large stones, in gaps in reef slopes or in sheltered areas.
Depth range: 0–20 m
Average length: 25 cm
Average weight: 0.4 kg
Body thickness: 6 mm

Processed appearance:
- Roughly oval shape, with arched upperside and flat underside.
- Upperside with shallow grooves across body, brown-black.
- Underside smooth, brown-black.
- No cuts.
- Common size: 10–12 cm.

Surf redfish
Actinopyga mauritiana

Habitat: Outer reef flats and fringing reefs, mostly in the surf zone.
Depth range: 0–20 m
Average length: 20 cm
Average weight: 0.3 kg
Body thickness: 6 mm

Processed appearance:
- Roughly oval shape, with arched upperside and flat underside.
- Upperside with grooves across body, black-brown.
- Underside granular, lighter reddish-brown.
- No cuts.
- Common size: 8–15 cm.

Tigerfish
Bohadschia argus

Habitat: Barrier reef flats and slopes, or outer lagoons on white sand.
Depth range: 0–30 m
Average length: 36 cm
Average weight: 1.8 kg
Body thickness: 10 mm

Processed appearance:
- Cylindrical shape slightly tapered at one end.
- Upperside smooth, brown to light-brown with obvious small white spots.
- Underside smooth, brown to light-brown.
- No cuts or small cut across mouth.
- Common size: 12–18 cm.

White teatfish
Holothuria (Microthele) fuscogilva

Habitat: Outer barrier reefs and passes, but also on shallow seagrass beds.
Depth range: 10–40 m
Average length: 42 cm
Average weight: 2.4 kg
Body thickness: 12 mm

Processed appearance:
- Flat and chunky shape with obvious teats along each side.
- Surface smooth to slightly wrinkled and powdery.
- Entire body different shades of grey-brown.
- One single long straight cut in the upperside.
- Common size: 18–24 cm.

Beche-de-mer processing methods

Method 1
Boil for a very short time (2–5 minutes) until it swells. Remove body content by gently pressing the beche-de-mer (if necessary, make a very small cut through the mouth). Put back in boiling water until hard and rubbery (should bounce like a ball when thrown on the ground). Bury in a sandpit for 12–18 hours. Rub to remove decomposed outer surface. Boil a third time in clean water until hard and rubbery. Hot air dry (≈ 2 days), but DO NOT SMOKE. Sun dry (4 days to 2 weeks).

Method 2
Boil for a very short time (2–5 minutes) until it swells. Remove body content by gently pressing the beche-de-mer (if necessary, make a very small cut through the mouth). Put back in boiling water until hard and rubbery (should bounce like a ball when thrown on the ground). Wash in seawater. Boil a third time in clean water until hard and rubbery. Hot air dry or smoke (≈ 2 days). Sun dry (4 days to 2 weeks).

Method 3

Boil until it swells (this first boil may take up to 10 minutes as this method is used for animals with very thick body walls). Slit upper dorsal side, up to 3 cm from each end, and remove body content, but don't remove the three longitudinal string muscles. Wash in seawater. Boil again, in clean water, until hard and rubbery (≈1/2 h). Remove remaining guts. Place sticks across the slit to keep it open. Hot air dry or smoke (12–48 h) then sun dry (1–2 days) with the slit downwards. Remove sticks and tie with string or vines. Sun dry again (4 days to 2 weeks). Remove strings/vines before packing.

Method 4

Same as Method 3, but slit along ventral side, not upper dorsal side.

PNG trade name	Method	
	Small specimens	Large specimens
Amberfish	2	4
Black teatfish	3	3
Blackfish	2	2
Brown sandfish	2	2
Chalkfish	2	2
Curryfish	2	2
Deep-water redfish	2	2
Dragonfish	2	2
Elephant trunkfish	2	4
Flowerfish	2	2
Greenfish	2	2
Lollyfish	2	2
Pinkfish	2	2
Prickly redfish	2	4
Sandfish	1	1
Snakefish	2	2
Stonefish	2	2
Surf redfish	2	2
Tigerfish	2	2
White teatfish	3	3

Processing recommendations

- All animals must be alive before processing.
- Before boiling, lay animals on a flat surface for 20 minutes so they can straighten themselves and expel most of the sand they contain (some species will also eviscerate).
- If cutting is needed to clean out the sea cucumber gut, use sharp knives and make cuts carefully.
- Don't mix species or sizes when boiling.
- If the water is too hot when boiling, the skin will peel off. The water temperature should allow you to hold your finger in it for two seconds.
- Some species — dragonfish, curryfish, brown sandfish, tigerfish and greenfish — are fragile and need extra care during handling and processing as their body wall can easily degrade.
- Stir gently, regularly and keep an eye on the beche-de-mer while boiling. If the very first boil is too long, the stomach will form a carbuncle, and expand and burst.
- If the weather is rainy or humid, keep smoking (or hot air drying) until sun drying is possible.
- Store the dried beche-de-mer in cardboard boxes or rice/copra bags, in a dry place.

PNG beche-de-mer fishery management measures

The PNG beche-de-mer (BDM) fishery is governed by the National Beche-de-mer Fishery Management Plan. Management measures cover the areas of access, size and catch limits, storage and export. These measures include:

Access

- Open to PNG citizens only.
- Closed every year from 1 October to 15 January.
- The use of hookah, scuba and lights are prohibited for the harvesting of BDM.

Size and catch limits

- Each province is allocated a total allowable catch (TAC) for each of the two value groups (high and low) during the season.
- The fishery is closed when the TAC or the TAC of one value group is reached. If the allocated TAC for a province is exceeded by more than 5 tonnes, the excess amount will be taken off their next season's TAC.
- Minimum sizes are set for live and dry specimens of 17 species. Undersized and broken pieces of BDM cannot be traded and will be confiscated.

Storage and export

- A license is required for storing or exporting BDM.
- Exporters must provide NFA with a monthly summary of their purchases, including species trade names, weights in kg for each species, suppliers' and ward names.
- BDM product for export must be clearly labelled. Exporters must declare their stored holdings to NFA within 5 days after the season closing date.
- BDM movement between provinces is prohibited unless authorised by NFA Managing Director.
- Export samples are limited to two pieces of each species.
- Export for self-consumption is limited to 2 kg.

Value groups, trade names and minimum size restrictions for the PNG beche-de-mer fishery*

PNG trade name	Scientific name	Minimum sizes Live	Minimum sizes Dry
High grade species (value group H)			
Black teatfish	*Holothuria nobilis*	22 cm	10 cm
Blackfish	*Actinopyga miliaris*	15 cm	10 cm
Curryfish	*Stichopus hermanni*	25 cm	10 cm
Greenfish	*Stichopus chloronotus*	20 cm	10 cm
Prickly redfish	*Thelenota ananas*	25 cm	15 cm
Sandfish	*Holothuria scabra*	22 cm	10 cm
Stonefish	*Actinopyga lecanora*	15 cm	10 cm
Surf redfish	*Actinopyga mauritiana*	20 cm	8 cm
White teatfish	*Holothuria fuscogilva*	35 cm	15 cm
Low grade species (value group L)			
Amberfish	*Thelenota anax*	20 cm	10 cm
Brown sandfish	*Bohadschia vitiensis*	20 cm	10 cm
Chalkfish	*Bohadschia similis*	25 cm	7 cm
Deep-water redfish	*Actinopyga echinites*	25 cm	15 cm
Dragonfish	*Stichopus horrens*	none	none
Elephant trunkfish	*Holothuria fuscopunctata*	45 cm	15 cm
Flowerfish	*Pearsonothuria graeffei*	none	none
Lollyfish	*Holothuria atra*	30 cm	15 cm
Pinkfish	*Holothuria edulis*	25 cm	10 cm
Snakefish	*Holothuria coluber*	none	none
Tigerfish	*Bohadschia argus*	20 cm	10 cm

* This information is partly extracted from the PNG National Beche-de-mer Fishery Management Plan. It is current at the date of printing (April 2003) but subject to change.

The information presented in these identification cards was gathered from personal communications with scientists, fishermen, processors and traders,[4] and from the following publications:

Conand, C. 1998. Holothurians. In: K.E. Carpenter and V.H. Niem (eds). FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific. Volume 2. Cephalopods, crustaceans, holothurians and sharks. FAO, Rome.

Guille, P., P. Laboute and J.-L. Menou. 1986. Handbook of the sea-stars, sea-urchins and related echinoderms of New Caledonia lagoon. Éditions de l'ORSTOM, Paris, France. (in French).

SPC. 1994. Sea cucumbers and beche-de-mer of the tropical Pacific. A handbook for fishers. Handbook N° 18. Secretariat of the Pacific Community, Noumea, New Caledonia.

For more information on the PNG beche-de-mer fishery, please contact:

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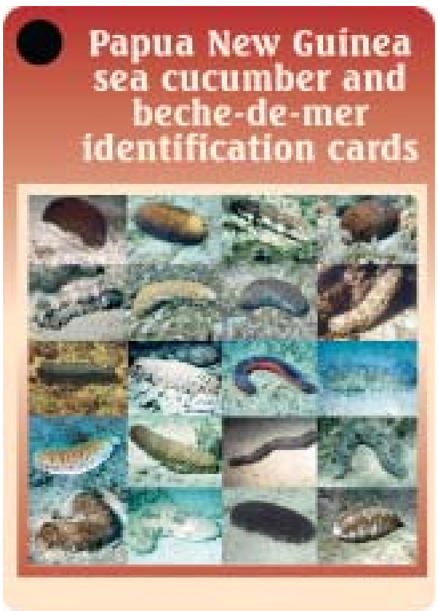

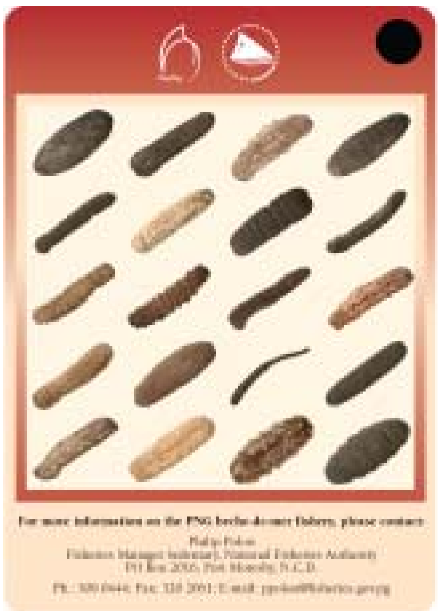

4. We wish to specially thank the following people for their assistance during the preparation of these identification cards: Derrick Pendle from Asil Group, Marie-Jo Aymard from Iaora Exports, Steve Purcell from the WorldFish Center, Kim Friedman from the Secretariat of the Pacific Community and Chantal Conand from L'Université de la Réunion.

To produce 100 tonnes of sandfish

R. Pitt[1] and N.D.Q. Duy[1]

The following article is based on an ongoing collaboration in Vietnam between the WorldFish Center (formerly ICLARM) and the Ministry of Fisheries, at the Research Institute for Aquaculture No. 3, Nha Trang City, Khanh Hoa Province. The work described is oriented towards regions near the equator, where induced spawning of on-grown broodstock should be possible over about 10 months of the year. A shorter breeding season (in subtropical areas) would necessitate bigger installations, but a larger market size would have the opposite effect.

Work started here in June 2000 using locally collected animals that averaged only about 150–200 g. In the first year, after growing for some months in ponds, they could only be spawned once (in February 2000), when they averaged 260 g. In the second year, with further on-growing in ponds or seabed pens (and after an isolated spawning in August 2001), groups of 30–45 animals of 200–600 g individual weight have generally been spawned once or twice a month from November 2001 to January 2003 (so far).

Most egg batches have been reared at least through to settlement, with the production of many hundreds of thousands of juveniles of 1–2 mm. However, nursery space for further rearing has been limited. Some 50,000 juveniles have been produced in bare- and sand-tank nursery stages, and about half of these have gone out into pond, seabed pen or cage trials. The largest F1 animals have reached about 350 g and have been spawned for the first (recorded) times at less than one year of age. F2 juveniles are now being reared. All stages of the rearing cycle have now been carried out on at least a medium or pilot-commercial scale. A tentative economic evaluation of the production process therefore becomes a possibility.

The hatchery here (35 m^3) has proved big enough, but the tank nursery facilities (about 230 m^2 total floor area) have not, and this has limited production. Facilities for further nursery have been another severe bottleneck: there have generally been not more than about 3000–4000 m^2 of ponds available, some 90 minutes drive from Nha Trang, and it has proved difficult to manage them effectively at that distance. Efforts to carry out nursery culture on the seabed are under way.

What follows grew out of a back-of-an-envelope calculation. Efforts have been made to avoid the classic pitfalls — among which are the use of excessive scale-up (i.e. extrapolating directly from an aquarium to a pond), taking the best result ever achieved and applying that to all future yield calculations, and incorporating the benefits of major technical advances before they have been achieved. Disease problems also tend to increase as the scale and intensity of culture progresses. On the other hand, it is assumed that with practice routine husbandry becomes more efficient and at least some blunders can be avoided.

Figures for growth are more robust than those for survival, since it is easier to collect a sample from a pond or pen than to harvest all the animals. Often animals have been held longer at a particular stage than would have been ideal, due to lack of space in the next stage. This has probably reduced the survival rates that have up to now been achieved.

After six years of research in Solomon Islands and Vietnam a better understanding has been reached of the general scale of installations needed to produce large quantities of sandfish based on hatchery seed. There are still many questions to be answered before a commercially viable system might become possible, but it is hoped that this calculation will be useful to anybody thinking of building a sandfish culture facility or assessing the feasibility of doing so. Spreadsheet calculations are available showing the data from a wide range of nursery and on-growing attempts, in tanks, ponds, pens and cages.

