

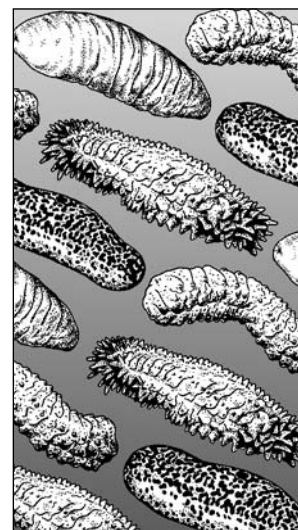


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I N F O R M A T I O N B U L L E T I N



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Editorial

It is a great pleasure to present the 20th issue of the SPC *Beche-de-Mer Information Bulletin*.

In recent months, several important CITES (Convention on the International Trade in Endangered Species) activities related to sea cucumber management have occurred. Following the CITES Technical Workshop in Malaysia, in March 2004, the CITES Animals Committee met in South Africa, in April 2004, and adopted several recommendations. The 13th meeting of the Conference of the Parties will be held in Thailand, in October 2004. Further details can be found in this issue (page 3).

During the workshop on Advances in Sea Cucumber Aquaculture and Management (ASCAM) organised by the Fisheries Department of the Food and Agriculture Organization (FAO), recommendations were formulated and will be used in future collaborations. The proceedings of the ASCAM workshop are published by FAO (see page 38 in the *Abstracts and publications* section).

Given the relative scarcity of direct observations of holothurian juveniles in the wild, Glenn Shiell submitted a questionnaire in issue 19 of this bulletin. He summarises here the information collected so far (p. 6), and hopes that responses will continue to arrive, helping us to better understand this critical life stage.

Culturing several marine species in the same pond at the same time (an activity referred to as "co-culturing") could be an important development path for sea cucumber aquaculture. Rayner Pitt describes his experiences in Vietnam with sandfish (*Holothuria scabra*) and shrimp (*Penaeus monodon*) (p. 12).

The consequences of fission on population densities and biomasses of *Holothuria atra* have been further studied on Reunion Island by Chantal Conand (p. 22).

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Pradina Purvati has studied fissiparity in *Holothuria leucospilota* from tropical northern Australian waters (p. 26).

For his Bachelor's degree in agribusiness (aquaculture), Tim Lo studied the valuation of sea cucumber attributes through laddering. His findings are presented on p. 34.

We continue to publish data on sea cucumber spawning observations in the wild (p. 37), following the questionnaire we submitted in 1992 to the bulletin's readers (see issue #4 of this bulletin).

Chantal Conand

PS: The SPC Information Section, producer of this bulletin, has just released a new set of "Pacific Island sea cucumber and beche-de-mer identification cards" on the same model that was used in 2003 for Papua New Guinea (see article by Aymeric Desurmont in issue #18 of this bulletin). For more information on this new publication please contact the SPC Information Section at: cfpinfo@spc.int (or see mailing address and telephone and fax numbers on cover page of this bulletin).

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Echinoderms on Internet

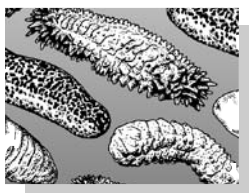
English and French versions of all previous issues of this bulletin are available on SPC's website at:
<http://www.spc.org.nc/coastfish/>

The last issue of the *Virtual Echinoderms Newsletter* is available at:
<http://www.nmnh.si.edu/iz/echinoderm>

A new echinoderm portal is maintained by Sabine Stohr from the Swedish Museum of Natural History:
<http://www.nrm.se/ev/echinoderms/echinoportal.html.en>

A brief summary of information concerning sea cucumber farming has been posted
on the SPC aquaculture portal at:
http://www.spc.int/aquaculture/site/commodities/sea_cucumber.asp?

A short list of websites related to Holothuroidea is given on the Serebella website at:
<http://www.serebella.com/directory/Science/Biology/FloraandFauna/Animalia/Echinodermata/Holothuroidea/>



new info beche-de-mer

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES): Conservation and trade in sea cucumbers

Chantal Conand¹

Introduction

Sea cucumbers are of increasing global interest. Following the FAO ASCAM workshop in China in 2003 (see SPC *Beche-de-Mer Bulletin* #19 and in this issue, Lovatelli et al. 2004), a number of conservation issues have been raised and the role of CITES has been discussed (Bruckner et al. 2003).

The issue of sea cucumber trade and conservation was first brought to the attention of CITES in 2002 through a discussion paper submitted at the 12th meeting of the Conference of the Parties in December 2002 (see document CoP12 Doc. 45 on the CITES Secretariat website at <http://www.cites.org>). CITES Parties adopted a decision stating that the CITES Secretariat should convene a technical workshop on the matter. Parties also instructed the CITES Animals Committee (a scientific advisory body) to review its outcomes and formulate follow-up recommendations.

CITES Technical Workshop

The technical workshop on the conservation of sea cucumbers in the families Holothuridae and Stichopodidae occurred in Malaysia in March 2004. It was attended by about 40 experts and representatives from exporting and importing countries, private industry, IGOs and NGOs. The workshop was supported by the USA, and was organised by the Department of Fisheries of Malaysia and TRAFIC Southeast Asia.

Objectives

The workshop objectives, as proposed by the CITES Secretariat, were to:

- 1) review information on the status, catch, bycatch and trade in specimens of sea cucumbers within the families Holothuridae and Stichopodidae,

and on domestic measures for their conservation, including considerations of the adequacy of these measures;

- 2) establish conservation priorities and actions to secure the conservation status of sea cucumbers within the families Holothuridae and Stichopodidae, addressing *inter alia* trade monitoring and controls, national legislation and regulations, fisheries management options, conservation management and research, enforcement and capacity building;
- 3) consider and review biological and trade information, and to assist in establishing conservation priorities and actions to secure their conservation status. The workshop considers species that are currently not listed under CITES, but for which CITES offers an important forum to address their conservation, management and regulatory needs.

During two initial workshop sessions, general background documents were presented on:

- 1) sea cucumber biology (including taxonomy, distribution, conservation status) (Conand 2004a),
- 2) utilisation and trade in sea cucumbers (including sea cucumber fisheries, levels of current international trade, illegal, unreported and unregulated trade, bycatch, socioeconomic characteristics) (Conand 2004b),
- 3) fisheries management and conservation (including management options and practices (Bruckner 2004), and
- 4) CITES and CITES listings (Sant 2004).

These general presentations were followed by country status reports.

In the final two workshop sessions, three working groups were established to address specific questions concerning national fisheries management,

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priorities for international conservation and protection, and potential CITES implementation issues (the terms of reference of the three working groups are found on the CITES website). Working group findings and recommendations were presented and commented upon in plenary.

Output and recommendations

Findings and recommendations (detailed on the CITES webpage <http://www.cites.org>) concern three main topics.

- 1) National fisheries management

General and specific recommendations concerning national fisheries measures for conservation and management of sea cucumbers in the families Holothuridae and Stichopodidae.
- 2) Priorities for international conservation and protection
 - a) General findings on international measures for conservation and management of sea cucumbers in the families Holothuridae and Stichopodidae,
 - b) Biogeographical “hot spots” for sea cucumbers in the families Holothuridae and Stichopodidae,
 - c) Taxa of conservation concern, and
 - d) International measures to enhance conservation and management of sea cucumbers in the families Holothuridae and Stichopodidae.
- 3) Potential CITES implementation issues
 - a) Evaluation of the benefits and constraints of including species of sea cucumbers in the families Holothuridae and Stichopodidae in the Appendices of CITES,
 - b) Recommendations for further CITES activities concerning the management and conservation of sea cucumbers in the families Holothuridae and Stichopodidae, and
 - c) Measures that States should consider in case

species of sea cucumbers are included in Appendices II or III.

Workshop participants also endorsed and built upon the recommendations made at the FAO ASCAM workshop. The findings and recommendations of the technical workshop on the conservation of sea cucumbers in the families Holothuridae and Stichopodidae should therefore be interpreted and applied in conjunction with the outcomes of the ASCAM workshop.

CITES Animals Committee meeting

The Animals Committee has been directed to review, with the assistance of experts as may be needed, workshop outcomes and other available information concerning the biology, catch and bycatch and trade in sea cucumbers in the families Holothuridae and Stichopodidae, and to develop appropriate recommendations. The Committee will also prepare, for consideration at the 13th meeting of the Conference of the Parties (Bangkok, 3–15 October 2004), a discussion paper on the biological and trade status of these sea cucumbers to provide scientific guidance on the actions needed to secure their conservation status.

The summary of the discussions and recommendations is detailed on CITES webpage under AC20 WG7 Doc 1 (<http://www.cites.org/common/cttee/ac/20/WG/E20-WG07-01.pdf>). It was suggested that conservation and sustainable use of sea cucumbers might also be achieved through CITES coordination with FAO and with regional fisheries management bodies.

The committee however agreed that further CITES considerations for certain countries or species should be examined in the future and the effects assessed. In this regard, the Animals Committee pro-



Participants to the Technical Workshop
(Picture: Pourkazemi)

poses the adoption of several recommendations that are directed to Parties, the CITES Secretariat and the Animals Committee (Doc 37.1 at: <http://www.cites.org/eng/cop/13/docs/index.shtml>).

Recommendations to Parties

Parties should endorse the recommendations formulated at the FAO Advances in Sea Cucumber Aquaculture and Management Workshop (Lovatelli et al. 2004) and should urge their fisheries agencies to:

- 1) conduct research on sea cucumber biology, fisheries and trade,
- 2) conduct research to resolve taxonomy and identification difficulties concerning sea cucumbers,
- 3) monitor the status and trends of sea cucumber stocks,
- 4) consult with the fishing industry and other stakeholders in the development and adoption of voluntary conservation guidelines for sea cucumbers, and
- 5) establish national management plans for sea cucumbers, and regional cooperation in management and conservation of sea cucumbers, particularly for acquisition and sharing of fisheries and trade data.

Parties should urge their CITES Scientific and Management Authorities to improve coordination with their fisheries management agencies on monitoring, assessment, and management of sea cucumber fisheries and the trade.