Broodstock

- 400 broodstock of 300–400 g average weight.
- Hold in at least 1000 m^2 of ponds or sea pens.
- Need 120 female-spawnings per year at 1.5×10^6 eggs per spawning to produce 180×10^6 eggs

Broodstock are held in ponds or seabed pens at a density not exceeding 200 g m^{-2}. It is not known how long spawned animals take to regenerate, but at least 3 spawnings per animal per year should be

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possible. Female spawning induction success rate currently averages only about 10%. Around half the animals are male, and they generally spawn more readily.

Hatching and larval rearing

- Stock at 0.8–1.2 eggs ml^{-1} for about 20,000 small juveniles m^{-2} with 2% survival
- 30–60 days
- 6 batches per year
- Need 30 m^3 of larval tanks to produce 3.6×10^6 newly settled 1–2 mm juveniles

This stage has generally proved quite easy although unexplained crashes are not uncommon. Survival rates have been low but with a plentiful supply of eggs this has not been a major limiting factor. Indoor fibreglass or concrete tanks (of 1.7–6.4 m^3 each) have proved easier to manage than smaller or outdoor tanks. Only partial water changes are made, and a flexible combination of algal species is fed, supplemented by dry algae after settlement. Metamorphosis and settlement, on tanks surfaces and added pre-conditioned plate stacks, start as soon as 8–12 days after spawning, depending on temperature, rearing density and feed availability. Settled juveniles are kept indoors for 1–2 months after settlement, sometimes even longer if there are no outdoor tanks free. During this phase copepod control (using Dipterex at 1–2 ppm for a few hours) is important.

Bare tanks for first nursery

- Stock 700 small juveniles m^{-2} for 280 juveniles m^{-2} at harvest (40% survival)
- 20–30 days
- 12 batches per year
- Need 430 m^2 of tanks to produce 1.44×10^6 juveniles of 10–20 mm (0.3–1 g)

Juveniles are transferred by moving settlement plate stacks or by siphoning and hosing down tank surfaces. They are stocked in bare, shaded, outdoor fibreglass or concrete tanks. There have been quite variable results during this stage, which remains a bottleneck to mass production. On a few occasions over 500 juveniles m^{-2} have been produced, but around half this rate is more usual.

Tank design, timing and methods of juvenile transfer, tank pre-treatment and management, diets, shade, water treatment, the use of additional preconditioned plates or seagrass and possible co-culture with shrimp are all factors which have been looked at, generally without definitive results. The current routine usually involves preconditioning tanks for a few days before stocking, a continuous flow of unfiltered seawater during the daylight hours with flow rates as high as possible (25–100% exchange per day), supplementary feeding using mixtures of dry algae, seaweed powder and / or shrimp postlarva starter feed (at 0.5–1 g m^{-3} twice a day) and quite heavy shading until most juveniles attain the adult coloration.

Growth rate is typically very variable, with some animals reaching 3–5 g while the majority are about one tenth of this size, and many remain below 0.1 g and have not even attained the adult type of skin and colour. Removal of large animals seems to help smaller ones to develop. By adding sand after some weeks, this stage and the next can be combined.

Sand nursery in tanks

- 0.3–1 g to 1–3 g
- Stock at 200 juveniles m^{-2} for 200 g m^{-2} at harvest with 50% survival
- 20–40 days
- 10 batches per year
- Need 720 m^2 of tanks to produce 720,000 juveniles of over 1 g

Small juveniles are graded and transferred to tanks with floors thinly covered in fine sand, or sand is added to first nursery tanks. This is another production bottleneck, probably the most expensive stage of the process due to the very large tank area required. Good survival is quite common, and growth has sometimes been better when sandfish juveniles were reared together with shrimp postlarvae. However, growth rates are usually very variable within a batch. Frequent sorting might allow somewhat higher initial stocking densities. Dry algae, powdered or blended seaweed and shrimp food have been fed in different combinations; currently shrimp starter food is usually given twice daily at not more than 1 g m^{-2}.

Clearly ponds are cheaper per square metre than tanks, both to build and to operate. However, transfer to ponds (or seabed pens / cages) at sizes of around 2 g has produced very variable results. Some batches have grown well while others have disappeared, immediately or within a few days, due to causes unknown. Until a protocol for pond preparation and management can be developed that yields consistently acceptable survival rates, the trade-off between tanks and ponds is hard to evaluate.

Pond nursery

- 1–3 g to 50 g
- Stock at 8 juveniles m^{-2} for 200 g m^{-2} at harvest with 50% survival

- 40–60 days
- 6 batches per year
- Need about 1.5 ha of nursery ponds to produce 360,000 small adults

Graded juveniles are stocked in ponds, which have preferably been recently dried, cleaned and refilled. Some batches have shown surprisingly rapid growth and excellent survival but others have disappeared without trace. Sometimes, test batches are put in small pens built inside the ponds for a week or so before the main batches are stocked. Co-culture with shrimp postlarvae at low densities and feeding rates might be possible but has not yet been proved in ponds. (Shrimp nursery culture has become less common here among farmers. Most stock hatchery-supplied shrimp postlarvae are put directly in big grow-out ponds, and many small nursery ponds have been abandoned or converted.)

This stage is now also being tried in seabed pens (consisting of simple low net fences, which usually do not reach the water surface) in sheltered water of a few metres depth, and in seabed cages of several types. In some of these pens and cages carnivorous Babylon snails are farmed at the same time.

Grow-out

- 50 g to 350 g
- Stock at 1 small adult m^{-2} for 2.8 t ha^{-1} at harvest with 80% survival
- Density kept below 200–240 g m^{-2} by selective harvesting
- 90–150 days
- 2–4 batches per year
- Need about 12 ha grow-out ponds or pens to produce 100 t (wet weight) of sandfish

Rapid growth and good survival are possible in ponds, but rearing attempts resulting in heavy or total mortalities remain common. The following conditions need to be prevented: salinity below about 20 ppt, stratification due to heavy rain, excessive filamentous weed growth, very black (anaerobic) and putrid pond floor conditions. Very good growth (2–3 g $animal^{-1}$ day^{-1}) has been obtained in some ponds at moderate densities (up to 200–300 g m^{-2}). There have also been ponds in which many animals developed skin lesions (not rapidly fatal but slowing growth) and others in which all animals have died. Management practices to maintain optimal conditions (of water and benthos) have not yet been seriously studied.

By thinning out the fastest-growing animals for sale periodically, a larger final size and higher stocking rates may be possible. Bigger animals generally fetch higher per-kilo prices, with 350–500 g probably the size to aim for in Vietnam. Growth rates of the generally bigger South Pacific sandfish are not known.

Seabed pen culture in big pens might be economic (if theft can be prevented), since the area enclosed by a fence increases as the square of its length ($Perimeter^2/4\pi$ for a round pen or $Perimeter^2/16$ for a square one). Complete release (perhaps into an area isolated by surrounding deep water or unsuitable habitat) would be the logical extension of this idea, avoiding the costs of pen construction and maintenance entirely, but survival and recovery figures can only be guessed at.

Algal culture

Stock culture room plus either:

- About eighty (!) 20-L carboys producing 320 L day^{-1} at 3000 cells μl^{-1} cme (*C. muelleri* equivalent)
- About ten 400-L polythene bags (or equivalent smaller sizes), producing 1000 L day^{-1} of 1000 cells μl^{-1} cme.
- About 10 m^3 of open tanks, producing 2000 L day^{-1} of 500 cells μl^{-1} cme.

Conclusion

The major barriers to commercial sandfish culture appear to be the high costs of tank nursery (due to the low density at which it can be carried out) and the very variable results of nursery and grow-out attempts in the sea or ponds. Plus of course the rather poor prices paid for the wet animals.

Effective diets, practical methods of pond management and ways to protect juveniles in the sea are the most urgent development needs if sandfish culture is to progress further.

Overview of sea cucumber farming and sea ranching practices in China

Jiaxin Chen[1]

History of trepang consumption in China and present status

Eating trepang is a custom of the Chinese, especially in coastal areas. The history can be traced back to the Ming Dynasty (1368–1644 BC) at least, when sea cucumber was recorded in the *Bencao Gangmu*, a famous materia medica written by Li Shizhen. Sea cucumber was recorded as a tonic and a traditional medicine in many ancient writings (e.g. *Shiwu Bencao, Bencao Gangmu Shiyi, Wuzazu, Bencao Congxin*) from the Ming Dynasty to the Qing Dynasty (Huizeng Fan 2001; Yuhai Jia 1996).

According to the "analysis by principles" of traditional Chinese medicine, the sea cucumber nourishes the blood and vital essence (*jing*), tonifies kidney *qi* (treats disorders of the kidney system, including reproductive organs), and moistens dryness (especially of the intestines). It has a salty quality and warming nature. Common uses include treating weakness, impotence, debility of the aged, constipation due to intestinal dryness, and frequent urination. Traditionally, sea cucumbers are eaten by Chinese people more for their tonic value than for their seafood taste. Hence, the popular Chinese name for sea cucumber is *haishen*, which means, roughly, ginseng of the sea (Anderson 1988; Zhang Enchin (ed.) 1988).

Chinese commonly consume certain types of food as medicines for prevention and treatment of illness. Chinese cooks have revered the sea cucumber since ancient times. In particular, sea cucumber meals are offered on numerous special occasions, especially the Chinese Spring Festival. The sea cucumber is rated along with several other delicacies, such as shark fin and bird's nest soup, as a disease preventive and longevity tonic.

From the nutritional viewpoint, sea cucumber is an ideal tonic food. It is higher in protein and lower in fat than most foods (Table 1). It contains the amino acids and trace elements essential for keeping healthy (Tables 2, 3, 4). For nourishing purposes and to clean the blood of people suffering from emaciation, it is combined in soup with pork. For impotence, frequent urination, and other signs of kidney deficiency, it is cooked with mutton. For yin and blood deficiency, especially manifesting as intestinal dryness, sea cucumber is combined with tremella (*yiner*, the silvery tree mushroom). All of these recipes are popular with the Chinese (Jilin Liu and Peck G 1995).

For modern applications, dried sea cucumber used as a nutritional supplement is prepared in capsules or tablets. The fully dried material has a protein concentration as high as 83 per cent. From the Western medical viewpoint, the reason sea cucum-

Table 1. **Main food groups in various species of sea cucumber***

Item	Protein %	Fat %	Moisture %	Carbohydrate %	Ash %
Fresh *Acaudina molpadioides*	12.94	0.03	77.00	0.43	1.03
Fresh body wall of *Acaudina molpadioides*	11.52	0.03	87.83	0.38	0.99
Dried *Acaudina molpadioides*	68.53	0.55	8.25	--	7.56
Fresh body wall of *Thelenota ananas*	16.64	0.27	76.97	2.47	1.60
Dried *Thelenota ananas*	69.72	3.70	8.55	--	9.51
Dried *Apostichopus japonicus***	55.51	1.85	21.55	--	21.09

* From Fangguo Wang (1997); modified by Jiaxin Chen
** Also contains essential amino acids

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Table 2. **Amino acid levels in *Acaudina molpadioides* and *Thelenota ananas****

Amino acids	Fresh *Acaudina molpadioides* x 10^{-2}	Fresh body wall of *Thelenota ananas* x 10^{-2}	Dried *Acaudina molpadioides* x 10^{-2}	Dried *Thelenota ananas* x 10^{-2}
Asp	1.387	1.890	6.260	5.78
Thr **	0.519	0.712	2.438	2.58
Ser	0.459	0.721	2.008	2.07
Glv	1.658	2.865	8.994	7.86
Pro	1.302	1.408	--	1.03
Gly	2.502	2.724	14,424	10.03
Ala	1.662	1.703	5.771	5.20
Cys	0.387	--	--	--
Val**	0.374	0.688	1.944	2.43
Met**	0.158	0.339	0.614	0.86
Ile**	0.189	0.473	0.965	1.64
Lev**	0.359	0.780	1.684	2.59
Tyr	0.195	0.435	0.655	1.41
Phe**	0.223	0.567	0.847	1.67
His	0.091	0.213	0.728	0.40
Lys**	0.182	0.524	1.288	0.92
Arg	0.647	0.773	3.778	4.46
Total	12.330	16.815	52.398	50.93

* From Fangguo Wang (1997)
** Essential amino acids

ber is valuable is it serves as a rich source of the polysaccharide condroitin sulfate, which is well known for its ability to reduce arthritis pain: as little as 3 g per day of dried sea cucumber has been helpful in significantly reducing arthralgia. Its action is similar to that of glucosamine sulfate, which is useful for treating osteoarthritis. Sulfated polysaccharides also inhibit viruses; there is a Japanese patent for sea cucumber chondroitin sulfate for HIV therapy.

Chinese studies reveal that sea cucumbers also contain saponin glycosides. These compounds have a structure similar to the active constituents of ginseng, ganoderma, and other famous tonic herbs. Additional Chinese studies indicate anticancer properties of both the sea cucumber saponins and the polysaccharides. These modern studies confirm that sea cucumber can be used as a tonic and nutrient supplement. Coinciding with economic development, the demand for trepang has greatly increased in mainland of China since the early 1980s (Huizeng Fan 2001).