Recommendations to the CITES Secretariat

In coordination with the Animals Committee, the CITES Secretariat shall encourage FAO to continue and, as far as possible, increase its efforts to address the challenges of managing sea cucumber fisheries for sustainability, as identified in the FAO Advances in Sea Cucumber Aquaculture and Management Workshop (Lovatelli et al. 2004) and the CITES Technical Workshop on the Conservation of Sea Cucumbers in the Families Holothuridae and Stichopodidae (Kuala Lumpur, 2004).

The CITES Secretariat shall, in consultation with FAO:

- 1) collate information on and evaluate voluntary measures taken by countries to monitor the sea cucumber trade,
- 2) where appropriate, control sea cucumber exports, and
- 3) make recommendations as appropriate, for instance at meetings of the FAO Subcommittee on Fish Trade or the FAO Committee on Fisheries.

In consultation with the FAO Secretariat, and in evaluating actions taken by the Parties to manage and conserve sea cucumber populations, the CITES Secretariat shall consider the necessity of a follow-

up workshop on sea cucumber biology, fisheries, trade, management and conservation prior to the 14th meeting of the Conference of the Parties, and take action accordingly.

Recommendations to the Animals Committee

In consultation with FAO and the CITES Secretariat, the Animals Committee shall: 1) review the recommendations of the FAO Advances in Sea Cucumber Aquaculture and Management Workshop (Lovatelli et al. 2004) and of the CITES Technical Workshop (Kuala Lumpur, 2004), and 2) formulate advice on the proposed recommendations, and communicate its findings to FAO and the CITES Secretariat for follow-up as appropriate. The findings should also be considered at a further CITES workshop on sea cucumbers in the event that such a workshop is organised prior to the 14th meeting of the Conference of the Parties. The Animals Committee may monitor the implementation of the decisions relating to the conservation of and trade in sea cucumbers, and report on progress at the 14th meeting of the Conference of the Parties as appropriate.

The 13th meeting of the Conference of the Parties will be held in Bangkok between 3 and 15 October 2004.

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Field observations of juvenile sea cucumbers

Glenn Shiell¹

Introduction

Recent advances in tropical sea cucumber mariculture have created scope for the rehabilitation of populations affected by overfishing through the production and release of hatchery-raised juveniles. Although the necessary technology required to implement rehabilitation programmes is progressing rapidly (Purcell 2004), there is some speculation as to the viability of such programmes, given major shortfalls in knowledge of important aspects of sea cucumber biology. (For a full review see Bell and Nash 2004.) One area of sea cucumber biology identified as being important to the ultimate success of rehabilitation programmes is a clear understanding of the habitat and ecological requirements of juvenile sea cucumbers (Wiedemeyer 1994; Mercier et al. 1999; Purcell 2004). An understanding of juvenile habitat preferences may help scientists to determine accurately the ultimate carrying capacity of a given sea cucumber habitat (while acknowledging the space occupied by juveniles) and additionally, enable the eventual release of juveniles to appropriate habitats with enhanced probability of survival (Bell and Nash 2004; Purcell 2004).

Much of the existing literature on juvenile holothurian biology has focused on observations or studies of hatchery-raised juveniles, particularly in the context of growth and mortality under laboratory or aquaculture conditions (e.g. Battaglione 1999; Battaglione and Seymore 1998; Battaglione et al. 1999; Engstrom 1980; Hamano et al. 1996; Hamel et al. 2003; Hatanaka 1996; Hatanaka et al. 1994; Ito et al. 1994; James et al. 1994; Kobayashi and Ishida 1984; Mercier et al. 1999, 2000a; Tanaka 2000). However, several authors have also made contributions to the understanding of juvenile biology based on studies of juveniles that were either captured or observed *in situ* (e.g. Cameron and Fankboner 1989; Daud et al. 1993; Hamel and Mercier 1996; Mercier et al. 2000b; Muliani 1993; Purcell 2004; Purcell et al. 2002; Ramofafia et al. 1997; Tiensongrussmee and Pontjoprawiro 1988; Wiedemeyer 1994; Young and Chia 1982). Additionally, observations of juvenile *Holothuria scabra* are reported from a variety of sources (Conand 1997; Gravely 1927; James 1976, 1983; Lokani et al. 1995; Long and Skewes 1997; Shelley 1985).

The relative scarcity of knowledge obtained through direct observation of field based juvenile sea cucumbers is due possibly to two problems. The first, as reported by Wiedemeyer (1994), is that the calcareous spicule arrangement in juveniles could be different to that of adults. Hence, the identification of juveniles based on keys developed for adults may lead to misidentification. Second, and perhaps most importantly, juveniles are very rarely encountered in sufficient numbers for study, if at all. The fact that small juvenile sea cucumbers are rarely encountered in the field (Seeto 1994) may be due to a number of scenarios. Juvenile holothurians have the potential to be misidentified given their potential for morphological differences relative to the adult forms (Wiedemeyer 1994); they occupy habitats different to that of larger specimens (James et al. 1994; Lokani et al. 1996), and finally, they exist in the habitat occupied by the adult form but are obscured from view within sediments or crevices or beneath obscuring objects such as coral (Cameron and Fankboner 1989; Wiedemeyer 1994).

The difficulty in locating juvenile sea cucumbers is perhaps highlighted by the fact that studies relevant to juvenile ecology often result from fortuitous encounters (Conand 1983; Mercier et al. 1999). For example, juvenile *Actinopyga echinites* used in Wiedemeyer's study (1994) were found on the upper reef zone following a strong typhoon. For this reason, and because juvenile sea cucumbers are rarely observed in large numbers, it seemed appropriate and useful to begin consolidating anecdotal observations of juveniles made in the field. This exercise may help to identify differences in habitat preferences between juveniles on the inter-species level and, additionally, between adults and juveniles of the same species. Also, by consolidating these observations, it may be possible to discern future research directions to clarify some of the details of this little known but important life phase.

Response to the questionnaire included in SPC's Beche-de-Mer Information Bulletin #19

Questionnaires on observations of holothurian spawning and fission have been published previously in SPC's *Beche-de-Mer Information Bulletin*. Following the success of these, a new questionnaire

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aimed at consolidating anecdotal observations of juvenile sea cucumbers in the field, was included in issue #19 (p. 41). Many questionnaire respondents provided observations of juveniles ranging between 0.3 and 21.0 cm in length. Given the inter-species variability in size at first maturity among holothurians, all of the observations were retained in the final results. Twenty-six responses to the questionnaire have been received at the time of writing.

Results and discussion

The results to date (Table 1) are organised under the following sub-headings: species observed, corresponding observed habitat, date and time of observation, proximity of adults in relation to observed juvenile(s) and the name and affiliation of the observer.

Results presented in Table 1 indicate a broad range of habitat preferences among juvenile holothurians. In most cases, juvenile holothurians were observed within close proximity to adult holothurians of the same species. These observations included representatives of the following genera: *Stichopus* (2 species), *Actinopyga* (3 species), *Isostichopus* (2 species), *Astichopus*, *Thelenota*, *Cucumaria*, *Chiridota*, and *Psolus* (1 species each). Habitat preferences of juvenile *Holothuria* spp. varied, but in most cases, juveniles of this genus were also observed in the presence of adults (e.g. *H. scabra*, *H. leucospilota*, *H. mexicana*, *H. atra* and in some instances, *H. nobilis*). Concurrent occupation of similar habitat between both juvenile and adult *H. scabra* was reported by Mercier et al. (1999, 2000b) who found newly settled and smaller juveniles in the same general area as adults. Both Cameron and Fankboner (1989) and Young and Chia (1982) provide similar evidence, where *Parastichopus californicus* and *Psolus chitonoides* juveniles were also regularly observed within habitats occupied by the adult form. Although it seems common for juveniles and adults to occupy habitats simultaneously, there is evidence that most small juveniles retain some degree of cryptic behaviour that appears to diminish with size. Therefore, it is likely that juveniles may be obscured from view even when present in large numbers within an adult habitat. For example, *Isostichopus fuscus* juveniles (< 6 cm) maintained in aquaculture ponds remain hidden in the rocky substrate during the day, but begin to emerge following nightfall; larger specimens of the same species were otherwise visible throughout the day (Mr Roberto Ycaza, pers. comm.). Similarly, *Cucumaria frondosa* and *Actinopyga echinites* juveniles displayed a progressive tendency to leave protected locations within the substrate as they grew larger (Hamel and Mercier 1996, Wiedemeyer 1994).

Smaller specimens of *H. scabra* (> 10–40 mm) are also reported to remain hidden for the majority of daylight hours. Larger *H. scabra* juveniles (> 40–140 mm) emerged from sediments in the middle of the day at around 13:30 hours (Mercier et al. 1999).

Additional results presented in Table 1 indicate a preference for juveniles of selected species to occupy habitats slightly different to those of adults. In these cases, juvenile *Holothuria fuscogilva* and *H. nobilis* were located in shallower water adjacent to the deeper water habitats occupied by adults (Conand 1981). A similar phenomenon was reported in *Cucumaria frondosa* (Hamel and Mercier 1996) that were observed to undergo a process of progressive migration from shallower protected reef areas to deeper more exposed sandy areas as they matured sexually. The reported observation of *H. fuscogilva* juveniles (Table 1) in very shallow water is suggestive of a similar pattern of migration in this species. Evidence for this notion was more recently provided by Ramofafia et al. (2000) who obtained sexually mature individuals of *H. fuscogilva* in water between 25 and 30 m depth. Size related migration from shallow water to deep water has also been reported in *Stichopus variegatus* (now *S. hermanni*) (Conand 1993).

Conclusions

From the observations provided in Table 1 and the additional evidence provided in the literature, it seems reasonable to conclude that juvenile holothurians display some degree of cryptic behaviour in the earliest stages of their life cycle following settlement. Cryptic behaviour most likely continues until juveniles are large enough to avoid most forms of predation (Cameron and Fankboner 1989). Further migration and hence greater habitat separation between juveniles and adults of some species may then occur as holothurians mature (Hamel and Mercier 1996), but the degree to which this process is common among all holothurians remains unclear.

An additional observation is that juvenile and adult sea cucumber habitat preferences consistently appear to differ at some level of scale. For example, although *H. scabra* juveniles and adults have been observed in the same general area, clear differences in habitat preferences at the microhabitat level have been identified (Mercier et al. 2000b). Microhabitat requirements of juvenile holothurians are likely to vary both between stages of development and between species. To further develop viable restocking programmes using hatchery-raised juveniles, it would be desirable to investigate microhabitat requirements in more detail. Specifically, future research direc-

Table 1. *In situ* observations of juvenile holothurians.

Species observed	Approx. size and number	Location	Habitat	Time	Date	Adults present?	Observers' name(s) and affiliation / Source of further information
<i>Astichopus multifidus</i>	8–21 cm	North at Isla de la Juventud	Seagrass	15:40	April 2002		Irma Alfonso Hernández, María del Pilar Frías; Fishery Research Centre of Cuba
<i>Actinopyga agassizii</i>	5–18 cm	North central region of Cuba	Seagrass	14:30	May 2001	Yes	Irma Alfonso Hernández, María del Pilar Frías; Fishery Research Centre of Cuba
<i>A. mauritiana</i>	2–3 cm	Unia Reef, New Caledonia	Reef flat	Daytime	1989	Yes	Chantal Conand; Université de La Réunion
<i>A. echinites</i>	4 cm	Ricaudy Reef, New Caledonia	Coral rubble	Daytime	Sept. 1981	Yes	Chantal Conand; Université de La Réunion (unpub. photo available)
<i>Chiridota laevis</i>	0.3–1 cm	Bic Provincial Park (Quebec), Canada	At low tide below the rocks on sand flat		Summer 1994	Yes	J.-F. Hamel & A. Mercier; Society for the Exploration & Valuing of the Environment, Canada
<i>Cucumaria frondosa</i>	1–3 cm	Passamaquoddy Bay, New Brunswick, Canada.	Within tide pools near the lowest tide mark; below rocks and in crevices		Summer 2000	Yes	J.-F. Hamel & A. Mercier; Society for the Exploration & Valuing of the Environment, Canada
<i>Holothuria mexicana</i>	5–18 cm	Pingües Channel, south eastern region of Cuba, Baie des Baraderes, Haiti'	Sand	11:20 and 14:25	May 2000 July 2001	No	Irma Alfonso Hernández, María del Pilar Frías; Fishery Research Centre of Cuba
<i>H. leucospilota</i>	1–5 cm	Guadalcanal, Solomon Islands	At low tide on reef flat; below rocks and in crevices		1998	Yes	J.-F. Hamel & A. Mercier; Society for the Exploration & Valuing of the Environment, Canada
<i>H. scabra</i>	1–5 cm	Ambandjoa, Madagascar	Muddy intertidal	Daytime	1997	Nearby, but in deeper water	Chantal Conand - Photo published in: Conand, C. 1999. Manuel de qualité des holothuries commerciales du Sud-Quest de l'Océan Indien. Commission Océan Indien: 39 p.
<i>H. scabra</i>	≈ 8 cm (1 individual)	Crab Island, Moreton Bay, Queensland.	Seagrass / algae Shallow water	Daytime	2002	Yes, within 50 m	Grant Leeworthy; Tasmanian Seafoods, Australia
<i>H. scabra</i>	10 cm long, 2 cm in diameter	Pouangué, Northern Province, New Caledonia	Seagrass on a muddy inshore reef flat (shallow water)	About 15:00 Low tide, when little water present on reef	Oct. 2002	Yes, same habitat, but juveniles generally burrowed in mud, adults foraging on surface	Steve Purcell; WorldFish Center, New Caledonia
<i>H. fucogilva</i>	1–5 cm	Fiji barrier reef	<i>Halimeda</i> field, very shallow water	Daytime	1979	Yes, nearby, but deeper on coral reefs	Chantal Conand; Université de La Réunion Photo published in Bull. Mar. Sci. 1981 31(3):523–543
<i>H. nobilis</i>	5 cm, colour different from adults, cream patches on black background	Fiji barrier reef and New Caledonia	Seagrass bed, shallow water	Daytime	1979	Yes, nearby, but deeper on coral reefs	Chantal Conand; Université de La Réunion Photo published in Bull. Mar. Sci. 1981 31(3):523–543
<i>H. nobilis</i>	14–21 cm (300–625 g), colour different from adults, 3 specimens	Raine Island, Great Barrier Reef, Queensland, Australia	Seagrass bed, shallow water	Daytime	Dec. 2003	Yes	Sven Uthicke; AIMS, Townsville Australia
<i>H. nobilis</i>	12 cm (estimated), colour different from adults, 3 specimens	Michaelmas Reef, Great Barrier Reef, Queensland, Australia	Shallow water; lagoonal reef area	Daytime	Mar. 2004	Yes	Sven Uthicke; AIMS, Townsville Australia
<i>H. atra</i>	2–3 cm (a few specimens)	Îlot Maitre reef flat, New Caledonia; Planch' Alizés, La Réunion	Coral rubble			Yes	Chantal Conand; Université de La Réunion
<i>H. atra</i>	1–4 cm	Likiep Atoll, Marshall Islands	At low tide on reef flat; in crevices		May 2001	Yes	J.-F. Hamel & A. Mercier; Society for the Exploration & Valuing of the Environment, Canada

Table 1 (continued). *In situ* observations of juvenile holothurians.

Species observed	Approx. size and number	Location	Habitat	Time	Date	Adults present?	Observers name and affiliation / Source of further information
<i>Holothuria atra</i>	1–4 cm	Likiep Atoll, Marshall Islands	At low tide on reef flat; in crevices		May 2001	Yes	J.-F. Hamel and A. Mercier; Society for the Exploration & Valuing of the Environment, Canada
<i>Isostichopus fuscus</i>	1–3 cm	Along the coast of mainland Ecuador	Between 5 and 10 m water depth	Autumn 2000.		Yes	J.-F. Hamel and A. Mercier; Society for the Exploration & Valuing of the Environment, Canada
<i>Isostichopus badiionotus</i>	5–14 cm	North at Isla de la Juventud, Banes Bay, northern region of Cuba; Pilón Inlet, south eastern region of Cuba; Baie des Baraderes, Haïti	Seagrass	Various daylight hours	April to Nov. 2002	Yes	Irma Alfonso Hernández, María del Pilar Frías; Fishery Research Centre of Cuba
<i>Psolus fabricii</i>	0.5–3 cm	Les Escoumins (Quebec), Canada	3–10 m depth; below rocks and in crevices		Summer 1991	Yes	J.-F. Hamel and A. Mercier; Society for the Exploration & Valuing of the Environment, Canada
<i>Stichopus hermanni</i>	9 cm	Sainte Marie Bay, New Caledonia	Seagrass		Sept. 1981	Yes	Chantal Conand; Université de La Réunion. For more information see: Bull. Mar. Sci. 52(3):970–981
<i>S. chloronotus</i>	3–4 cm (two specimens)	Coral Bay, Ningaloo Reef, Western Australia	Reef flat near crevice	Daytime, afternoon	Aug. 2003	Yes	Glenn Shiell; University of Western Australia
<i>S. chloronotus</i>	2–3 cm (very rare, observed only 3–5 in a 2-year field study at that site)	Great Palm Island, Great Barrier Reef, Queensland, Australia	On <i>Sargassum</i>	Daytime		Yes, dense populations	Sven Uthicke; AIMS, Townsville Australia
<i>S. chloronotus</i>	2–3 cm	Several Reunion Island reefs	Rubble and sand	Daytime		Yes	For more information see: Conand C., Uthicke S. and Hoareau T. 2002. Invert. Reprod. Develop. 41 (1–3):235–242
<i>Thelenota ananas</i>	12 cm	Uitoe Pass, New Caledonia	Coral		1981	Yes	Chantal Conand Photo available in: Bull. Mar. Sci. 1981 31 (3):523–543

tions may investigate the extent to which microhabitat selection at different stages of development are influenced by variables such as settlement, predation and feeding, or at later stages of development, spawning and reproduction.

The observations presented in Table 1 help to consolidate the information relevant to habitat preferences of juvenile holothurians. Based on the observations presented in this review, many juvenile holothurians appear to be present within the same broadly defined habitats as those of the adult form.

However, the significance and extent of this relationship relative to conflicting evidence of size related distribution and migration among certain juvenile holothurian species requires further and more detailed investigation.

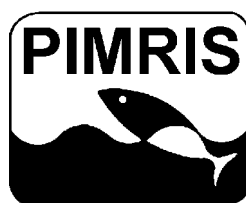
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the availability of information on marine resources to users in the region, so as to support their rational development and management. PIMRIS activities include: the active collection, cataloguing and archiving of technical documents, especially ephemera ('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.

Sandfish (*Holothuria scabra*) with shrimp (*Penaeus monodon*) co-culture tank trials

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Abstract

Seven tank trials were undertaken involving the co-culture of sandfish and shrimp on sand. Sizes, stocking densities, feeding and other conditions were all varied. Results indicated that powdered sargassum did not support sandfish growth, although it may have prevented starvation, which otherwise killed juveniles within three to six weeks. Sandfish grew well on commercial shrimp starter feed, reaching densities of 300 g m⁻² or more, but feeding rates much above 1 g total dry weight m⁻² day⁻¹ could lead to anaerobic benthic conditions and sandfish mortalities. Growth was better with higher, rather than lower, water exchange rates. Semi-opaque covers slightly reduced sandfish growth, although appearing to increase survival of small shrimp.

Sandfish were never seen to have a negative impact on shrimp growth or survival. The effect of shrimp on sandfish, however, was more complex. Survival and growth of sandfish were often as good with shrimp as without, and sometimes apparently better. This may be because shrimp improved the benthic conditions by eating excess food, or for other (unknown) reasons. In several trials, however, it seemed that shrimp caused the deaths of sandfish, and in some cases, it was clear that they did so. A range of sizes for which predation did or did not occur is shown.

Introduction

A major objective of the sea cucumber rearing project (2000–2003) of the WorldFish Center (previously ICLARM) and the Vietnam Ministry of Fisheries at RIA3 (Research Institute for Aquaculture no 3), was to look at ways to combine the culture of sandfish (*Holothuria scabra*) with that of shrimp (*Penaeus monodon*). Farming *P. monodon* is an important activity in Khanh Hoa Province, which has over a thousand hatcheries and many areas of sea and brackish-water ponds. As elsewhere in the world, disease problems make shrimp aquaculture a high-risk business in which big profits or big losses can be made. Many ponds stand empty at least part of the time, and farmers look for additional or alternative culture systems and species.