Table 3. **Vitamins, saponins and polysaccharides in *Acaudina molpadioides* and *Thelenota ananas****

	Vitamins						Saponins	Polysaccharides
	B1 x 10^{-5}	B2 x 10^{-5}	B6 x 10^{-5}	A x 10^{-5}	D x 10^{-5}	E x 10^{-5}	x 10^{-3}	x 10^{-5}
Fresh *A. molpadioides*	0.114	0.15	0.039	0.15	0.0066	3.95	26.76	4.21
Fresh body wall of *A. molpadioides*	0.102	0.13	0.035	0.13	0.0059	3.52	26.50	3.75
Fresh body wall of *T. ananas*	0.782	0.23	19.000	0.35	0.0180	0.90	379.40	4.12

* From Fangguo Wang (1997)

Table 4. **Trace elements contents in *Acaudina molpadioides* and *Thelenota ananas****

	Mn x 10^{-6}	Fe x 10^{-6}	Zn x 10^{-6}	Co x 10^{-6}	Cu x 10^{-6}	Se x 10^{-6}
Fresh *A. molpadioides*	1.5	2231	10.48	0.48	0.43	1.32
Fresh body wall of *A. molpadioides*	1.5	1982	9.34	0.43	0.43	1.40
Fresh body wall of *T. ananas*	7.1	794	7.35	0.23	0.36	0.34

* From Fangguo Wang (1997)

Apostichopus japonicus and its hatchery techniques

There are 134 species of sea cucumbers identified in China seas, among which about 20 species (Table 5) have commercial value for edible consumption. *Apostichopus japonicus* (Fig. 1) is the only species to be cultured in China. This is due to its high meat quality and to the success of the techniques used in commercial hatcheries (Yulin Liao 1997).

In the early 1980s the shortage of sea cucumber seed was a bottleneck for developing aquaculture. The Ministry of Agriculture prioritised setting up hatcheries of sea cucumber (*Apostichopus japonicus*) and improving techniques of seed production. Since then, sea cucumber farming has been becoming a vigorous sector in mariculture.

Sea cucumber is dioecious, but it is hard to differentiate the male from the female. The genital pore located on the posterior back of the head is very small. Most individuals only possess one genital pore, but a few have 2 or 3 pores with a spawning function.

Individuals at two years old, weighing about 250 g, enter their mature period. Females are very fecund and can produce as much as 1–2 million eggs — sometimes even 10 million — in one spawning event. Normally, fecundity is related to body weight. During mature periods, there are 220,000–290,000 eggs per gram of ovary. When the water temperature near the seabed reaches 15–17ºC, it is a good time for broodstock collection. The procedure for artificial reproduction of sea cucumber is as follows:

1. Broodstock collection: from late May to early July, when the gonad index is over 10.
2. Broodstock care in land-based tanks: 30 individuals m^{-3}, DO over 5 mg L^{-1}, feeding rate about 5–10% of body weight.
3. Spawning stimulation: thermal shock (water temperature raised by 3–5°C) and desiccation followed by seawater jet for 10–15 minutes.
4. Fertilisation: when the diameter of the oocyte is around 120–130 µm. Maximum density 200–300 eggs ml^{-1} in spawning tank; 1 million eggs m^{-3} in hatchery tank.
5. Hatching.
6. Nursery of juveniles.

Experimental results reveal that auricularia larvae and 7–10-day-old juveniles are sensitive to environmental conditions; highest mortalities will occur during these two stages. The main problems come from diseases of digestive duct, especially gastritis. Hence, the key to increasing survival rate is to provide the appropriate feed and to follow sophisticated routine management.

On entering the pre-auricularia stage, the larvae begin to feed on phytoplankton. In a commercial sea

a. Live specimen

b. Dried specimens

Figure 1. ***Apostichopus japonicus***

Table 5. Edible sea cucumbers in China seas

Latin name	Common name	Latin name	Common name
Actinopyga mauritiana	Redfish; shoes trepang	*Holothuria fuscogilva*	White teat-fish
Actinopyga lecanora	Stone trepang; sea cucumber	*Holothuria nobilis***	Black teat-fish
Actinopyga echinites		*Holothuria moebii*	
Actinopyga miliaris	Black trepang	*Holothuria cinerascens*	
Bohadschia argus	Tiger-fish; spotted fish	*Holothuria arenicola*	
Bohadschia marmorata	White-fish	*Apostichopus japonicus**	Thorn trepang
Holothuria atra	Black trepang	*Stichopus chloronotus*	Square trepang
Holothuria edulis		*Stichopus horrens*	
Holothuria fuscocinerea	Stone trepang	*Stichopus variegatus*	Yellow meat
Holothuria leucospilota	Black trepang, black dog	*Thelenota ananas***	Plum-flower trepang
Holothuria pervicax	Tiger spotted trepang	*Thelenota anax*	Plum-flower trepang
*Holothuria scabra***	Sandy-fish; white-fish	*Acaudina leucoprocta*	Perfume trepang

* Highest commercial value
** High commercial value

cucumber hatchery, *Dunaliella salina*, *Phaeodactylum tricornutum*, and *Chaetoceros simplex*, as well as marine yeast, are commonly considered ideal feeds.

The feeding regime depends on the development stage. From pre-auricularia to post-auricularia stage, algal cells in the rearing water are gradually increased from 10,000 cells ml^{-1} to 25,000 cells ml^{-1}; the feeding frequency is 2–4 times per day. A feeding experiment indicated that the survival rate of juveniles is influenced by feed and feeding quantity (Tables 7 and 8).

Table 6 . The developmental stages from fertilised egg to juvenile (water temperature: 20–21°C)

Stages	Size (µm)	Density (/l)	Time
First polar body			20–30 min.
Second polar body			30–35 min.
First cleavage			43–48 min.
Blastula			3 hr 40 min. – 5 hr 40 min.
Hatch out		1000–1500	12–15 hrs
Pre-gastrula		500–600	14–18 hrs
Gastrula			18–25 hrs
Pre-auricularia	360–430		25–30 hrs
Mid-auricularia	600–700		5–6 days
Post–auricularia	800–1000		8–9 days
Doliolaria	400–500		about 10 days
Pentactula			about 11–12 days
Juvenile	300–400	50–100	about 12–13 days

Table 7. Influence of feed type on survival rate of larvae and juveniles (density of pre-auricularia: 1000 L^{-1})

Feed	Auricularia stage		Juvenile stage	
	Density (individuals L^{-1})	Survival rate (%)	Density (individuals L^{-1})	Survival rate (%)
Marine yeast	190	19.0	55.5	5.55
Tetraselmis sp.	9	0.9	1.85	0.18
Phaeodactylum sp.	20	2.0	50.9	5.09

Table 8. Influence of feed quantity on survival rate of juveniles (density of juveniles: 1300 L^{-1})

Feed quantity (cells ml^{-1})	Juvenile stage	
	Density (individuals L^{-1})	Survival rate (%)
5000	59.1	4.56
3000	13.7	1.54
1000	5.5	0.42

The results in Table 7 indicate that marine yeast is a desirable feed for breeding juveniles of sea cucumber. In practice, in commercial production a mixture of feed organisms is adopted that provides a range of nutrients to juveniles and increases the survival rate.

As larvae develop to doliolaria and pentactula stages, their bodies start to constrict and shrink to half the original size. About one or two days later, they metamorphose to early juveniles (about 400 µm long). During this stage, their behaviour changes from swimming to attaching. Hence, there should be substrates for attachment put in the rearing tank for this stage. Normally the attached density of juveniles should be controlled at 20–50 individuals 100 cm^{-2}.

Normally, the young seeds will spend several months in the nursery tank. Formulated feed has been used to feed the young animals until they grow to 2–3 cm. They are then moved to ponds for farming or to the open sea for sea ranching (Jiansan Jia and Jiaxin Chen 2001; Jiaxin Chen 1990).

Farming and sea ranching

In recent years, farming sea cucumber in ponds has become very popular in China. Digging new earth ponds is best, but used shrimp ponds can also be used after being improved to meet the ecological demands of sea cucumber.

Site selection

- The site must be at lower tide level, so seawater can be filled by gravity;
- There must be no pollution issues;
- The salinity should be over 27 ppt;
- Sandy or sand-muddy bottom is better;
- 2-metre depth is needed (no less than 1.5 m);
- Best pond size is in the 1–4 ha range;
- Ponds must be protected from typhoon or strong waves.

Layout of substrate of stone block

Before filling the ponds with seawater, stone blocks are laid on the bottom in rows or in cones (Fig. 2a, 2b). The stone blocks will be the “home” of the sea cucumbers, and are used as substrata to grow benthic algae and other organisms, which are a feed for the sea cucumbers.

Rows of stone blocks are 3 m wide by 1.5 m high. The interval between each row is 3–4 m. Cones of stone blocks have a diameter of 4–5 m at the base and a height of 1.5 m. The volume of stone used for substrata is around 2250 m^3 per hectare. Figure 3 shows a pond ready for sea cucumber farming.

The optimum temperature for sea cucumber growth is 10–17°C, but juveniles can maintain high growth rates at 24–25°C. In the northern part of China, the stocking season is from March to May. The stocking density depends on the size of seed (Table 9) and habitat conditions — including natural feed availability, seawater exchange rate, etc.

If the individual weight of seeds is 10 g at the start of the stocking season, mean weight of 150 g will be reached in October to November of the same year. If the seed weight is less than 1 g, it will take 15–18 months to reach commercial size.

The oxygen consumption of sea cucumber is much lower than that of shrimp (Table 10). This makes farming of sea cucumber easier than shrimp culture due to lower water exchange rate and no aeration facilities required. The cost of routine management is also much lower than that of shrimp culture.

In experimental farming, juveniles (body length: 3–4 cm) were stocked in early spring, with a density of 150,000 individuals per hectare. The yield reached 4000 to 7000 kg ha^{-1} in the following year.

Growth rates are very variable. Sampling showed that the weight of 0.5-year-olds ranges from 1.7 to 13 g, and 2.5-year-olds from 65 to 225 g. This is a factor influencing profit margins. Notwithstanding, farming sea cucumber is a lucrative industry in China that has been attracting more and more investors, transferring investment from shrimp culture to sea cucumber farming.

Sea ranching

Sea ranching of sea cucumber was initiated by the Yellow Sea Fisheries Research Institute in 1980. The results revealed that it was important to add substrata — like stone blocks — in the sea cucumber habitat. The functions of artificial substrata are to:

- protect the broodstock and their larvae against the predators,
- increase the availability of natural feed like benthic algae and accumulating organic debris, and
- improve the habitat for aestivation and hibernation.

A simple measure — to be tried in Shandong and Liaoning provinces — is to place stones or artificial reefs into selected sea areas. The criteria for site selection include water temperature (less than 25° C), salinity (27–35 ppt), and relative absence of predators like sea stars and crabs. The results indicate that the keys to success are site selection and routine management. In one site, located in Shandong Province, the output was increased by 16 fold after using enhancement practices (Jiansan Jia and Jiaxin Chen 2001; Shaodun Mu 1999.).

Marketing trends

The retail prices of beche-de-mer (dried sea cucumber) have increased dramatically since the 1980s. In 1960, the price for 1 kg of beche-de-mer (*Apostichopus japonicus*) was CYD[2] 18, in 1980 it was

Table 9. **Stocking density of different size of seed**

Size of seeds (individuals kg^{-1})	Stocking density (individuals ha^{-1})
60–100	100,000–150,000
200–400	250,000–300,000
> 1000	400,000–450,000

Table 10. **Sea cucumber oxygen consumption***

Age (yrs)	Mean body weight (g $ind.^{-1}$)	Consumption of oxygen (ml O_2 h^{-1})	Consumption rate of oxygen (ml O_2 g^{-1} h^{-1})
0.5	7.5	0.488	0.016
1.0	26.3	1.152	0.011
2.5	110.5	1.051	0.009

* Temperature: 18–20°C and salinity: 29.9–30.8 ppt

2. CYD: China Yuan Renminbi. In April 2003: CYD 100 = USD 12.10

a. Using rows of stones b. Using cones of stones

Figure 2. Two types of ponds used for sea cucumber farming

Figure 3. Ponds ready to be used for sea cucumber farming

CYD 500, and in 1990, CYD 600–1000. At present, the price can exceed CYD 3000 (about USD 370) per kilo! The soaring price has stimulated the development of sea cucumber farming. Prices for beche-de-mer from tropical regions — including white teatfish, black teatfish and sandfish — have increased steadily, but not as rapidly as those of *Apostichopus japonicus*. The reason for this is that the quality of these tropical species cannot compare with the quality of *Apostichopus japonicus*. The area of sea cucumber farming has reached 10,000 ha. The increase in farming area should result in productivity increase. The author estimates that prices of beche-de-mer, especially of *A. japonicus,* will stabilise in response to the increase in domestic production and imports from Russia and Japan in the near future.

New products — including frozen or lyophilised sea cucumbers, and extracts used as nutrient supplement or function food — have emerged in the domestic market. Changes to the traditional processing method have been initiated because the old method damages some useful elements like glycosaminoglycan.

It is believed that sea cucumber farming will become a prosperous sector of Chinese mariculture. It will involve the development of a processing industry and pharmaceutical industry related to the sea cucumber. Meanwhile, it plays an active role in protecting natural populations.

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Conservation strategies for sea cucumbers: Can a CITES Appendix II listing promote sustainable international trade?

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Introduction

Sea cucumbers, especially of the families Holothuridae and Stichopodidae, form an important part of a multi-species invertebrate fishery that has been in existence in the Indo-Pacific for traditional and subsistence uses for over 1000 years. Since the late 1980s, sea cucumber fisheries have expanded to supply growing international markets with beche-de-mer, and also to provide organisms for aquaria and biomedical research. Trends during the 1990s indicate that the number of producing countries and species in trade have increased worldwide, both in tropical and temperate regions, and holothurian fisheries have spread to many non-traditional fishing areas such as Mexico, the Galapagos and North America. In Hong Kong Special Administrative Region (Hong Kong SAR) import statistics show an increase from 25 source countries in 1987–1989 to 49 countries that exported beche-de-mer in 2000–2001. While worldwide landings of sea cucumbers were estimated to amount to 25,000 metric tonnes (t) live (approx. 2500 t dried weight) in 1983, the total trade in holothurians reached a global annual volume of about 13,000 t of dried sea cucumber (130,000 t live) by 1995, valued at about USD 60 million (Jaquemet and Conand 1999; Conand 2001).