Empty ponds, particularly those in areas of generally high salinity (which many farmers believe are less favourable for shrimp), represent a potential resource that could be used for culturing sandfish (either by itself or in conjunction with shrimp). This approach could lead to either commercial hatchery-based sea cucumber farming or large-scale restocking of overfished sea areas.

Co-culturing is a particularly interesting proposition. By providing an extra crop with few extra costs (apart from the juveniles themselves and in particular using no additional feed), sandfish

might make shrimp culture at lower densities more economically attractive. This could help reduce the environmental impact of shrimp farming. Sandfish would live off benthic organic material, and should therefore also clean the pond floors to some extent.

Seven tank trials, examining the co-culture of sandfish and shrimp, are summarised in this report, in chronological order. With the exception of trial C, trials are of the second nursery phase, using sandfish juveniles bred in the project hatchery. These juveniles passed through the first nursery phase in bare outdoor tanks. In these trials they were put on a sand substrate. Sand came initially from a reasonably clean beach source, but was not cleaned during the course of the trials. (Some tank and also pond trials were carried out by RIA3 scientists under a separate DANIDA-funded project, usually with juveniles from the same hatchery and nursery. These are not described here.)

Presentation of the different trials

Trial A: Two stocking densities, with and without shrimp and shrimp feed, and with and without seaweed powder

Eight fibreglass tanks (1.5 m diameter with water depth 65 cm — 1.76 m² floor area and 1.15 m³ volume) were installed outdoors in two adjacent rows (numbered 1, 3, 5, 7 and 2, 4, 6, 8). Tanks were cov-

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ered with a single layer of 60% shade netting. Fine washed beach sand (30 L) was put in each tank, covering the floor to a depth of about 17 mm. Double sand-filtered seawater was supplied via 2 mm nozzles so that flows in all tanks were within 15% of each other even with varying supply pressure. Water generally flowed for 8–12 daylight hours, with a mean exchange rate of about 300–400 L tank⁻¹ day⁻¹ (i.e. about one third of the tank volumes). Tank water temperature, measured only occasionally, was usually between 29 and 31°C.

On 31 May 2001, the eight tanks were stocked with small sandfish, averaging 0.94 g using matched groups of 36 (low density) or 72 (high density) animals per tank (20 or 40 m² of tank floor). Four of the tanks were also stocked with 80 postlarval shrimp per tank. Sandfish were weighed after about five minutes of shade drying after 20 and 39 days. Shrimp were sampled after 20 days, and fully harvested and weighed after 39 days.

All four tanks with shrimp were fed with Betagro 501S juvenile shrimp feed, generally given in three equal amounts per day. After an initial overfeeding error in the first two days, feeding rates were cut back and then gradually increased over the course of the experiment as animals grew. Over the first period, feedings averaged 1.5 g tank⁻¹ day⁻¹ (0.9 g m⁻²), and over the second period 2.4 g tank⁻¹ day⁻¹ (1.4 g m⁻²). Four tanks (two with shrimp and two without) were also fed every second day with a finely ground

powder made from dried seaweed, mostly sargassum: those with sandfish stocked at low density received 1.7 g every two days for the first period and 4.6 g every two days for the second, while those with sandfish at high density were fed at twice this rate. Finally, sandfish in two of the tanks with no shrimp received no feed at all.

Conclusions from trial A

1. Rapid sandfish growth occurred only in tanks with shrimp and shrimp food. Growth continued with sandfish biomass reaching densities of over 300 g m⁻². In these tanks powdered seaweed had little effect.
2. In the two tanks with no food, most sandfish died during the second period. In other tanks, sandfish survival rates averaged almost 94%.
3. Seaweed alone may have helped keep sandfish alive, but did not support good growth.
4. Low sandfish stocking densities generally gave better individual growth rates than high stocking densities.
5. Shrimp survival rates averaged better than 60% from postlarvae to above 0.4 g average weight.

Trial B: With shrimp food, with and without shrimp, with and without *Gracillaria* and chicken manure

Eight 1.5 m diameter tanks were set up as in trial A, although with slightly less sand in each (24 L). On 11 July 2001, tanks were stocked with matched groups of 36 juveniles, averaging 0.83 g per tank (20 m² of

Table 1. Treatments and results of trial A

tank		1	2	3	4	5	6	7	8
treatment	sandfish density	high	low	low	high	high	low	low	high
	shrimp + feed	yes	no	yes	no	no	yes	no	yes
	weed	high	low	no	no	high	low	no	no
20 June									
sandfish	number	71	35	35	64	73	34	36	68
	average wt. (g)	5.6	1.8	7.3	0.7	1.1	5.4	1.2	3.7
	density (g m ⁻²)	227	36	144	27	46	103	25	143
	growth rate (g day ⁻¹)	0.24	0.04	0.32	-0.01	0.01	0.22	0.01	0.14
shrimp	average wt. (g)	0.12		0.09			0.10		0.11
10 July									
sandfish	number	61	36	35	6	70	32	16	66
	average wt. (g)	9.9	4.0	16.0	2.0	1.7	17.2	1.6	10.7
	density (g m ⁻²)	342	81	317	7	67	311	14	401
	growth rate (g day ⁻¹)	0.21	0.11	0.44	0.06	0.03	0.59	0.02	0.35
	survival (%)	86	103	100	9	96	94	44	97
shrimp	number	48		33			58		54
	average wt. (g)	0.41		0.48			0.41		0.43
	survival (%)	60		41			73		68

tank floor). Half the tanks were also stocked with 80 postlarvae shrimp in each (about 45 m²).

All tanks, including those without shrimp, were fed with Betagro 501S juvenile shrimp feed, generally given in three equal amounts per day. Half the tanks were also fed every second day with fresh chopped and blended *Gracillaria* plus ground and blended (dried) chicken manure. There were, thus, four different feeding treatments, each with two replicates. Feeding rates were gradually increased with time (Table 2). After 22 days all sandfish and samples of shrimp from each tank were weighed. After a further 18 days, the remaining animals were counted and weighed (except, unfortunately, for shrimp from tank 1, which were only sampled).

Shrimp grew well, with survival rates of 59–95% in the three tanks where they were counted. There were heavy sandfish mortalities, however, during the second period in most tanks, with black and smelly sand. Sandfish survival was good only in

the two tanks with shrimp and without *Gracillaria* or manure.

The experiment apparently failed in the second period because feeding rates were too high, with all tanks receiving shrimp food at 1.36 g m⁻² day⁻¹ for the last 16 days. This was made worse in tanks that also received large amounts of *Gracillaria* and manure.

Conclusions from trial B

1. Feeding rates of shrimp food appear to have been too high (1.36 g m⁻² day⁻¹) in the second period. The problem was exacerbated in tanks also receiving *Gracillaria* and manure.
2. Sandfish are more vulnerable to foul benthic conditions than are shrimp.
3. The main beneficial effect of shrimp on sandfish was probably just to consume the excess food.

Trial C: Large sandfish with and without shrimp, with shrimp feed, and with seaweed

This experiment was set up to take a preliminary look at interactions between large sandfish (of wild origin) and shrimp, as might occur during growout in ponds.

It was thought that the presence of shrimp might be of direct benefit to sandfish, with, perhaps, shrimp faeces providing a better food source than shrimp feed. On the other hand, large shrimp were seen sitting on large sandfish, and it was feared that the shrimp might damage sandfish skin or prevent wounds from healing.

Five, 6 m³ outdoor concrete tanks were used. Tank floors were covered with washed beach sand to a depth of about 10 mm in all except tank 2, which had sand to about 25 mm depth; the extra sand depth was to allow sandfish to bury themselves in case they needed protection from shrimp. Water flows of about 500–1000 L day⁻¹ were provided from a reservoir plus settlement tank via nozzles. Initially water was sand-filtered, although filtration was later omitted.

On 6 September 2001 sandfish were divided into groups of seven animals each. Individual weights ranged from about 40–

Table 2. Feeding rates in trial B

all tanks (g tank ⁻¹ day ⁻¹)		tanks 1, 3, 6, 8 (g tank ⁻¹ 2 days ⁻¹)		
dates	shrimp food (dry)	dates	<i>Gracillaria</i> (fresh)	manure (dry)
12/7	1.50	14/7–24/7	12.50	5.0
13/7–24/7	0.90	26/7–3/8	18.75	7.5
25/7–3/8	1.50	5/8–19/8	30.00	12.0
4/8–19/8	2.40			
average g day⁻¹	1.64		9.75	3.9

Table 3. Treatments and results in trial B

tank		1	2	3	4	5	6	7	8
shrimp		yes	no	no	yes	yes	no	no	yes
<i>Gracillaria</i> + manure		yes	no	yes	no	no	yes	no	yes
02 Aug.									
sandfish	number	34	31	21	34	30	36	35	32
	av. wt. (g)	1.8	2.5	1.7	2.4	2.1	2.5	2.7	3.5
	survival (%)	94	86	58	94	83	100	97	89
shrimp	av. wt. (g)	0.062			0.043	0.046			0.088
20 Aug.									
sandfish	number	0	0	13	32	26	2	0	4
	av. wt. (g)			5.4	10.1	3.2	1.2		5.4
	survival (%)			36	89	72	6		11
shrimp	av. wt. (g)	0.48			0.37	0.26			0.43
	number	?			76	62			47
	survival (%)	?			95	78			59

440 g, but the groups were “matched” so that the mean of each group was between 160 and 170 g. By using such a wide range of sizes, individuals could be followed through successive weighings. Feeds were either commercial shrimp food (Betagro 503) or seaweed (mainly sargassum), milled dry and then sieved (< 250 μm) to produce a fine powder.

There were five treatments; individually identifiable sandfish provided the only repetitions. Tank 1 contained no shrimp and was given 3 g shrimp food per day. Tanks 2 (extra sand) and 4 were stocked with approximately equal numbers and weights of shrimp (~ 17.4 m⁻²), averaging about 1.6 g and given 6 g shrimp food per day. Tank 3

contained no shrimp, was given 3 g seaweed powder per day, and tank 5 contained no shrimp and was not given food. Sandfish were collected and weighed on six occasions covering a period of 107 days. Shrimp were counted and weighed only at the beginning and end of the trial.

All sandfish survived and appeared healthy in all tanks with no shrimp. In tank 2, one sandfish eviscerated on final handling (viscera were included in the weighing), perhaps indicating it was weak. In tank 4, on 24 October, one sandfish had skin lesions; on 5 November, there were two sandfish with lesions; and on 22 December, only the three largest sandfish were found.