The high value of some species, the ease with which such shallow water forms can be harvested, and their vulnerable nature due to their biology, population dynamics and habitat preferences all contribute to the overexploitation and collapse of fisheries that have been reported in some regions. Holothurians are susceptible to overexploitation due to their late maturity, density-dependent reproduction, and low rates of recruitment. Although sea cucumbers have a wide distribution, with some species occurring throughout entire ocean basins, most species have very specific habitat preferences such as a specific zone within reef habitats, algae, or grass beds. A marked increase in landings and export of holothurians, combined with a limited amount of fishery data, a paucity of biological information and population parameters for commercially important species, and the existence of few management measures are all factors involved in the decline of holothurian populations (Conand and Byrne 1993).

Biological and trade information strongly suggest that sea cucumbers may qualify for listing in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Given the past and continuing levels of exploitation to meet international demand, these species meet CITES criteria for inclusion of species in Appendix II, as adopted in Resolution Conf. 9.24 (Annex 2a Bi): "harvesting of specimens from the wild for international trade has or may have a detrimental impact on the species by exceeding, over an extended period, the level that can be continued in perpetuity". Available trade data are thought to represent an underestimate of the total global commerce, as trade routes for holothurians are complicated, export data are incompletely reported, commodities in trade can include several forms of dried product as well as chilled, frozen and salted beche-de-mer, and individual species are rarely differentiated in trade reports. Beche-de-mer is primarily exported from producer countries to a central market in Hong Kong SAR, Singapore or Chinese Taipei, and then re-exported to Chinese consumers worldwide (Conand and Byrne 1993). Also, a large number of species and possibly several hundred thousand sea cucumbers are available for home aquaria, but data on species, quantities and source countries are largely undocumented due to a lack of international trade controls.

The United States of America submitted a discussion document (CoP 12 Doc. 45) to the CITES Secretariat requesting that this issue be discussed by the Conference of Parties in Chile, November 2002, to address the fundamental questions of whether a CITES listing is appropriate for and can contribute to the conservation of sea cucumbers. Of critical importance is whether a CITES listing can contribute to the sustainable management of sea cucumbers. A number of issues have to be addressed before this question can be answered, including taxonomic uncertainties within the families, ability to distinguish taxa in the form they are traded, adequacy of biological information for making non-detriment findings, and ability to

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Table 1. Primary species involved in the international trade in sea cucumbers and location of collection. High value (*), medium value (**) and low value (***) species are indicated. Most species shrink to approximately 50% of their length and 8% of their weight when dried (adapted from Conand 1990)

Species	Common name	Distribution
*Actinopyga echinites****	brownfish (deepwater red fish)	S. Pacific
*A. lecanora **	stone fish	S. Pacific
*A. mauritiana***	surf red fish	S. Pacific
*A. miliaris***	black fish	S. Pacific
Athyonidium chilensis		Peru, Chile
*Bohadschia argus****	leopard (tiger) fish	S. Pacific, SE Asia
*B. graeffei**** (= *Pearsonothuria graeffei*)	orange fish	S. Pacific, SE Asia
*B. marmorata marmorata***	chalky fish	SE Asia, S. Pacific, Red Sea
*B. marmorata vitiensis***	brown sandfish	SE Asia, S. Pacific, Red Sea
*B. vitiensis****	brown sandfish	S. Pacific, Indian Ocean
Cucumaria frondosa	pumpkins; orange footed cucumber	West Atlantic (Maine/Canada)
*Halodeima atra****	lolly fish	S. Pacific
*H. edulis****	pink fish	S. Pacific
*H. fuscogilva**	white teatfish	S. Pacific, SE Asia, Indian
H fuscopunctata	elephant trunkfish	S. Pacific, SE Asia
H. impatiens	slender sea cucumber	Caribbean (Mexico)
H. mexicana	donkey dung	Caribbean (Venezuela)
*H. nobilis***	black teatfish	S. Pacific, SE Asia
*H. scabra**	sandfish	S. Pacific, SE Asia, Indian Ocean
*H. scabra versicolor**	golden sandfish	S. Pacific, SE Asia
Isostichopus badionotus	three-rowed sea cucumber	Caribbean (Venezuela)
I. fuscus (= Stichopus fuscus)		East Pacific from Baja to Peru (Galapagos)
Parastichopus californicus (= Stichopus californicus)	giant red sea cucumber	East Pacific (US/Canada)
P. parvimensis (= Stichopus parvimensis)	warty sea cucumber	East Pacific (California/Mexico) [to Cedros Island, Baja]
*Stichopus chloronotus**	green fish	S. Pacific, Indian
*S. hermanni**	curry fish	SE Asia, S. Pacific
S. japonicus		Japan
S. mollis	New Zealand sea cucumber	New Zealand, W. Australia, Tasmania
*Thelenota ananas**	prickly redfish	S. Pacific
*T. anax****	amberfish	S. Pacific

make legal acquisition findings. The main purpose for highlighting this issue at CoP 12 is to: (1) establish dialogue between Parties, scientists, industry and communities dependent on these resources; (2) encourage continued research to clarify taxonomy and identification of live and dried specimens in trade, and compile life-history characteristics, species distribution and demographic data; (3) improve the collection of data quantifying the extent of harvest and international trade, documenting location and catch data by species; (4) compile the best information about the current status of these species and the impact trade has on sea cucumber populations and their environments; and (5) evaluate possible management approaches to promote sustainable harvest. This paper summarises the discussion document, the full text of which is available at: http://www.CITES.org/eng/cop/12/doc/E12-45.pdf.

Harvest and trade

Holothurians that are targeted for beche-de-mer range in size from about 5 cm to over 1 m in length, and include over 30 deposit-feeding species and one filter feeder belonging to two families and seven genera of the Aspidochirotids: *Actinopyga, Bohadschia, Holothuria* (Holothuridae) and *Isostichopus, Parastichopus, Stichopus* and *Thelenota* (Stichopodidae) and one family and genus of the Dendrochirotids: *Cucumaria* (Cucumariidae) (Table 1). Tropical and subtropical fisheries are multi-species with fishers primarily targeting shallow water (up to 50 m depth) environments, while most temperate fisheries are based on single species. The species of highest commercial value in tropical waters of the western Pacific and Indian Oceans are *Holothuria fuscogilva* (white teatfish), *H. nobilis* (black teatfish) and *H. scabra* (sandfish). Species of medium value include *Actinopyga echinites* (brownfish), *A. miliaris* (blackfish) and *Thelenota ananas* (prickly redfish). Species of low value include *H. atra, H. fuscopunctata, Stichopus chloronotus* and *S. variegatus*. A small, but growing fishery exists in the eastern Pacific, including Ecuador and Galapagos, for *Isostichopus fuscus*. Temperate fisheries are divided into western Pacific regions for *Stichopus japonicus*, eastern Pacific coasts of North America for *Parastichopus californicus* and *P. parvimensis* (Alaska, Oregon, California and Washington, USA, and British Columbia, Canada), and a small fishery in the Atlantic for *Cucumaria frondosa* (Maine, USA, and Quebec, Canada). Fishing gear and methods include small bottom trawl nets (roller pulling nets and beam trawl nets) for sandy bottoms, scallop-drag gear in nearshore rocky-bottom habitats, spears, hooks and scoop nets for reefs, and scuba and hookah for deeper reef and lagoonal environments.

World landings of sea cucumbers were estimated to amount to 25,000 t (live) in 1983. *Stichopus japonicus* was the most important species by weight during the early 1980s, with over 13,371 t harvested in Japan and Korea each year prior to 1985. Most of the remaining harvest consisted of tropical species from the Indo-Pacific. Worldwide harvest increased threefold from 1985–1986, and it again doubled during 1987–1989 in response to increased demand in Asian markets. In 1989, a total catch of 90,000 t was recorded, consisting of about 78,000 t from the South Pacific and Southeast Asia, and 12,000 t from temperate fisheries. Holothurian fisheries have continued to expand, with a total worldwide harvest of 120,000 t by the early 1990s (Conand 1997).

There is a substantial amount of information on the trade routes and main sea cucumber markets, but the volume and location of harvest and export are still incompletely recorded. The Chinese have sought sea cucumbers for over 1000 years in India, Indonesia and the Philippines, but traders began gathering them from a wider area in the 18th and 19th century (Conand and Byrne 1993). Over the last two decades, much of the beche-de-mer in international trade was exported from the producer countries to a central location, and then re-exported to Chinese consumers (Conand and Byrne 1993). Hong Kong SAR, China, Singapore, Malaysia, Chinese Taipei, Korea and Japan currently account for almost 90 per cent of the total imports of beche-de-mer, with approximately 80 per cent of the overall international trade destined initially for Hong Kong. Based on import data from Hong Kong, the number of exporting countries for dried, fresh and frozen beche-de-mer has continued to increase from about 25 countries in 1989 to 49 in 2000/2001, with exports dominated by about 30 species (Table 2). In 2000 and 2001, Chinese Taipei imported sea cucumbers from 28 countries. Singapore currently receives about 50 per cent of its imports from Hong Kong SAR, with Papua New Guinea, Tanzania and Madagascar the other main suppliers. An examination of trade statistics for the three main markets also reveals the existence of two-way trade, particularly for the Singapore and Chinese Taipei markets. For instance, between 1995 and 1996 Singapore shipped 72 per cent of its re-exports to Hong Kong SAR and 6 per cent to Chinese Taipei; Chinese Taipei also imported 42 per cent of its beche-de-mer from Hong Kong SAR, with imports destined for local consumption or later re-export, depending on the market (Jaquemet and Conand 1999).

Export data are available for only a small number of countries, and only limited information is available on total harvest of individual species. In the late 1980s and early 1990s, Indonesia was the major world producer and exporter, with a production of around 4700 t of dried sea cucumbers per year since 1987. The Philippines emerged in the mid 1990s as the second major producer and exporter of dried sea cucumbers, with catches of around 20,000 t (live) per year (Conand and Byrne 1993). Other major exporters include Fiji Islands, Japan, Madagascar, Papua New Guinea, Solomon Islands, Thailand and USA (Table 3).

Population status and trends

There are a growing number of reports indicating that sea cucumber populations are declining worldwide in tropical and subtropical countries with sea cucumber fisheries, including information from collection areas in Australia, India, Thailand, Papua New Guinea and the Galapagos (Conand 1997; Jaquemet and Conand 1999; TRAFFIC South America 2000). For instance, in the Great Barrier Reef in Australia, densities of *H. nobilis* were found to be four to five times higher on reefs protected from fishing when compared to 16 reefs open to fishing, and the average weight of individuals was substantially smaller (1763 g) on fished reefs than on unfished reefs (2200 g) (Uthicke and Benzie 2001). In many locations fisheries have gone through boom and bust cycles, and high value species are typically rapidly depleted shortly after a fishery became established. As certain high value species become overexploited the focus first shifts

Table 2. **Amount of dried sea cucumbers (metric tonnes) imported into Hong Kong SAR. Source: Hong Kong SAR import statistics. * Data from Singapore, Hong Kong SAR and Chinese Taipei. ** The Western Indian Ocean countries that export sea cucumbers include South Africa, Mozambique, Tanzania, Kenya, Yemen, United Arab Emirates and Madagascar, some of which are listed separately in subsequent years.**

Country	1983	1988	1989	1993	1994	1995	2000	2001
Africa	145.43	0	0					
Australia	0	7.60	1.10				14.19	21.83
Brazil							0	0.45
Canada	0	33.60	15.00				2.69	58.54
Chile							22.32	7.60
China	0	98.50	117.10				13.16	11.78
Colombia							0	0.55
Costa Rica							0.66	0
Cuba							19.02	13.94
Djibouti							0	0.01
Ecuador	0	0	0				15.28	0.09
Fiji Islands	0	*1295.00	*251.00	119	176	402	364.37	275.54
France							0	0.16
India	0	*33.00	*94.00				0.40	3.81
Indonesia	836.65	*3633.00	*1987.00	2620	2599	1694	1007.06	1060.39
Japan	483.98	34.20	39.40				74.94	102.76
Kiribati				99	130		9.07	13.96
Korea	368.26	42.90	22.40				2.54	0
Madagascar	0	86.60	57.70	379	318	170	178.39	179.08
Malaysia	0	19.50	125.16	17.50			59.31	66.04
Maldives	0	*347.00	*367.00				39.42	28.76
Mauritius							3.19	0
Mexico							0.15	0.59
Morocco							0	2.24
Mozambique	0	39.10	22.90				0.11	0.95
Netherlands							0	0.01
New Caledonia	0	*34.00	*28.00				0	0
New Zealand							11.04	31.19
Oceania	59.28	0	0				14.19	21.83
Oman							0.96	0.49
Papau New Guinea	0	327.00	226.00	179	150	236	531.90	493.41
Philippines	918.07	1718.50	621.70	1,872	1726	1270	1069.95	736.93
Seychelles							7.12	15.68
Singapore	51.93	797.70	1067.90				345.39	334.81
Solomon Islands	0	139.60	91.50	319	247	161	144.37	259.73
South Africa	0	34.30	22.30	28	93		27.88	28.78
Spain							1.00	0
Sri Lanka	1.30	*72.00	*52.00				64.85	32.90
Swaziland							0.35	0
Chinese Taipei	0	0	0				40.36	56.72
Tanzania	0	61.20	18.30	478	303	257	114.58	56.38
Thailand	0	0	15.50				133.86	101.02
Tonga	0	0.20	0				0	0
Tuvalu	0	0	0		0.871		0	0
United Arab Emirates							10.85	40.62
USA	0	12.10	24.20				181.57	89.74
Vanuatu	0	2.20	0	6	40		28.48	16.35
Vietnam							0.70	3.27
Western Indian Ocean countries**	0	*620.00	*470.00					
Yemen							0	3.20
Other	0	151.80	161.70					
TOTAL	**2125.4**	**9640.6**	**5898.9**	**6099**	**5782**	**4190**	**4758.7**	**4382.3**

Table 3. **Countries involved in the export of sea cucumbers, species collected, type of use, status of fishery and existing regulations. Information was compiled from a variety of sources, including range state consultations, reports identified in the *SPC Beche-de-Mer Information Bulletin*, and other published documents.**

Country/Region	Species	Comments and trade volume	Status and management
Australia	*H. scabra; H. nobilis;T. ananas;* 3 other species	Decreasing catch rates and declines in abundance and biomass of *H. nobilis*	Fishery for *H. nobilis* closed in October 1999 on the Great Barrier Reef
Canada	*S. californicus; S. parvimensis; C. frondosa*	East coast: *Cucumaria*; west coast: *Stichopus*	Fishery began in 1971 in BC, and a rapid increase in the 1980s; management actions including a limited entry, reduced fishing times, area closures, and an area quotas were introduced in 1991. 1999: new fishery in Quebec
CNMI	*A. mauritiana; H. nobilis*	Harvest in 1995–1996 in Rota; fishery moved to Saipan in 1996–1997	Fishery managed using CPUE data only; fishery halted due to declining CPUE
Cook Islands	*A. mauritiana*	Low population abundance; small export market	Export from 2 areas in the 1980s, Rarotonga and Palmerston; most today for subsistence only
Ecuador	*I. fuscus*	Fishery started in 1989	Stocks depleted; fishery moved to Galapagos
Fiji	*H. scabra;A. miliaris*	*H. scabra* catches rose to 700 t in 1988; stocks depleted. Export of *H. scabra* prohibited (1995). *A. miliaris* 95% of exports (1993)	Harvest restricted to Fijian natives; use of scuba gear forbidden; minimum legal dry length of 7.62 cm for all species
Galapagos (Ecuador)	*I. fuscus*	Fishery started in 1990	New management plan in place in 1999; two-month season
India	*H. scabra; H. spinifera; B. marmorata;A. echinites; A. miliaris; H. nobilis; T. ananas; H. atra;A. mauritiana; S. chloronotus*	*H. scabra; H. spinifera; B. marmorata* collected over last 1000 years; began collecting other species in 1990, in response to high export value and population declines; *A. echinites* and *A. miliaris* populations overexploited in some areas after 2 years	Sea cucumber collection banned in Andaman and Nicobar Islands; fishery exists in Gulf of Manner, Pal Bay, but CPUE and size of specimens has dramatically declined
Indonesia	16 species	16 species harvested in Sulawesi. Estimated exports from Indonesia increased from 878 t in 1981 to over 4600 t per year from 1987 to 1990	The world's largest source of sea cucumbers. No known management measures specific for sea cucumbers
Japan	*S. japonicus*	The catch of *S. japonicus* in Japan has decreased annually by 5–10%, dropping from over 10,000 t (wet weight) in 1978 to 7133 t in 1987	
Madagascar	*B. vitiensis; H. scabra;* other species	Export fishery began in 1921, with exports of 50–140 t annually. Exports increased from 56 t in 1986 to over 500 t in 1991 and 1994	Declining exports, quality and size of sea cucumbers indicate resources are overexploited (1998)
Malaysia	*S. hermanni; S. horrens; H nobilis; H. scabra, H. fuscogilva;T. ananas; T. anax; B. argus*	Imports may exceed exports. Annual catch 1989–1991 about 800 t	There are no countrywide regulations for the holothurian fishery
Maldives	*T. ananas; H. nobilis; B. marmorata*	Export increased from 3 t in 1986 (start of the fishery) to 740 t in 1990	
Mexico	*I. fuscus*	Fishery in Baja started with *I. fuscus* in 1988, *P. parvimensis* in 1989 and *H. impatiens* in 1994. Catch for each species from 57–1038 t (live)	*I. fuscus* declared endangered in 1994. Dive surveys in Baja indicate drops in CPUE from 2000 kg/diver/boat to 150 kg, along with increases in number of permits, diver hours and diver depths
Micronesia		Minimal subsistence use.	No international trade (1993)
Mozambique	*H. scabra; H. nobilis; H. fuscogilva; H. atra;A. echinites; A. mauritiana*	High fluctuation in exports may be due to irregular reporting or to overexploitation. Catch reported at 500 t in 1990; 700 t in 1993; 6 t in 1995; and 54 t in 1996	In Inhambane Province, holothurian fishery is closed until stocks rebuild

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Table 3 **(continued)**

Country/Region	Species	Comments and trade volume	Status and management
New Caledonia	*A. miliaris; H. scabra; H. scabra versicolor*	Exports of over 125 t in 1990 and 1991 with declines to less than 81 t yr^{-1} from 1992 to 1994. Exports continued to decline from 79.8 t in 1994 to 39.1 t in 1998	*A. miliaris* harvest ~75% of exports; *H. scabra* harvest ~25% of exports
New Zealand	*S. mollis*	Experimental fishery started in 1990	15 t quota
Palau	*B. argus; H. scabra*	Small export fishery (2.13 t 1990)	
Philippines	25 species including: *H. scabra; H. nobilis; B. marmorata; H. fuscogilva; H. atra; A. Lecanora*	Exports increased from 250 t in 1977 and 1189 t in 1984 to 2123 t in 1996	
Papau New Guinea (PNG)	*H. scabra; A. mauritiana; H. nobilis; H. fuscogilva;* 13 other species	Dramatic increase in exports from 1982 to 1989	In Torres Strait, 1000 t of *H. scabra* in 1995; populations collapsed and fishery for this species stopped. In Milne Bay total allowable catch of 140 t implemented in 2001, with new fishery management provisions planned for 2002
Solomon Islands	22 species	Increase from 15 species in 1988 to 22 species in 1993. Dramatic increase in exports from 17 t in 1982 to 622 t in 1991	50% of exports from western province but populations in severe decline (1992); ban on collection and sale of *H.scabra* in 1997, but locals continue to collect them
Tanzania	7 primary, 13 additional species	*H. atra* is the most prized species	Fishery is unregulated
Thailand	*H. scabra; H. atra; H. leucospilota; B. marmorata; B. argus; S. hermanni; S. chloronotus*	Decrease in abundance in fished areas	No management or regulations
Tonga	*A. mauritiana; H.atra; S. chloronotus; A. lecanora; H.fuscogilva; S.variegatus;* 8 other species	Traditional use: commercial fishery began in mid1980s; increased in 1990 due to unregulated use of scuba and hookah. Recorded exports are 9767 kg (1991); 35,367 kg (1993); 61,449 kg (1994) and 60,160 kg (1995, 5 months). Top species are listed for 1994–1995 exports	Legal minimum sizes for some species; ban on use of scuba and hookah. A ten-year ban on take implemented in 1999
Torres Strait (Australia, PNG)	*H. nobilis; H. fuscogilva; H. scabra; Actinopyga* spp.	*H. nobilis, H. fuscogilva* at turn of century; annual catch averaged around 500 t; *H. scabra* dominated catch in 1990–1991, but other species including *Actinopyga* spp. are targeted because *H. scabra* stocks are depleted	Fishery primarily on Warrior Reef complex. Australia and PNG cooperate in management, conservation. Australia imposed a minimum size of 18 cm and total catch of 260 t in 1996. The fishery has been closed on the PNG side since 1992
Tuvalu	*H. fuscogilva; T. ananas; H. nobilis; H. fuscopunctata;* 4 other species	Small fishery between 1979 and 1982 with exports of 1800 kg in 1979, 805 kg in 1980, 90 kg in 1981, and 198.5 kg in 1982; fishery active between 1993 and 1995 with exports of over 3000 kg each year. *H. fuscogilva* (50–70% of export); *T. ananas* (14–20% of export); *H. nobilis* (0–10% of export); *H. fuscopunctata* (5–13.4%); 4 other species (2.8–12.8%)	The fishery is not regulated, but there are recommendations to ban use of scuba and hookah gear to harvest sessile organisms including sea cucumbers
USA	*S. californicus; S. parvimensis; C. frondosa* (Maine)	Fishery started in 1970s on the west coast; 1994 in Maine	Management plan, research, monitoring in place; west coast fishery appears to be sustainable
Vanuatu	At least 15 species	No traditional fishery, but important export product. Low population abundance	Annual export limit of 40 t established in 1991, but fishers never reach the quota
Venezuela	*I. badionotus; H. mexicana*	Fishery began in 1991–1992, but catches were made in a national park and were illegal. In 1993, 4 boats received one-year license each to harvest 200 kg	Sporadic legal commercial fishing and frequent closures; illegal fishing in parks involving Asian entrepreneurs

to other, lower-value species, and once collectors have removed all animals from one location they search for new populations in other areas. Until recently, deepwater populations may have provided a refuge for some heavily fished species, because most collection was done by wading or snorkelling. However, populations have been depleted in shallow water in many locations, and the use of scuba and hookah is rapidly increasing throughout the Pacific and Southeast Asia.

Populations may fail to recover even after fishery closures, and some studies indicate that populations of sea cucumbers in overexploited fishing grounds may require as much as 50 years in the absence of fishing pressure to rebuild. For instance, the Torres Strait fishery for *H. scabra* was closed in the mid 1990s, and the current biomass today is still estimated at less than 8 per cent of the virgin biomass (Skewes et al. 2000). Average densities of *H. nobilis* populations for the Torres Straits, Papua New Guinea (PNG), New Caledonia and Tonga ranged from 9.4–18.4 individuals per hectare in the late 1980s, with maximum reported densities of 100 (Conand 1990) to 275 ind. ha^{-1} (Lokani 1990). In PNG waters, peak catches occurred in 1991–1992 and subsequently declined, with the fishery switching to other less valuable species. As sites were serially depleted, fishing effort shifted to more distant locations, until the fishery was closed. Surveys conducted in 1995–1998 on Warrior Reef identified progressively smaller breeding populations each year, leading to smaller and smaller recruitments. Breeding year classes (larger than 18 cm) were heavily depleted in both Australian and PNG waters, while recruiting year classes were more abundant in Australian waters. Surveys conducted in PNG several years after closure indicate little recovery; both adults and the recruiting year class were notably absent (D'Silva 2001).

Importance in the ecosystem

Sea cucumbers are important components of the food chain in temperate and coral reef ecosystems, and they play an important role as deposit feeders and suspension feeders. Rapid declines in populations may have serious consequences for the survival of other species that are part of the same complex food web, as the eggs, larvae and juveniles constitute an important food source for other marine species including crustaceans, fish and molluscs. In addition, several species have unique symbionts, including molluscs and fish, that may disappear once a species is overexploited.

Sea cucumbers have often been called the earthworms of the sea, because they are responsible for the extensive shifting and mixing of the substrate, and recycling of detrital matter. Sea cucumbers consume and grind sediment and organic material into finer particles, turning over the top layers of sediment in lagoons, reefs and other habitats and allowing the penetration of oxygen. Sea cucumbers are important in determining habitat structure for other species, and can represent a substantial portion of the ecosystem biomass. In absence of fishing pressure, sea cucumbers may occur on Indo-Pacific reef flats at densities in excess of 35 per square metre, where individuals process an immense amount of sediment each day. For example, the common western Atlantic *I. badionotus*, which is about 20 cm in length, can process 160 g of ocean debris in 24 hours (Fechter 1972). In Bermuda, in an area of 4.4 km^2, *I. badionotus* populations have been estimated to ingest 500–1000 t of sand annually. This process prevents the build-up of decaying organic matter and may help control populations of pest and pathogenic organisms including certain bacteria and cyanobacterial mats. In some areas, extirpation of sea cucumbers has resulted in a hardening of the sea floor, eliminating habitat for other benthic and infaunal organisms.

Issues that need to be addressed in relation to CITES

To address the fundamental questions of whether CITES listing is appropriate for and can contribute to the conservation of sea cucumbers, a number of issues have to be considered, including taxonomic uncertainties within the families, ability to distinguish taxa in the form they are traded, adequacy of biological information for making non-detriment findings, and ability to make legal acquisition findings, among others. Below we elaborate on what we perceive to be some of the key issues.

A. Taxonomic uncertainties within the families

While the taxonomy of the holothurian families is generally well known, the distinction of similar species is difficult, as they may exhibit similar morphology. In recent years several new species have been described from the Indo-Pacific, which is the centre of holothurian biodiversity. Nevertheless, there are many undescribed large species that are common in shallow water and there are relatively few holothurian taxonomists. The large number of extant sea cucumber species (1250) and the growing number of species in commercial trade complicate this issue even further.

B. Ability to distinguish taxa in the form they are traded

It is possible to identify most of the common species that are traded as live animals for home aquaria and other uses, based on the gross morphology. In contrast, it is very difficult to determine the species from the dried processed product, which is the dominant component of the international trade in sea cucumbers. Customs officials and wildlife inspectors may have difficulty identifying dried specimens even to genus. Photos of dried specimens of the main commercial species of the western tropical Pacific are available in a booklet from the Secretariat of the Pacific Community (1994), but there are no detailed identification guides. Most sea cucumber species can be identified by holothurian taxonomists by using the calcareous skeletal ossicles found in the body wall, and the ossicles are preserved during the drying process, but this may be unfeasible for law enforcement.