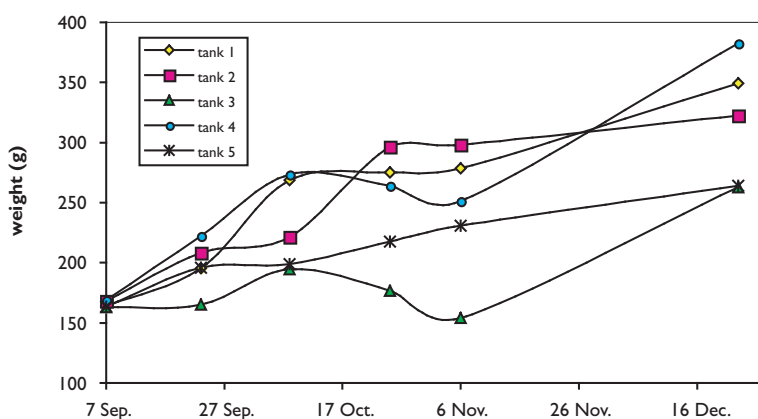


Figure 1. Average weight (g) of sandfish with time in trial C

Conclusions from trial C

1. Reasonable sandfish growth rates were obtained in tanks at densities up to almost 400 g m⁻².
2. Shrimp were not needed, shrimp food alone appeared to support this growth.
3. Feeding sandfish with seaweed powder did not appear any more beneficial than not feeding them at all.
4. Shrimp of an average weight less than 6 g may have caused mortalities of 70–190 g sandfish in tank 4.
5. Extra sand or other factors may have protected sandfish in tank 2.
6. It is not clear why shrimp survival was low in tank 2.

Table 4. Tank treatments, sandfish survival, densities and growth rates (ranked) in trial C

tank	sand (mm)	shrimp	feed type	feed (g day ⁻¹)	survival (%)	initial density (g m ⁻²)	final density (g m ⁻²)	mean growth (g day ⁻¹)
1	10	no	shrimp	3	100	187	399	1.700
2	25	yes	shrimp	6	100	192	369	1.410
4	10	yes	shrimp	6	43	193	219	*1.100
5	10	no	none	-	100	187	302	0.920
3	10	no	weed	3	100	186	301	0.916

* for all animals (1.65 for the three largest which survived to end of trial)

Table 5. Shrimp stocking and harvest data in trial C

	stock (6/9/01)		harvest (15/12/01)		
	number	average wt. (g)	number	average wt. (g)	survival (%)
tank 2	107	1.56	21	9.67	19.6
tank 4	102	1.64	67	5.66	65.7

Trial D: Factorial: size, shrimp, tank covers and flow

Sixteen fibreglass tanks (1.5 m diameter, depth to outlet 65 cm) were installed in two adjacent rows outdoors. The site was near a row of coconut trees, but was otherwise unshaded. Beach sand was washed and sieved through 400 x 800 µm mesh. A sample of this sand was sieved while wet, using available screens, and then dried and weighed. Size distribution was > 250 µm: 9.6%, > 140 µm: 78.9%, > 100 µm: 6.3%, and > 50 µm: 5.3%. Eight litres of this sand were put into each tank. The following four factors were tested, in 16 combinations, randomly assigned.

a) Size

Juveniles from bare nursery tanks were sorted into matched groups and then sorted into groups of 24 large or 36 small animals. They were weighed after three to five minutes of drying and after removing remaining excess water with a towel. Total weights of large juvenile groups were within 7% of each other, those of small juveniles were within 20%. Large juveniles averaged 0.53 g, small juveniles 0.12 g.

b) Shrimp

Eighty postlarval *P. monodon*, recently supplied from a hatchery, were stocked in each of eight tanks.

c) Covers

Blue semi-translucent PVC roofing panels (2 m x 80 cm) were put on eight of the tanks, using two slightly overlapping panels per tanks. A timber batten was used to give a slight slope to the panel and a small gap was left at one edge to facilitate feeding and checking. Panels reduced water temperature fluctuations, rain and dirt (mainly coconut tree debris), but they also substantially lowered light levels and, therefore, photosynthesis, which might be important in sandfish feeding.

d) Flow rate

Tanks were supplied with unfiltered seawater via nozzles of two sizes from a header/settlement tank, whose water level varied throughout the day. (Water was pumped from the sea nearly always during daylight hours.) At mid-level, flows were approximately 1800 and 600 ml min⁻¹ for the two nozzle sizes, giving retention times of about one and three days.

Table 6. Treatments and results of trial D

tank	treatment				15 Dec.		14 Jan.				7 Feb.				28 Feb.					
					sandfish		sandfish		shr.	sandfish		shr.	sandfish		shrimp					
	size	shr.	cover	flow	no.	av. wt. (g)	no.	av. wt. (g)	grow. (g day ⁻¹)	av. wt. (g)	no.	av. wt. (g)	grow. (g day ⁻¹)	av. wt. (g)	no.	av. wt. (g)	grow. (g day ⁻¹)	no.	av. wt. (g)	surv. (%)
1	small	-	cover	low	36	0.12	32	2.73	0.09		37	10.1	0.31		37	14.1	0.19			
2	large	-	open	high	24	0.52	23	5.76	0.17		24	17.6	0.49		24	19.8	0.10			
3	small	-	open	high	36	0.11	35	3.03	0.10		36	12.6	0.40		36	20.2	0.36			
4	small	+	cover	low	36	0.12	23	7.52	0.25	0.07	23	33.7	1.09	0.27	23	36.7	0.14	60	0.68	75
5	large	+	open	high	24	0.55	24	12.67	0.40	0.13	24	41.8	1.21	0.22	24	50.6	0.42	45	0.69	56
6	large	+	open	low	24	0.55	24	12.04	0.38	0.13	24	20.8	0.37	0.32	22	32.0	0.53	38	0.82	48
7	large	-	open	low	24	0.54	23	6.83	0.21		24	15.4	0.36		23	12.7	-0.13			
8	large	+	cover	high	24	0.55	22	14.68	0.47	0.13	22	41.4	1.11	0.29	20	40.5	-0.04	75	0.66	94
9	small	-	open	low	36	0.12	34	2.88	0.09		36	10.8	0.33		36	10.9	0.00			
10	large	+	cover	low	24	0.54	23	14.26	0.46	0.10	23	36.3	0.92	0.39	20	30.0	-0.30	60	0.65	75
11	large	-	cover	high	24	0.54	21	10.14	0.32		24	18.7	0.36		24	28.0	0.44			
12	small	+	cover	high	36	0.12	36	7.31	0.24	0.15	36	24.3	0.71	0.37	31	23.7	-0.03	71	0.61	89
13	small	+	open	low	36	0.11	33	5.42	0.18	0.10	36	16.3	0.45	0.27	30	12.0	-0.20	52	0.71	65
14	small	-	cover	high	36	0.11	28	4.46	0.15		35	12.1	0.32		35	8.3	-0.18			
15	large	-	cover	low	24	0.54	24	8.83	0.28		24	17.2	0.35		24	19.4	0.11			
16	small	+	open	high	36	0.13	30	8.00	0.26	0.14	31	29.6	0.90	0.41	30	27.9	-0.08	44	0.79	55

Tanks were stocked on 15 December 2001. Sandfish tanks were given dry seaweed powder once a day. Initially, tanks with large juveniles received 1.5 g day⁻¹, and tanks with small juveniles received 0.75 g day⁻¹. From 1 January 2002, this was increased to 2 g day⁻¹ for all tanks. Tanks with shrimp were also fed commercial feed (Betagro 501S or Betagro 501) at 1.5 g day⁻¹. For about two weeks, this was divided into three feeds per day, and then reduced to two feeds per day. The rate was not increased throughout the trial to avoid overfeeding. Animals were monitored for three growth periods: they were weighed on 14 January, 7 February and 28 February.

For each factor, there were eight pairs of tanks that differed only with respect to that factor, and which received similar treatments with respect to the other three factors. While the absence of replication prevented statistical analysis (according to the best available advice), growth rates of sandfish in these pairs of tanks could be ranked for each growth period, and for the overall experiment. The early mortality in tank 4 led to later higher-than-expected growth among the remaining sandfish, so for the later and overall periods, this tank pair was left out of these comparisons. The fraction of tank pairs for which the growth rate advantage was in the direction indicated is shown in Table 7.

Conclusions from trial D

1. Some tanks with shrimp reached surprisingly high sandfish densities, up to 690 g m⁻².
2. The heavier juveniles at the beginning of the experiment generally remained heavier, in part because fewer were stocked (a trivial finding).
3. The apparent growth gain due to the presence of shrimp may well have been due (mainly or entirely) to the better feeding in these tanks, which received shrimp food as well as seaweed powder.
4. The four tanks stocked with small sandfish and shrimp had slightly lower sandfish survival

Table 7. Summary of effects of factors on sandfish growth in trial D

factor	period 1	period 2	period 3	overall	average of ratios of mean final weights
large>small	8/8	6/7	3/7	6/7	1.53
shrimp>none	8/8	7/7	3/7	7/7	1.91
open>covered	6/8	6/7	3/7	4/7	1.15
high flow>low	6/8	7/7	5/7	6/7	1.87

rates. Mortality first occurred when sandfish averaged 0.12–0.26 g and shrimp 0.07–0.15 g. It is not clear whether predation by shrimp was to blame.

5. Sandfish growth was slightly better without covers than with covers.
6. High water exchange was beneficial to sandfish growth.
7. Mean shrimp survival was higher in covered tanks (83.1%) than open tanks (44.8%), and growth slightly lower.

Trial E: Two sizes (and none) of sandfish juveniles, shrimp

Sixteen 1.5-m diameter tanks were set up without covers. Mean water exchange was about 300–400 L tank⁻¹ day⁻¹, one third of the tank volume. Tanks were stocked on 15 March 2002 using eight regimes (with two replicates): large, small or no sandfish juveniles with ongrown (large), postlarval (small) or no shrimp (omitting the treatment with neither sandfish, nor shrimp).

Sandfish were stocked to equal biomass/tank. Thus, 12 large, or about 168 small juveniles, were placed in groups of approximately 170 g total weight/group; care was taken that the weight range of individuals was also similar in different groups. Shrimp were stocked by number, with groups of 54 postlarvae (30 m⁻²) or 27 ongrown animals (15 m⁻²).