C. Adequacy of biological information for making non-detriment findings

There are very limited data currently available on the biological status of populations from areas with holothurian fisheries, with exception of selected countries such as Australia, Canada, New Zealand and the United States that have established, regulated fisheries. In these countries, population surveys are undertaken and this information is used in combination with fishery-dependent data to determine sustainable levels of harvest. Unfortunately, various parameters such as recruitment, growth and mortality are available for only selected high value species, and catch data may be incompletely reported, complicating the ability of scientific authorities to make a non-detriment finding. In addition, in response to the rapid expansion of holothurian fisheries and the high value of beche-de-mer, several countries have established experimental fisheries without having sufficient information to determine sustainable harvest. There are virtually no data available on the biological status of sea cucumbers and few management measures in the two largest exporting countries, the Philippines and Indonesia, and thus it is unlikely that these countries could make a non-detriment finding without capacity building for improved monitoring and data collection.

D. Ability to make legal acquisition findings

Because of the complex trade routes for sea cucumbers, often involving import and subsequent re-export, or transshipment ports that export mixed shipments of different origins, it is very difficult to determine the country of origin. For instance, Malaysia has a well established holothurian fishery, and they also import and export holothurians. It is also difficult to determine whether the harvest was legal, as shipments often include multiple species that are difficult to differentiate when dried, and those countries that have established regulations for holothurian fisheries generally prohibit the harvest of selected species or in specific locations, while harvest of other species is legal. Furthermore, the processed product generally passes from the producing country to the main world distribution centres (Hong Kong SAR, Singapore and Chinese Taipei) before being imported to the consumer country, making it difficult to determine its origin. Trade statistics are further complicated by the variety of products available in international markets, including several types of dried holothurians (spiked and not spiked), as well as frozen, live, fresh or chilled, and salted or in brine.

E. Research needs

There is currently insufficient knowledge to develop models for sustainable management of beche-de-mer fisheries due to very limited biological information of the local fisheries and stocks (Conand 1990 and 2001). Further studies are needed on: recruitment, growth, and mortality of most commercial species; stock assessments; and improved statistics on catch and international trade. Sea cucumbers are sedentary animals that are especially susceptible to overexploitation because they are large, easily collected, and do not require sophisticated fishing techniques. Heavy fishing pressure can cause a decline in the density and biomass of the target species, and populations may be unable to rebound once they fall below a critical biomass. Most tropical and subtropical holothurians are broadcast spawners, and fertilisation success is highly dependent on population density. Reduction of population densities by fishing may render remaining individuals incapable of successful reproduction, due to the greater distance between males and females. Possible approaches to enhance and increase yield of sea cucumber stocks may include relocation of recruits, induced asexual reproduction through fission, hatchery rearing of larvae, and grow-out of juveniles in cages placed on the sea floor.

More research is needed to quantify population parameters, and stock assessments are needed in fished and unfished areas to develop sustainable management approaches. Because of the paucity of data for the spatial distribution of fishing effort, the depletion of stocks may not be detected using surplus yield models without detailed field monitoring. Additionally, fishery monitoring that only involves catch and effort statistics is likely to be erroneous as fishers may report catch as being made in areas other than those actually fished. For instance, the overall catch for the *P. californicus* fishery in Washington State, USA, appeared to be stable, but in reality half of the fished areas were overfished.

As stocks were serially depleted CPUE did not appear to decrease, due to a shift in fishing effort to deeper waters (Bradbury 1994).

There is substantial risk associated with managing fisheries of species assemblages (e.g. "sea cucumbers") versus managing and collecting catch data for individual species. As one species is depleted, fishing effort may shift to less valuable species, and the CPUE for the "sea cucumber" fishery may actually increase. There is also the danger that fisheries targeting more abundant species can support continued fishing pressure on rare, but extremely valuable, species. Thus, the management presumption that a fishery will become economically extinct before it is biologically extinct is not necessarily true.

Population genetic analyses are necessary to determine the appropriate scale of management strategies. The protection of whole reefs from fishing appears to be an effective management tool for the conservation of holothurian stocks. However, the division of a reef into fished and unfished zones may be effective only when the protected areas are large (Uthicke and Benzie 2001). In Australia, *H. nobilis* populations were found to have high gene flow, suggesting that recruits can be received from a wide geographical area and stocks could be managed on a regional scale. In contrast, separate genetic stocks of *H. scabra* were detected, which implies limited recruitment within regions that may reduce the potential for recovery of overfished areas. *H. scabra*, in particular, needs to be managed as separate stocks and local refugia are needed (Uthicke and Benzie 2001).

F. Capacity building

Capacity building is necessary in most developing countries with sea cucumber fisheries to promote development and implementation of sustainable management approaches and conservation of sea cucumber populations through mariculture, restocking programs, and other strategies.

Conclusion

While sea cucumber fisheries remain unregulated in a number of developing countries, other countries have established management measures to various degrees, in attempt to prevent overfishing (Table 3). In many countries, certain sites have been closed to harvest a short time after the fishery commenced, due to rapid overexploitation and biological or commercial extirpations, while the take of certain species is now prohibited in other locations due to their rarity. Traditional fishery management approaches were formerly successful in many countries because holothurians were primarily harvested at much lower levels, only for traditional and subsistence uses. In many countries, these approaches are no longer effective because 1) some of the traditional cultures are being lost; 2) population growth has put increasing pressure on the resource; 3) populations of sea cucumbers are being targeted that were not traditionally exploited, due to availability of motorised boats and scuba and hookah gear which allows fishers to reach distant and deepwater reefs and lagoons; and 4) non-local collectors are fishing in many areas and poaching and illegal trade has increased.

Possible approaches to sustainable management include adoption of specific collection and no-collection areas, permitting systems, quotas, seasonal harvest, rotational harvest, and other fishery management strategies. A CITES listing may provide an additional tool to ensure that harvest to supply international markets is conducted in a sustainable manner, without detriment to the target species or its ecosystem. CITES establishes an international legal framework for the prevention of trade in endangered species and for effective regulation in trade in other species. It gives producer and consumer countries their share of the joint responsibility, creates the necessary means for the international cooperation which is essential for fulfilling this responsibility, and it provides for monitoring of international trade. Through an Appendix II listing sea cucumber trade can be managed so as to yield the greatest sustainable benefit to fishers, exporters and importers, while maintaining these species such that they can continue to serve their important ecological role and also meet the needs and aspirations of future generations.

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Sexual reproduction in a fissiparous holothurian species, *Holothuria leucospilota* Clark 1920 (Echinodermata: Holothuroidea)

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Abstract

Holothuria leucospilota Clark 1920 inhabiting tropical Darwin waters primarily undergo asexual reproduction by fission throughout the year (Purwati 2001). However, there is also evidence of sexual reproduction. Monthly sampling from August 1998 to January 2000 revealed that the gonadal tubules within each individual of *H. leucospilota* grew simultaneously. Complete spawning, where the oocytes throughout the gonad have equal opportunity to be released in one spawning event, could therefore be expected. Post-spawning tubules were absorbed, resulting in the disappearance of gonads between reproductive cycles. The development of gonadal tubules in this holothurian does not conform to the "tubules recruitment model" proposed by Smiley (1988), as reassessed by Sewell et al. (1997).

A seasonal reproductive cycle with a restricted spawning period was recognised in the population studied. The resting stage that occurred simultaneously amongst individuals in the population made it possible to estimate gametogenesis, which may take less than a year. It is likely that gamete release occured in the period between new moon and full moon of April, at the end of the wet season in Darwin. The continuous flooding of the reefs during this period is thought to be effective for fertilisation.

Introduction

Variations occur in holothurian gonad structures and development (Conand 1981; Harriott 1985; Tuwo and Conand 1992; Hamel et al. 1993; Conand et al. 1997). In a holothurian population where the gonads develop simultaneously and spent tubules are absorbed after the reproductive season, the gonads may not be visible for a certain period. However, intraspecific variation can occur, such as in *Stichopus mollis* of New Zealand, where the population from the east coast of the North Island absorbs the after-spawned tubules and the gonadal basis, whereas the population in the South Island maintains its spent tubules (Sewell 1992). Intraspecific variation in number of gonad tufts is also possible. One example is dendrochirote *Cucumaria frondosa*, in which geographical and latitudinal factors are the suggested influencing factors (Sewell 1992; Hamel and Mercier 1996).

In view of these variations occurring amongst holothurian populations, it was of interest to study the sexual reproduction of *Holothuria leucospilota* from Darwin harbours, northern Australia. The investigation aimed to elucidate the types of gonadal

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tubule recruitment, and synchrony and seasonality of gonad development over the population. *H. leucospilota* has been observed to reproduce asexually by fission throughout the year (Purwati 2001; Conand et al. 1997) and this fission may influence the sexual reproductive activities.

Materials and methods

Individuals of *H. leucospilota* were collected from East Point reef, Darwin, northern Australia (12°24.20'S and 130°49.20'E). The population occupied an area of approximately 500 x 700 m with a relatively low density (0.077–0.29 individuals m^{-2}) and was composed of small animals, mostly less than 350 g in fresh body weight.

Tubule fractions of 170 gonads in total, sampled from individuals weighing 200 g or more in fresh body weight, were examined. This size was determined after a preliminary study revealed that individuals weighing at least 200 g in fresh condition carried gonads. Collections were conducted once every month from August 1998 to January 2000, except in April 1999 when sampling was carried out twice (15 and 29 April). Sample size ranged from 5 to 18 individuals per month, the inconsistency being due to the conservation policy practised on the study sites.

A small incision was made on the antero-dorsal integument of each individual to remove fractions of gonadal tubules from the body cavities. This was made on the site and the dissected bodies were returned to the reef. Chao et al. 1994 utilised this method and reported that the scar on the dorsal part of *Holothuria atra* caused by incision disappeared within six months. During our study, two individuals with scar at the point of incision were observed on the reef of East Point approximately 8–11 months after the first sampling.

Gonads collected were classified into four stages: early, growing, fecund and post-spawning stage, based on morphology and histology of the gonads. Tubule fractions were prepared for microscope slides by applying 10 per cent buffered formaldehyde fixation, paraffin procedures and hematoxylen-eosin staining. A camera lucida was set up on a compound microscope to enable diagrams of the ovarian histology to be drawn. Data on the environmental conditions provided by the Bureau of Meteorology Darwin were used to identify possible clues to the factors leading to spawning.

Results

Characteristics of the gonadal tubules

Gonadal tubules of *H. leucospilota* hang freely in the body cavity from a transparent saddle-like gonadal basis located at the side of the anterior part of the intestine. A simple gonoduct emerges from the gonadal basis and ends at the gonopore, approximately 2–3 cm from the oral end. Tubules were observed to protrude from the gonadal basis in two rows. Each tubule was straight and bifurcated twice or three times, rarely exceeding four times. The dimension, colour and number of the tubules were correlated with the stages of development (Fig. 1).

Male tubules were always creamy white in colour. Female tubules were more transparent, with the interior having a granulated appearance. The female tubules became reddish-orange with the development of fecund ovaries. After spawning, the tubules deteriorated and turned brown; unspawned oocytes were likely to be reabsorbed. Of the individuals sectioned, 59 were males, 64 were females and 47 either carried unidentified gonads or had no visible gonads. The number of males was calculated to be similar to the number of females, in which x observed (0.2030) was smaller than x expected (3.841) (d.f. +1; p = 0.05).

Table 1 gives the dimensions of the ovarian tubules and oocytes at various stages. The smallest ovaries were in the early development stage. They consisted of 7 transparent tubules, less than 8 mm long and 0.01 g fresh weight. The largest ovary in fecund condition consisted of more than 14 large orange tubules weighing 81.92 g fresh weight.

Table 1. Size of ovarian tubules and oocytes at different stages of development

Ovarian stage of development	Ovarian tubules		Oocyte
	Length	Diameter	Diameter
Early developing	≤70 mm	≤0.9 mm	5–60 mm
Growing	22–25 cm	<2.5 mm, but may reach 4 mm	5–110 mm
Fecund	20–30 cm, may reach 40–45 cm	4–5 mm	120–140 mm
Post-spawning	Varied	Shrinking	Large oocytes remained

Advanced ovaries were heavier as a consequence of increased gamete number and volume. Tubules protruding from the anterior part of the basis were frequently shorter but diameter, coloration and internal appearance were similar to the others.

All tubules within each individual gonad were always at the same stage of maturity. Furthermore, gonads collected in one sampling event tended to be in a similar state of maturity, indicating synchronous progression throughout the population (Fig. 2). A seasonal pattern can therefore be expected.

Stage of development

Figure 2 illustrates the pattern of development observed between August 1998 and January 2000. The early stage of development was mainly found in October–November 1998 and again in August–September 1999. Growing gonads were gathered among samples collected in December 1998–January 1999 and December 1999. From January to early April 1999 and in January 2000, collected gonads were mostly in fecund condition. In the last week of April through June 1999, post-spawning

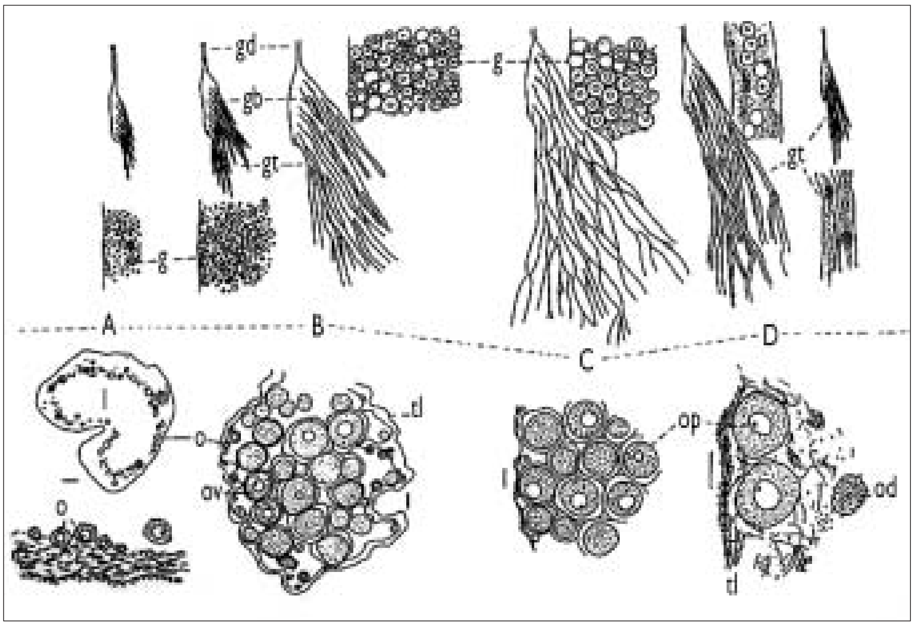

Figure 1.

Ovarian tubules of *H. leucospilota* under dissecting (above line) and compound microscope (below line). A: early stage; B: growing stage; C: fecund; D: post spawning. gb: gonadal base; gd: gonoduct; gt: gonadal tubules; l: lumen; o: pre-vitellogenic oocytes; od: degenerated oocytes; op: postvitellogenic oocyte; ov: vitellogenic oocyte; t: tubule; tl: tubule lining.
Scale bars in A, B, C, and D: 20, 40, 50 and 50 µm

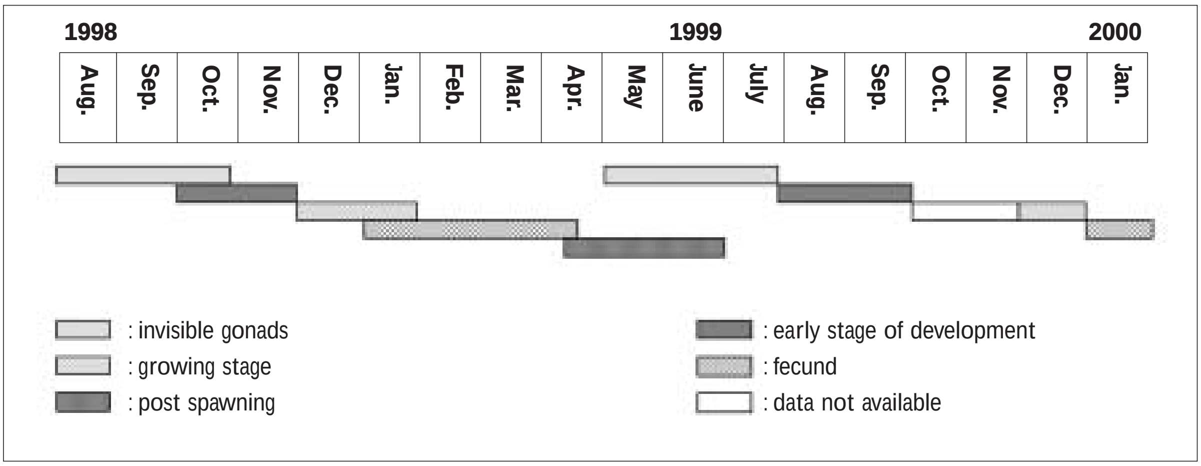

Figure 2. Condition of collected gonads

gonads were common and several of them were being absorbed. A similar condition was detected in gonadal sections in August, September and October 1998.

These observations indicate that oocyte release occurred in late April. This was between new and full moon, coinciding with almost continuous flooding of the reefs. April also marked the end of the wet season and the commencement of the dry season, when mean daily bright sunshine increases steeply and precipitation gradually decreases to a minimum (BOM data, in Purwati 2001).

Discussion

Development of gonadal tubules

Individuals of *H. leucospilota* at East Point as well as those from tropical southern Taiwan (Chao et al. 1995) and Vietnam (Nguyen and Britayev 1992), and subtropical Heron reef (Franklin 1980), Hong Kong (OngChe 1990) and La Réunion (Conand et al. 1997), possess a single tuft of gonadal tubules. Intraspecific variations such as those reported in dendrochirote *Cucumaria frondosa* (Hamel and Mercier 1996) due to influences of geographic position and latitudinal difference are unlikely to occur for *H. leucospilota*.

Gonadal tubules of each individual studied developed simultaneously and became fecund at the same period, similar to the same species at subtropical Heron Island (Franklin 1980) and Hong Kong (OngChe 1990). Therefore, growth of new tubules in each reproductive cycle can be expected. Species that have been reported to maintain their after-spawn tubules are *Psolus fabricii* (Hamel et al. 1993) and *Stichopus chloronotus* (Franklin 1980).

The gonadal tubule development observed in *H. leucospilota* did not follow the recruitment model proposed by Smiley (1988) and re-evaluated by Sewell et al. (1997) for other species. Instead of having three groups of tubules that develop subsequently, *H. leucospilota* has only one cohort of tubules that grow concurrently.

The reabsorbtion of gonads in spawned individuals also made this species different to the "tubule recruitment model". Rather than the gonads being present throughout the year as in the model, there was a period on each reproductive cycle in which they were absent. Furthermore, in the model each group of tubules takes more than one year to reach fecundity, while *H. leucospilota* required less than one year. Instead, the pattern of the studied population showed similarities with three species evaluated by Ramofafia and Byrne (2001).

Reproductive cycle

The population of *H. leucospilota* inhabiting tropical Darwin waters exhibited a seasonally reproductive pattern, with a restricted spawning period of only about two weeks. Developing gonads were estimated to reach maturity in less than one year, inclusive of a 1–2 months resting period between cycles. The reproductive periods of most dendrochirote and aspidochirote species tend to be longer for tropical species. *H. leucospilota* in tropical Darwin harbour did not appear to follow this tropical reproductive pattern. Observations in mid March 2001 at East Point reef revealed three anterior males (A individuals) resulting from fission (see stages in Conand et al. 1997) having fecund testicular tubules. This was an indication of the period of maximum sexual reproductive activity, and spawning was expected to occur shortly after. Spawning was estimated to occur around the last two weeks of April, between new and full moon, when rainfall was at a minimum and the reef was flooded during most of the day. Both the strict period of spawning and the long period of time during which the reef was flooded are factors possibly leading to increased chances of oocytes making contact with sperm. In addition, warmer waters due to the dry season following the period of breeding would facilitate larval development.

In comparison, the same species from tropical southern Taiwan breeds every summer (Chao et al. 1995). In subtropical Heron Island, *H. leucospilota* showed a long spawning season from November to March (Franklin 1980). This period was much longer than the suggested maximum period of two weeks in the investigated population. In the northern hemisphere, in Hong Kong (OngChe 1990) gonads of *H. leucospilota* do not develop synchronously, and the gonad index analysis has been applied to estimate the spawning season to be from August to September. This also occurs in a population from tropical southern Vietnam, which exhibited two peaks, the summer spawning (June–August) being not as intensive and synchronised as the spring spawning (February–March) (Nguyen and Britayev 1992).

Interannual variation in the spawning period probably occurs in the population investigated. This may be caused by variations in environmental conditions. Changes in environmental factors may be responsible for interannual variation in various ways. Stimulation of spawning may involve more than one environmental factor (Conand 1993; Hamel and Mercier 1995). Spawning in *Aslia levefrei* is stimulated by high temperature and light intensity, and in *Holothuria scabra* by changes of salinity (OngChe 1985, Krishnaswamy and Krisnan 1967). In *Holothu-*

ria pulla and *H. coluber*, temperature, monsoon, lunar cycle and chemicals produced by males and females are suggested to be important factors for spawning (Bantula-Batoy et al. 1998).

The importance of sexual reproduction on population

Relative importance of sexual reproduction has been questioned in holothurian populations with intensive fission activity. During the 18-month study, juveniles were hardly found among the fissiparous populations of *H. leucospilota*. This suggests that, unless the larvae were washed away, recruitment from sexual reproduction on the habitat may have been unsuccessful. Considering the lack of juveniles on the reef, well developed gonads in individuals of *H. leucospilota* are probably not a guarantee of recruitment from sexual reproduction.

Maturation of gonads in the *H. leucospilota* of East Point took place during a period of intensive asexual reproduction, which occurred from January to April (Purwati 2001). Furthermore, fission seemed to occur regardless of the maturity stage of the individuals, as anterior individuals having fecund testes were observed dividing. It is possible that fission is more significant in population maintenance of *H. leucospilota* of Darwin waters than sexual reproduction. This raises the question: Does intensive fission prevent recruitment following sexual reproduction, or does failure of sexual recruitment generate intensive fission activity?

Acknowledgements

The work reported in this paper formed part of the MSc thesis of the first author. We wish to acknowledge AusAID for its financial support for the research. We would like to express our gratitude to Dr Michael Guinea for excellent scientific suggestions and encouragement. Thanks are addressed to Ms Grey Coupland and Ms Zeehan Jafar for their assistance during the final editing.

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Natural spawning observations of *Pearsonothuria graeffei*

Pradina Purwati[1]

Spawning of *Pearsonothuria graeffei* in its natural habitat was observed during Anambas Expedition 2001. The animals stood up, waving the anterior part of the body slowly, and spilled their gametes into the water column.

Dates and locations: 13 March 2002 on the north-eastern part of Jebung Bay, Jemaja Island (03°15.19'N and 106°13.48'E) and 14 March 2002 on the south western coast of Matak Island (02°52.43'N to 02°54.63'N and 105°50.97'E), Anambas islands, South China Sea.

Depth: down to 32 m

Time of spawning observation: 05:00–06:00 pm

Habitat: reef slope, white sand, a lot of boulders and branching corals (first site); shallow disturbed fringing reef, damage and dead corals (second site).

Other echinoderm on the sites: *Diadema setosum*

***Pearsonothuria graeffei* spawning in the wild**

Natural spawning observation of *Stichopus hermanni*

Aymeric Desurmont[2]

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

Date and time: 12 February 2003, 05:30 pm

Depth: 4 m

Bottom: rocky with small patches of sand and coral

Moon phase: 4 days before full moon

Tide: 1.5 hours after high tide.

Description: One specimen of curryfish (*Stichopus hermanni*), about 50 cm long, was erected on the top of a small rocky pinnacle. It was slowly swaying while releasing dribbles of gametes. No other curryfish was visible in a 15-m radius. Several specimens of other sea cucumber species (*Bohadschia argus, B. vitiensis, Holothuria atra, H. coluber, H. edulis* and *Stichopus chloronotus*) were present in the surroundings, but none was showing signs of reproductive activity. The curryfish kept releasing gametes during the 20 minutes that the observation lasted.

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Correspondence beche-de-mer

January 2003 letter

From: Andrew Bruckner, PhD, Coral Reef Ecologist, Endangered Species Division, Office of Protected Resources, NOAA / National Marine Fisheries Service, 1315 East West Highway, Silver Spring, MD 20910

To: Pr Chantal Conand, Université de la Réunion, Faculté des Sciences, 15 Ave René Cassin, 97715-SAINT-DENIS Cedex, France

Dear Pr Conand

I wanted to follow up with you on the outcome of the sea cucumber proposal developed by the United States. The U.S. presented the Discussion document on sea cucumbers at the CITES Conference of Parties (COP12) this past November in Chile. The U.S. proposal requested that sea cucumber conservation be evaluated (and whether an Appendix II listing for some or all species is appropriate) through the CITES Animals Committee following a technical workshop on sea cucumbers. This effort was supported by most Parties.

The following is the draft decision that came out of the meeting:

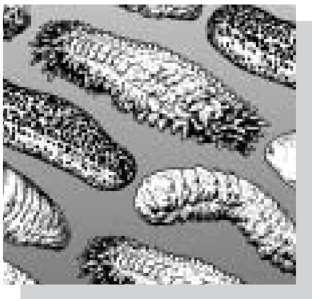
The Secretariat shall:

- assist in obtaining funds from interested Parties, intergovernmental and non-governmental organisations, exporters, importers and other stakeholders, to support a technical workshop of relevant experts on the conservation of sea cucumbers (in the families Holothuridae and Stichopodidae);
- contingent on the availability of external funding, cooperate with other relevant bodies, including the fisheries sector, to convene a technical workshop to consider and review biological and trade information that would assist in establishing conservation priorities and actions to secure the conservation status of sea cucumbers in these families;
- request Parties to provide, for discussion at the technical workshop, all relevant available information concerning the status, catches and bycatches of, and trade in members of the families Stichopodidae and Holothuridae and on any domestic measures for their conservation and protection, and to review the adequacy of such measures.

The Animals Committee shall:

- review, with the assistance of experts as may be needed, the outcomes of the technical workshop convened by the Secretariat and other available information concerning the biology, catch and bycatch of and trade in sea cucumbers (families Stichopodidae and Holothuridae) and develop appropriate recommendations; and
- prepare, for consideration at the 13th meeting of the Conference of the Parties, a discussion paper on the biological and trade status of sea cucumbers in the above families to provide scientific guidance on the actions needed to secure their conservation status.

The draft decisions were supported by the several delegations. The Chairman, noting broad support for the document, announced that the draft decision was agreed.