Tanks with shrimp were fed starter food (Betagro 501S). Other tanks received a mixture that was being used as the standard feed for sandfish during second nursery phase, consisting of two parts dry spirulina powder, one part Betagro 501S and one part dried ground seaweed. The seaweed was mainly sargassum — locally collected, sun dried, ground and sieved through a 250- μ m screen. In either case, two daily feeds of 1 g tank⁻¹ were given.

Results of trial E

On 25 March, many dead or sick/dying sandfish were seen in tanks with large shrimp and small sandfish. They were left in the tanks and feeding continued. On 10 April, all tanks were emptied. Sandfish from the “large” group were weighed individually, shrimp and sandfish from the “small” group were counted, and the total weight measured.

Sandfish losses were negligible in most tanks and growth was good, averaging over 1 g day⁻¹ for large juveniles and

0.1 g day⁻¹ for small juveniles. Sandfish biomass densities reached around 300 g m⁻². Shrimp survival was also good, 70–80% for both ongrown animals and postlarvae. Shrimp growth was about 0.03 g day⁻¹ for ongrown animals and 0.007 g day⁻¹ for postlarvae.

Sandfish mortalities, however, were noticed from the tenth day in the two tanks stocked with small sandfish and large shrimp. Final sandfish survival in these two tanks was only 9%, and there was an overall slight drop in average weight. If shrimp growth was roughly linear, at the time these mortalities started, the average weight of shrimp in the two tanks would have been about 0.95 g, similar to the starting weight of the sandfish.

Conclusions from trial E

1. Shrimp of about 1 g caused the death of sandfish of a similar size.
2. Shrimp feed could support good sandfish growth in the absence of shrimp.
3. The survival of small shrimp was highest with large sandfish, otherwise the presence or absence of sandfish had little effect on shrimp growth and survival.

Trial F: Four sizes of sandfish, three sizes of shrimp and no shrimp

Sixteen 1.5 m diameter tanks were set up (unshaded) as before, but with only six litres of sand

Table 8. Results grouped by treatment in trial E

treatment			15 March				10 April						
tank	sandfish	shrimp	sandfish		shrimp		sandfish				shrimp		
			av. wt. (g)	no.	av. wt. (g)	no.	av. wt. (g)	no.	growth (g day ⁻¹)	survival (%)	av. wt. (g)	no.	survival (%)
12	large	large	14.40	12	0.580	27	44.5	12	1.16	100.0	1.25	20	74.1
13	large	large	14.30	12	0.620	27	37.2	12	0.88	100.0	1.44	18	66.7
2	large	small	14.30	12	0.008	54	42.0	12	1.06	100.0	0.23	47	87.0
14	large	small	14.50	12	0.008	54	37.7	12	0.89	100.0	0.18	52	96.3
3	large	none	14.20	12			47.6	12	1.29	100.0			
16	large	none	14.30	12			43.2	12	1.11	100.0			
7	small	large	0.98	168	0.560	27	0.24	13	-0.03	7.7	1.44	21	77.8
15	small	large	0.98	167	0.600	27	0.33	17	-0.02	10.2	1.66	16	59.3
4	small	small	0.99	168	0.008	54	3.36	169	0.09	100.6	0.20	45	83.3
10	small	small	0.99	163	0.008	54	3.40	163	0.09	100.0	0.19	47	87.0
6	small	none	0.98	166			4.69	166	0.14	100.0			
9	small	none	0.96	170			3.12	169	0.08	99.4			
5	none	large			0.610	27					1.31	16	59.3
11	none	large			0.610	27					1.23	26	96.3
1	none	small			0.008	54					0.25	34	63.0
8	none	small			0.008	54					0.19	42	77.8

Table 9. Averaged results of treatment pairs in trial E

tanks	treatment		sandfish			shrimp		
	sandfish	shrimp	survival (%)	final density (g m ⁻²)	growth rate (g day ⁻¹)	survival (%)	final density (g m ⁻²)	growth rate (g day ⁻¹)
12, 13	large	large	100.0	277.3	1.02	70.4	14.4	0.028
2, 14	large	small	100.0	270.7	0.98	91.7	5.7	0.007
3, 16	large	none	100.0	308.4	1.20			
7, 15	small	large	9.0	2.5	-0.03	68.5	16.0	0.037
4, 10	small	small	100.0	317.5	0.09	85.2	5.1	0.007
6, 9	small	none	99.7	369.6	0.11			
5, 11	none	large				77.8	15.0	0.025
1, 8	none	small				70.4	4.7	0.008

(3.5 mm depth). Filling started on 26 July 2002, and tanks were stocked on 29 July with four size groups of sandfish bred at RIA3. Some were nursed for two months in seabed babylon cages, with and without snails, while the smaller sizes came directly from the RIA3 onshore nursery tanks.

For the two larger sizes of sandfish, tanks were stocked with 12 juveniles each; for the two smaller sizes there were 18 sandfish per tank. Treatments with shrimp (hatchery-bred and pond-grown) had 18 sandfish per tank, about 10 m². Care was taken to equalise both the average weights and size distribution of the sandfish groups, and to minimise the spread. With the shrimp, average weights were matched. The 16 treatments were assigned randomly (by drawing paper slips from a beaker). All tanks were fed 1 g shrimp starter food (Betagro 501S) twice daily. In the first couple of days the large shrimp that died were replaced (generally by smaller animals, since they were all that were available).

On the second weighing (12 August) all sandfish were collected but only total weights were measured. Survival then was 100%, but two days later, some sandfish in tank 6 were sick. Those that died were not removed. Ten shrimp from each tank

were also caught and weighed. On the third weighing (26 August) all surviving animals were collected. Sandfish were weighed individually, shrimp counted and weighed as groups.

In tanks with small, medium or no shrimp, sandfish survival averaged 99%, but with large shrimp only 69%. (It is unfortunate that the experiment was not continued for one more period to see if these losses continued.) Tanks with small shrimp had the best sandfish growth. Survival rates of shrimp were reasonable, at 79.6%. Small shrimp almost doubled in size over the course of the experiment, while large shrimp hardly grew at all. (Perhaps they were underfed, or unable to use the small-size feed efficiently.)

Conclusions from trial F

1. The size of sandfish had no apparent effect on growth or survival of the shrimp.
2. Large shrimp (about 5 g average weight) may have reduced the survival of sandfish in the second period in the small, medium and large sandfish groups (7.6–28.1 g average weights).
3. The presence of small shrimp (up to about 1.5 g average) may have had a slight positive effect on the growth of sandfish.

Table 10. Results arranged by treatments in trial F

treatment			29 July			12 August				26 August							
tank	sandfish	shrimp	sandfish			shrimp				sandfish				shrimp			
			no.	av. wt (g)	av. wt (g)	no.	av. wt (g)	period one, growth (g day ⁻¹)	av. wt (g)	no.	av. wt (g)	period two, growth (g day ⁻¹)	overall growth (g day ⁻¹)	surv. (%)	no.	av. wt (g)	surv. (%)
12	XL	none	12	30.8		12	46.3	1.11		12	41.3	-0.36	0.38	100			
3	XL	small	12	30.9	0.8	12	42.3	0.82	1.1	12	47.9	0.40	0.61	100	15	1.5	83
13	XL	med.	12	30.9	2.1	12	37.2	0.45	3	12	38.4	0.09	0.27	100	14	2.7	78
9	XL	large	12	29.8	5.0	12	36.7	0.49	5.7	11	42.5	0.41	0.45	92	12	5.1	67
6	large	none	12	10.3		12	23.8	0.97		11	24.4	0.04	0.50	92			
10	large	small	12	10.2	0.9	12	25.4	1.09	1.1	12	34.3	0.63	0.86	100	14	1.8	78
5	large	med.	12	9.4	2.1	12	24.3	1.06	2.6	12	27.7	0.24	0.65	100	14	3.1	78
4	large	large	12	9.5	4.5	12	23.4	1.00	4.6	8	28.1	0.34	0.67	67	16	4.8	89
16	med.	none	20	3.2		20	15.0	0.84		20	20.4	0.38	0.61	100			
7	med.	small	20	3.6	0.9	20	12.1	0.61	1.1	20	19.0	0.49	0.55	100	13	1.5	72
14	med.	med.	20	3.3	2.3	20	9.5	0.44	2.3	20	13.3	0.28	0.36	100	14	2.6	78
1	med.	large	20	3.1	4.7	20	13.4	0.73	5.4	15	17.1	0.27	0.50	75	16	5.8	89
2	small	none	20	1.1		20	7.9	0.49		20	7.3	-0.04	0.22	100			
8	small	small	20	1.0	0.9	20	7.6	0.47	1.1	20	18.1	0.75	0.61	100	13	1.5	72
11	small	med.	20	1.1	2.2	20	8.5	0.53	2.8	19	15.4	0.49	0.51	95	14	3.0	78
15	small	large	20	1.0	4.9	20	7.6	0.47	4.6	10	9.2	0.12	0.29	50	17	4.8	94

Trial G: Two sizes of sandfish and two sizes of shrimp in tanks and aquaria**Tanks**

Fifteen small fibreglass tanks (85 cm internal floor diameter (0.57 m²) and 46 cm water depth (280 L)) were arranged outdoors in three rows with partial shading (60%). Unfiltered water was supplied from a settlement tank (of varying head and with varying demand on the line) using uniform nozzles, for about 10 hours per day. This gave a mean water retention time of about 24 hours. Tank floors were covered with a thin layer of sieved beach sand. All tanks were covered with a further lightweight net (about 4.5 mm mesh) to prevent shrimp from jumping out (and tanks with shrimp had outlet screens). Tanks received a 0.5 g ration of fine shrimp starter (CP 9000) once a day, starting on the first day. Feedings were kept quite low and infrequent to test the behaviour of shrimp towards sandfish when hungry.

On 6 June 2003, tanks were stocked using five stocking combinations. Small shrimp had been grown from postlarvae in a tank, large shrimp had been grown in a farmer's pond. There were three replicates of each tank treatment (randomly assigned within rows so that each row had one of each treatment). The treatments were:

1. 12 medium sandfish (av. wt. 3.6 g, density 21 m⁻²) with 18 medium shrimp (av. wt. 1.4 g, density 32 m⁻²).

2. 12 medium sandfish (av. wt. 3.6 g, density 21 m⁻²) with no shrimp.
3. 18 small sandfish (av. wt 0.5 g, density 32 m⁻²) with 18 medium shrimp (av. wt. 1.4 g, density 32 m⁻²).
4. 18 small sandfish (av. wt 0.5 g, density 32 m⁻²) with 24 small shrimp (0.02 g average weight, density 42 m⁻²).
5. 18 small sandfish (av. wt. 0.5 g, density 32 m⁻²) with no shrimp.

Aquaria

Six small glass aquaria (30 cm x 20 cm x 30 cm deep) were set up using similar sizes of sandfish and shrimp. Two treatments without shrimp were omitted. The floor area of an aquarium was about one tenth that of a fibreglass tank, and the stocking density per unit area about 3.3 times higher — volume stocking densities in aquaria were about 4.4 times more than in tanks. The aquaria were given an approximate daily ration of 20 mg each of fine shrimp starter, beginning on the second day. Water changes were carried out only occasionally.

Results of trial G

A couple of days after stocking, a small sandfish was found bitten in half in aquarium 6 (which contained medium shrimp). On 14 June, more small sandfish appeared to have been attacked by medium shrimp: some had eviscerated, and some were dead (and partly eaten).

Table 11. Tank results grouped by treatments in trial G

tank	combination		06 June				16 June						
			sandfish		shrimp		sandfish				shrimp		
	sandfish	shrimp	no.	av. wt (g)	no.	av. wt (g)	no.	av. wt (g)	growth (g/day)	survival (%)	no.	av. wt (g)	growth (g/day)
2	medium	medium	12	3.7	18	1.40	3	5.7	0.20	25	18	1.390	-0.010
8	medium	medium	12	3.6	18	1.40	0			0	17	1.820	0.040
14	medium	medium	12	3.5	18	1.40	1	3.0	-0.05	8	18	1.560	0.010
3	medium	none	12	3.5			12	7.9	0.44	100			
6	medium	none	12	3.6			12	8.6	0.50	100			
12	medium	none	12	3.7			12	9.6	0.59	100			
4	small	medium	18	0.5	18	1.40	0			0	18	1.610	0.020
7	small	medium	18	0.5	18	1.40	0			0	18	1.500	0.010
11	small	medium	18	0.5	18	1.40	0			0	18	1.560	0.010
5	small	small	18	0.5	24	0.02	18	2.7	0.21	100		0.064	0.004
10	small	small	18	0.5	24	0.02	17	1.6	0.11	94			
13	small	small	18	0.5	24	0.02	18	2.5	0.20	100			
1	small	none	18	0.5			18	2.8	0.23	100			
9	small	none	18	0.5			18	2.3	0.18	100			
15	small	none	18	0.5			18	2.6	0.21	100			

On 16 June, sandfish of both sizes, as well as medium shrimp, were collected from tanks, counted and weighed. In tanks with medium shrimp most sandfish were either completely flat and flaccid, dead, or had disappeared. Some remains of viscera were found. In the six tanks without shrimp (or with small shrimp), nearly all sandfish had survived and grown. Sandfish growth was low in tank 10 (small sandfish, small shrimp), but otherwise sandfish appeared to be unaffected by the presence of small shrimp. Unfortunately, the small shrimp were not counted, and only a sample from tank 5 were weighed, so their survival and most growth data was lost. Nearly all medium shrimp in tanks survived, though growth was poor.

All sandfish with medium shrimp died except for those in aquarium 4, which lost weight. Sandfish with small shrimp all survived. Six shrimp also died under these rather severe conditions of high density and temperatures, with little water exchange.

Conclusions from trial G

1. Shrimp of about 1.5 g average weight caused the deaths of juvenile sandfish, of average weight 2.8–3.7 g.
2. Shrimp of 0.02 g average weight did not harm sandfish of 0.5 g.
3. Small shrimp did not appear to affect sandfish growth.

Discussion

Taken together, the results of these seven trials indicate that co-culturing *Holothuria scabra* and *Penaeus monodon* should be possible in many situations, and that any adverse interactions are likely to be at the expense of sandfish, not shrimp. In addition, scientists at RIA3 have reared sandfish and shrimp together (to market size) in ponds on at least two occasions (Thu 2003). In these larger-scale

trials, there was reasonable survival to harvest size of both shrimp and sandfish in two out of four ponds using wild-collected sandfish, and in one of two ponds with our hatchery-produced juveniles.

Despite the generally promising results, predation of sandfish by *P. monodon* was a real and rapid phenomenon under certain conditions. Thu and co-workers (pers. comm.) have run tank trials that appear to indicate that shrimp may attack sandfish when stocked at high density, but not at low density. Predation of sandfish juveniles by young swimming crabs and by rabbitfish has also been observed (Pitt and Duy 2004).

It may be that sandfish are not a natural or preferred food source for shrimp, but rather a feed they can learn to use when hungry. Shrimp may be able to induce evisceration of sandfish, and thus feed on the viscera. This is supported by our observations of flat, empty-looking sandfish juveniles with unbroken skin in some co-culture tanks.

A summary of cases where predation of sandfish during co-culture did or did not occur is shown in Figure 2. It is clear that mortality occurred in a minority of cases and that it was not simply restricted to combinations of relatively small sandfish and relatively small shrimp. Rather, it appears that certain rearing conditions may promote aggression of shrimp towards sandfish.

We caution that the results presented here need to be interpreted with care. While the large number of trials provides a measure of confidence that the results represent the range of interactions that can be expected between *H. scabra* and *P. monodon*, most of the experiments had little or no replication. Thus, there is no certainty that the results of individual experiments were not due to chance alone. We strongly encourage further, more rigorous, research on this subject using sufficient replicates to investigate the effects of different sizes of sandfish

Table 12. Aquarium results grouped by treatments in trial G

aquarium	combination		06 June				16 June						
			sandfish		shrimp		sandfish				shrimp		
			sandfish	shrimp	no.	av. wt (g)	no.	av. wt (g)	no.	av. wt (g)	growth (g/day)	survival	no.
1	medium	medium	4	3.0	6	1.40	0			0	5	1.6	0.016
6	medium	medium	4	2.8	6	1.40	0			0	3	2.0	0.056
4	small	medium	6	0.5	6	1.40	6	0.3	-0.017	100	5	2.6	0.116
5	small	medium	6	0.5	6	1.40	0			0	5	1.8	0.036
2	small	small	6	0.5	8	0.02	6	1.2	0.067	100	8	0.063	0.004
3	small	small	6	0.5	8	0.02	6	0.8	0.033	100	8	0.063	0.004

and shrimp at different densities, under different feeding regimes, etc. The results of such experiments may then form the basis of a guide to growers regarding safe size combinations for co-culturing the two species.

References

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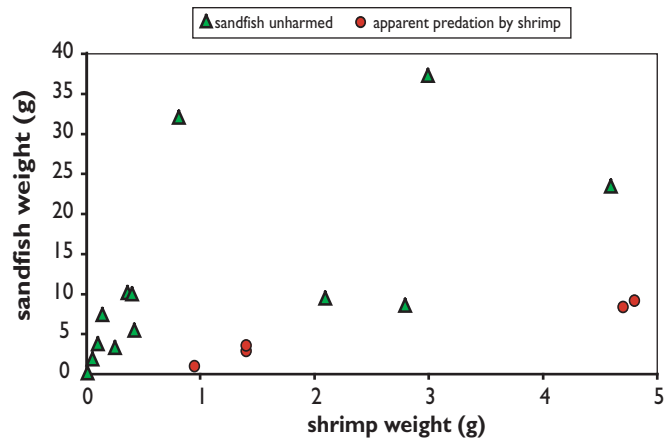


Figure 2. Mean sizes in tanks where sandfish were unharmed, and where they appear to have been killed by shrimp.

Monitoring a fissiparous population of *Holothuria atra* on a fringing reef on Reunion Island (Indian Ocean)

Chantal Conand¹

Introduction

Holothuria atra is the most common and abundant sea cucumber species on the fringing reefs of Reunion Island, which is generally the case with other Indo-Pacific reefs (Conand 1996; Conand and Mangion 2002; Jaquemet et al. 1999; Uthicke 2001). In Reunion, its density varies depending on the site and reef zone studied and its populations show a variety of structures (Conand 1996). In addition, this species' role in the ecology of soft bottoms of Reunion Island reefs is now understood. It plays an important role in remodelling sediments as the studied population ingests some 78 kg m⁻² annually (Mangion et al. in press).

This is one of the sea cucumbers species that can reproduce asexually by fission, with a range of modes depending on the study site (Chao et al. 1994; Conand 1996; Jaquemet et al. 1999; Uthicke 2001). The scope of asexual reproduction is a key to understanding population genetics. In fact, genetic studies on this species have shown that in spite of the significance of asexual reproduction, sexual reproduction is vital for large-scale dispersion of lar-

vae (Uthicke et al. 2001). However, asexual reproduction is a very widespread mechanism in this species and its influence on population abundance and specimen size has been studied at several sites in the Great Barrier Reef in Australia (Uthicke 1997, 2001), Taiwan (Chao et al. 1994), New Caledonia (Conand 1989) and Reunion (Conand 1996; Jaquemet et al. 1999).

The results presented here deal with the continuation in 1998, 1999 and 2000 of the sampling conducted between November 1993 and November 1997; sampling that had demonstrated a relative stability in densities and mean specimen weights (Jaquemet et al. 1999). This study involved monitoring the influence that asexual reproduction by fission has on population dynamics, in particular on density and mean specimen sizes (weights).

Materials and methods

Sampling was carried out at the back-reef station at Planch'Alizés (Saline Reef), once a year, during the hot season. The methods were the same as those used previously (Conand 1996; Jaquemet et al.

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1999). The mean depth was 0.70 m. In eight 10 m² quadrates (A1 to A4 on a transect perpendicular to the shore and B1 to B4 on a transect parallel to the shore), all the *H. atra* were weighed in grams and classified by 10 g fresh weight groups.