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

The reproductive biology of the dendrochirote sea cucumber *Cucumaria frondosa* (Echinodermata: Holothuriodea) using new quantitative methods

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

Source: Invertebrate Reproduction and Development (2001) 40:12–14.

Previous studies on the reproductive cycle of echinoderms have used the gonadal index and descriptions of histological preparations of the gonad to determine reproductive state. The size frequency distributions of oocytes are also commonly used to delineate the various phases of the reproductive cycle. These methods, however, do not provide accurate descriptions of the reproductive cycle of the sea cucumber *Cucumaria frondosa* because they do not show a clear single spawning event. In this study, several more quantitative methods were applied and they all point to a single spawning event in the spring. Methods that provided good indications of reproductive condition included a combination of gonad volume fraction and gonad dry weight, measurements of cross-sectional tubule area and tubule wall area. In males, the percentage of tubule area occupied by the haemal fluid and the spermatids / spermatozoa provided good indications of spawning. The increase in haemal fluid immediately after spawning indicates that the haemal system may be involved in delivery or storage of nutrients. Although sea cucumbers exhibit a definite seasonal feeding rhythm, the process of gametogenesis continues even in the non-feeding periods. This indicates the ability of *C. frondosa* to store nutrients for extended periods.

A genetic fingerprint recapture technique for measuring growth in “unmarkable” invertebrates: negative growth in commercially fished holothurians (*Holothuria nobilis*)

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Source: Marine Ecology Progress Series 241:221–226, 2002

A DNA fingerprinting technique based on amplified fragment length polymorphism (AFLP) was developed to identify individual beche-de-mer (*Holothuria nobilis*) and analyse their growth in the wild. A size comparison of 74 individuals over two 6-month periods and of 25 individuals over 12 months showed that 1 kg individuals grew slowly (64 to 128 g annually). Larger holothurians (>1.5 kg) consistently decreased in weight, suggesting a plastic nature of weight in individuals holothurians. This technique holds promise for ecological studies and for providing accurate data for the management of holothurians and other invertebrates that are difficult to tag.

Culture of sea cucumbers in prawn farms - a take off in technology

D.B. James, P.S. Asha, M.K. Ram Mohan and P. Jaigenesh

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Source: James, D.B., Asha, P.S., Ram Mohan, M.K. and Jaigenesh, P. (eds). Proc. Natl. Sem. Devt. Tran. Fish. Tech. pp. 5–7. Organised by Fisheries College and Research Institute, Tuticorin.

The seed of *Holothuria scabra*, commercially the most important sea cucumber, was produced for the first time in the hatchery of Tuticorin Research Centre of CMFRI in 1988. Since then, the seed has been produced at a number of occasions. The juvenile of sea cucumbers produced can be grown in prawn farms since

much of the feed given to the prawns goes as waste and settles down in the bottom of the pond enriching the farm soil. The sea cucumbers being detritus feeders, subsist on the organic matter present in the farm soil. They convert organic wastes into body protein and grow fast. The presence of sea cucumbers on the bottom of the pond in no way affects the activities of the prawns. In fact, the prawns grow faster since the pollution in the farm is reduced and the environment is kept clean. The average increase in weight of the juvenile sea cucumbers per month when grown at other places is only 10 g. Inside the prawn farms, the average increase in weight per month was more than 30 g. All the results regarding growth, mortality and organic content of the soil in the farm are presented in the paper.

Reproduction of the commercial sea cucumber *Holothuria scabra* (Echinodermata: Holothuriodea) in the Solomon Islands

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Source: Marine Biology (2003) 142:281–288.

Over a 3-year period (1996–1998), reproduction of the commercial sea cucumber *Holothuria scabra* (Jaeger, 1833) was investigated in the Solomon Islands to determine the spawning pattern and whether gametogenesis is continuous or seasonal. The gonad consisted of a single cohort of tubules that developed uniformly. Macroscopic examination of the gonads revealed that mature gametes were present throughout the year. Individuals with gonads at different stages of maturity were present in most samples. Partly spawned gonads were prevalent in females, whereas mature gonads were prevalent in males. The time at which the peak gonad index was recorded differed among years. Although gametogenesis was continuous, with a potential for prolonged gamete release, a period of enhanced spawning occurred during the dry season, from September to December. Maximum gonad indices were reached prior to and during this period of enhanced spawning. Histology revealed that gametogenesis reinitiated in partly spawned gonads, resulting in the presence of gametes at different stage of development in the gonad. The uniform growth of gonad tubules indicated that *H. scabra* does not conform to the progressive tubule recruitment model described for holothurian oogenesis. Continuous reproduction in *H. scabra* and prolonged availability of mature gametes would facilitate use of this species for aquaculture.

Reproductive cycle of two commercial species of sea cucumber (Echinodermata: Holothuriodea) from Caribbean Panama

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Source: Marine Biology (2003) 142:271–279

The reproductive status of the holothuroid species *Isostichopus badionotus* (Selenka, 1867) and *Holothuria mexicana* (Ludwig, 1875) was studied over 16 months in Bocas del Toro (Panama), from November 1999 to February 2001. Sexual reproduction was evaluated by the gonad index method, and by histology of gonad development. In addition, population structure was assessed based on sex ratio, minimum reproductive size, and length and weight distributions of males and females. The sex ratio in both species was 1:1, with a unimodal population distribution composed mainly of mature individuals. The minimum reproductive length and weight were 13–20 cm and 150 g, respectively, for both species, although reproductive individuals 10 cm in length were also found. A consistently higher gonad index was observed in *H. mexicana*, due to a high proportion of mature females and males and high gonad indices in most monthly samples. Gametogenesis and spawning patterns seemed to occur throughout the year, with periods of enhanced activity. Two periods of maximum reproductive activity were tentatively identified: July–November for *I. badionotus* and February–July for *H. mexicana*, but neither species had a single, sharply defined annual spawning event. Further work on these exploited holothuroids should examine the relationships between reproduction and environmental factors and between reproductive status and recruitment.

Sexual and asexual reproduction of the holothurian *Stichopus chloronotus* (Echinodermata): a comparison between La Réunion (Indian Ocean) and east Australia (Pacific Ocean)

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Source: Invertebrate Reproduction and Development 41:1–3 (2002) 235–242

Stichopus chloronotus (Brandt, 1835) is one among nine aspidochirotide holothurian species known to reproduce both sexually by broadcast spawning and asexually by transverse fission. New data on the sexual cycle of this species in La Réunion are presented here and information available on sexual and asexual reproduction in this species is summarised. Sexual reproduction on La Réunion shows a distinct seasonality with a main spawning period in the warm season (November–February). The spawning period on the Great Barrier Reef appears to be at the same time. Some intriguing deviations from unity in sex-ratio, usually biased towards more male individuals, have been observed in both geographic regions (sex ratio at La Réunion 31:1). New data on the asexual reproduction of this species in La Réunion confirm the high rates of fission. The peak of asexual reproduction in both the Indian and Pacific Ocean was observed in winter (June–July). Thus, asexual reproduction in this species occurs outside the season for sexual reproduction. The rate of asexual reproduction appears to vary between sample locations. However, results of population genetic studies on *S. chloronotus* (Uthicke et al. 1999; Uthicke et al. 2001) indicated that in most populations investigated a maximum of about 60 per cent of all individuals may be derived from sexual recruitment. Cluster analyses on genetic distances between populations grouped populations within Oceans together, with the exception of one sample from a nearshore reef of the GBR. Although genetic differences between the two regions exist, these are relatively small regarding the large geographic distance. We conclude that asexual reproduction in *S. chloronotus* is important to maintain local population sizes, but that larval exchange between populations mediated by sexual reproduction is important for colonisation of new areas and to provide connectivity between populations. Here, we present the first synthesis of these phenomena for a holothurian species.

Workshops and Meetings

Beche-de-mer workshop held in Torres Strait

A workshop on the biology, management and potential for reseeding of *aber* (beche-de-mer) was held on Thursday Island on 28–29 May 2002. The workshop brought together Torres Strait island community representatives, scientists, fishers, managers, compliance officers, and processors to discuss the current state of the stocks in Torres Strait and future management of the Torres Strait beche-de-mer fishery.

The Torres Strait beche-de-mer fishery began prior to the 1700s, involving Torres Strait and Papua New Guinea communities, as well as Macassan fishers from South Celebes. After a long period of inactivity, the fishery was revived in 1994. The fishery initially targeted sandfish (*Holothuria scabra*). However, since the depletion of the sandfish stocks and the subsequent ban on taking this species, introduced in 1998, fishing effort has mainly focused on surf redfish (*Actinopyga mauritiana*), black teatfish (*H. nobilis*) and white teatfish (*H. fuscogilva*). Fishing for *aber* remains an important income source for many Torres Strait Islanders.

The Torres Strait Protected Zone Joint Authority (PZJA) manages the beche-de-mer fishery in the Australian section of the Torres Strait Protected Zone under the *Torres Strait Fisheries Act 1984,* in accordance with the provisions of the Torres Strait Treaty (1985). In line with the treaty, the PZJA has reserved any increase in *aber* fishing effort exclusively for Torres Strait Islanders. Management arrangements in place to protect this significant fishery include size limits on most of the commercial species, a ban on the use of hookah, vessel length restrictions and total allowable catches (TACs). The Australian Fisheries Management Authority (AFMA) and Queensland Fisheries Service (QFS) take on the administrative roles in managing fisheries under the PZJA.

Objectives of the workshop were:

- To identify and assess alternative approaches to determining scientifically based estimates of a total allowable catch for sandfish, black teatfish, white teatfish and surf redfish.

- To develop an appropriate recovery strategy for the sandfish fishery.
- To assess the effectiveness of existing management arrangements in the Torres Strait beche-de-mer fishery.
- To identify potential impacts on the ecosystem (habitat and other environmental factors) from the harvesting of beche-de-mer and to identify strategies to address such impacts.
- To review existing information on the Torres Strait beche-de-mer fishery and to identify areas where further information is required.
- To identify the prerequisites for a successful restocking program for sandfish and to identify those aspects that would need addressing before a restocking programme might possibly be implemented in the Torres Strait.
- To identify the need and potential for increased compatibility in the management of Torres Strait, east coast and PNG beche-de-mer fisheries.
- To identify strategic research priorities for the beche-de-mer fishery in the Torres Strait.

Some of the recommendations to come out of the workshop included:

- introduce systems to improve data collection;
- gather traditional management knowledge;
- implement a management plan consistent with the objectives of Commonwealth environmental legislation (Environment Protection and Biodiversity Conservation Act 1999), continuing fishery independent surveys and targeted research into important life history parameters;
- investigate criteria and ecological implications for reseeding of sandfish.

There is very little information available to assess the status of the fishery populations. Independent surveys have been the main source of information on the beche-de-mer populations and have been conducted in 1995–1996, 1998, 2000 and 2002. CSIRO scientists, headed by Tim Skewes, conducted the latest survey during a two-week period in May 2002, surveying 424 sites (159 edge and 265 reef top sites) throughout eastern Torres Strait. These surveys were conducted by swimming along a series of transects and counting the *aber* as well as giant clams and lobsters. While the research team successfully completed surveying eastern Torres Strait, they were unable to resurvey the Warrior Reef sandfish population due to bad weather. The resurvey of sandfish will be carried out later in the year.

Workshop participants discussed the preliminary results from the latest survey, which suggested that lollyfish *(H. atra)* are the most abundant species (17% of total weight) in Torres Strait. The overall stock size estimate from the survey is encouraging. Many of the lower valued species appear to be only lightly or completely unexploited at this stage. However, some high value species such as black teatfish and surf redfish appear depleted.

Reviewing the current management arrangements in light of the *Environment Protection and Biodiversity Conservation Amendment (Wildlife Protection) Bill 2001* was one of the key topics throughout the workshop. The majority of the *aber* taken from Torres Strait is exported to markets in Asia. This fishery, like many other Commonwealth managed fisheries, has until 1 December 2003 to be assessed and approved for export by the Commonwealth Minister for the Environment. Fisheries managers, Torres Strait island communities, industry, processors and scientists will need to work together to develop management arrangements that meet the new requirements of this assessment.

AFMA and QFS wish to extend their gratitude to all those who participated in the workshop and those who pitched in with preparations.

Anyone who was unable to attend the meeting, but would like more information about the Torres Strait beche-de-mer fishery, should contact: the Australian Fisheries Management Authority (AFMA), PO Box 376, Thursday Island QLD 4875, Australia; Tel: +61 7 4069 1990; or the Queensland Fisheries Service (QFS), GPO Box 46, Brisbane QLD 4001, Australia; Tel: +61 7 3225 1851.

Echinoderms 2003

The 11th International Echinoderm Conference will be held at the Ludwig-Maximilians-Universität, Munich, Germany, 6–10 October 2003.

More information is given on the website: http://www.iec2003.uni-muenchen.de

Workshop on "Advances in Sea Cucumber Aquaculture and Management"

A workshop on "Advances in Sea Cucumber Aquaculture and Management" is being organised by the Fishery Department of the Food and Agriculture Organization (FAO) for next October in China. The workshop, which aims at gathering experts from different parts of the world, is planned to last for four full days.

Three days would be fully devoted to presentations and discussions aimed at exposing the current status of sea cucumber fisheries, aquaculture advances, resources management and trade and utilisation. One day would allow the invited participants to visit some of the major sea cucumber operations, including hatcheries and on-growing facilities.

The workshop as a whole is still in preparation. For additional information you are invited to contact Mr Alessandro Lovatelli, FAO Fishery Resources Office (Aquaculture) by fax: +39 06 57053020 or by email: Alessandro.Lovatelli@fao.org

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