The stage of each specimen with regards to fission was noted. As in the previous studies (Conand and De Ridder 1990; Conand 1996; Jaquemet et al. 1999), there were two major specimen types (i.e. normal specimens and those in the process of asexual reproduction). These two types made it possible to classify specimens according to various categories (Conand and De Ridder 1990; Conand 1996):

- “N” (normal) specimens: did not show any signs of asexual reproduction,
- “F” (fission) specimens: showed signs of ongoing transversal division (constriction at 45% of the body starting from the anterior section),
- “A” (anterior) specimens: had just divided and only possessed the anterior part,

- “P” (posterior) specimens: had just divided and only possessed the posterior part,
- “Ap” (Anterior-posterior) specimens: showed signs of regeneration of the posterior part,
- “Pa” (Posterior-anterior) specimens: showed signs of regeneration of the anterior part.

The “S” category covered all the specimens that were the result of asexual reproduction (F, A, P, Ap, Pa).

Results

Fission and regeneration rates

Table 1 shows a summary of the abundances (and percentages) for the various categories of specimens for each year from 1998 to 2000 as well as the mean calculated for these three years.

A+P fission rates averaged about 7.38% of the total number of specimens counted and corresponded to those specimens that had recently undergone fission. Ap+Pa regeneration rates were 8.46% of the total number of specimens counted (i.e. still slightly higher than the fission rates). In all, specimens resulting from asexual reproduction (S) accounted for 15.84%. Overall, a slight increase in this S rate was visible over this three-year period.

Changes in density

Figure 1 includes the values for the three years of this study, as a follow-up to those from the previous study. It appears that there was little variation in densities; the mean for the last three years was 4.6 specimens m⁻² at this back-reef station.

Table 1: Number of specimens, various percentages, means (m) and standard deviations (sd) for the total (T), normal specimens (N), those that had recently undergone fission (A+P), and those in the process of regeneration (Ap+Pa).

Date	T	N	A+P	Ap+Pa	F	S
Nov. 1998	380	329	23	27	1	50
%	100	86.58	6.05	7.1	0.26	13.16
Nov. 1999	386	319	27	31	0	58
%	100	82.64	6.99	8.03	0	15.03
Dec. 2000	345	277	32	36	0	68
%	100	80.29	9.27	10.43	0	19.71
m	370.33	308.33	27.33	31.33	0.33	58.67
sd	22.14	27.59	4.51	4.51	0.58	9.02
%	100	83.26	7.38	8.46	0.9	15.84

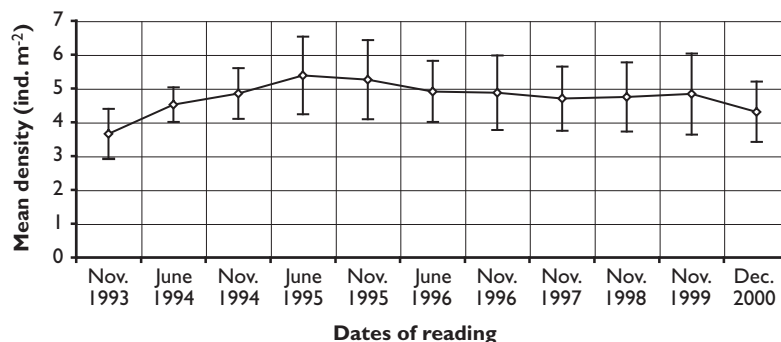


Figure 1: Changes in mean densities (\pm standard deviation) from 1993 to 2000.

Changes in weight distributions

Figure 2 provides a summary of weight distributions of normal specimens for the three consecutive years. The overall appearance was very similar for these years, with three identifiable modes, at about 30 g in 1998 (slightly bigger in 1999 and 2000), 70 g and 95 g. Specimens above that were rare as the largest (except for a few specimens) weighed 170 g.

Figure 3 shows a summary of weight distributions for specimens resulting from fission (S on Table 1). They were mainly under 20 g and spread out up to 75 g. These small dimensions clearly show the weight brought about by fission.

Discussion

Fission and regeneration rate study

These three additional years of study confirmed the importance of asexual reproduction in this *H. atra* population. Between 1993 and 1997, 15% of specimens resulted from asexual reproduction; between 1998 and 2000, the mean was 15.84 % (i.e. similar) and so accounted for a stable portion of the population. These values are fairly close to those already published for other populations of this species (Conand 1996; Conand and De Ridder 1990; Chao et al. 1994; Uthicke 1997). Comparing the results for the rates of the various specimen categories presented here, along with the table corresponding to the previous study (Jaquemet et al. 1999), confirms this stability.

In the same way, specimens resulting from the anterior part (A and Ap) were slightly more numerous than those resulting from the posterior (P and Pa), but the latter were larger in size, a result of fission which divides specimens into unequal parts, as previously shown (Conand and de Ridder 1990).

Changes in density

Figure 1 shows the relative stability of *H. atra* densities at this back-reef station. For the entire hot season data (to eliminate seasonal variations), the mean density was 4.8 specimens m⁻², with the previous data included (Jaquemet et al. 1999). Asexual reproduction, therefore, did not result in any variation in this parameter at this station.

Uthicke (1997, 2001) showed the variations that exist between *H. atra* samplings on the Great Barrier Reef and in New Caledonia (Conand 1989) and Reunion Island (Conand 1996). Seasonal variations in fission have, then, been confirmed. This 10-year study conducted outside the fission season, shows that overall, densities did not vary.

Changes in weight distributions

For the three years 1998 to 2000, the weight distributions of normal specimens were very close, with a possible identification of three modes that could correspond to the growth of specimens, whether or not they had undergone fission.

The weight distributions of specimens arising from fission were between 0 and 80 g, and differed little by year. These specimens weighed slightly less than those from the Great Barrier Reef (Uthicke 2001).

Conclusion

The *H. atra* population studied, which showed stable density and weight distributions, seems to have attained optimum density in relation to the abiotic and biotic back-reef conditions at a eutrophic station at a Reunion Island reef. These results can be extended to an assessment of mortality. In fact, fission (and the non-assessed contribution of sexual reproduction) compensates for mortality (Uthicke 2001). This is, then, much higher in the back-reef zones than on reef flats in Reunion Island (Conand 1996), as is also the case in other mixed populations of this species, for example in Taiwan (Chao et al. 1994) and on the Great Barrier Reef (Uthicke 1997, 2001).

Uthicke (2001) has presented a model for asexual reproduction. In order to validate the theories and analyse their consequences, controlled experiments on environmental parameters (stability, sediment richness, temperature, salinity, effect of cyclones, etc.) and populations will have to be conducted.

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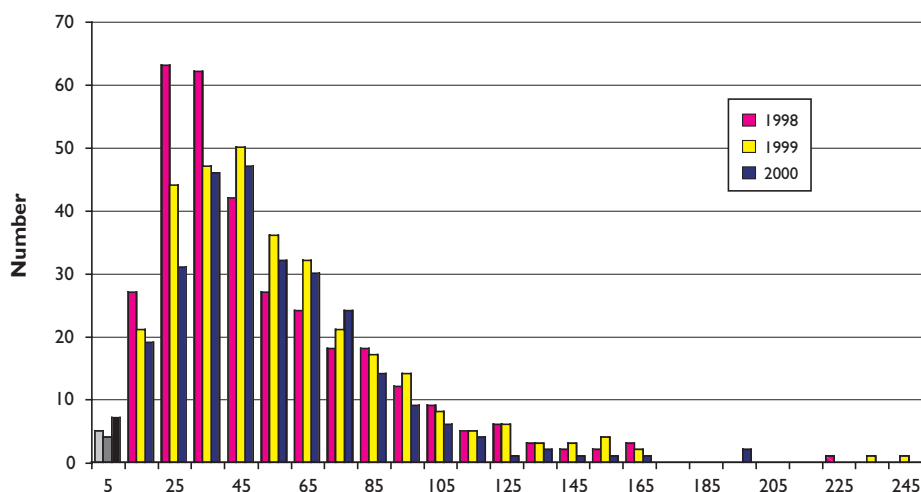


Figure 2: Weight distributions of normal specimens for the hot seasons 1998, 1999, 2000.

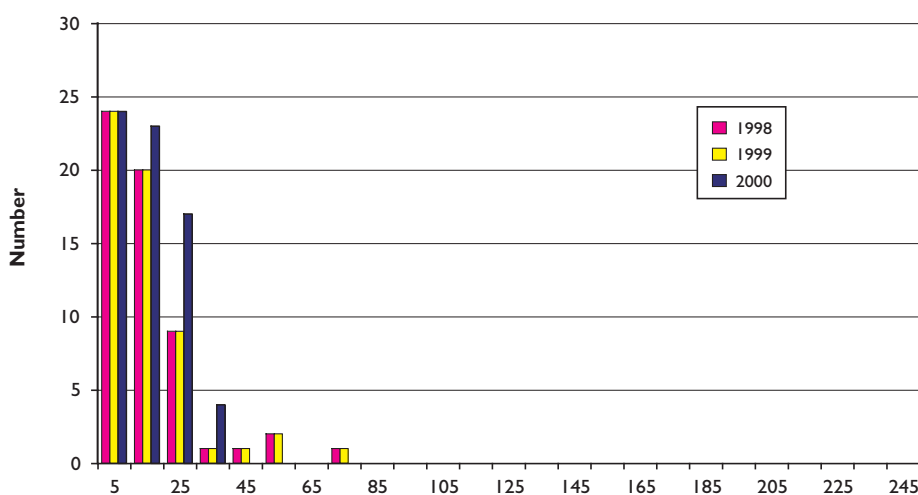


Figure 3: Weight distributions of specimens resulting from fission for the hot seasons 1998, 1999, 2000.

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Fissiparity in *Holothuria leucospilota* from tropical Darwin waters, northern Australia

Pradina Purwati¹

Abstract

Fission was studied in a population of *Holothuria leucospilota* at Darwin harbour. Fission resulted in smaller size anterior portions (A to P ca. 34.81%). A greater number of posterior individuals (P and Pa) may be assumed to mean a greater survival capacity than with anterior individuals (A and Ap). Monthly observations from September 1998 to September 1999 revealed that fission occurred throughout the year at an estimated rate of up to 28% at East Point and 8% at Nightcliff. At East Point, maximum fission occurred in April and coincided with a period of sexual reproduction, when annual precipitation was at a maximum and the reefs were exposed for less than 4 hrs day⁻¹. This study suggests that *H. leucospilota* may use fission to maintain population level when sexual recruitment fails.

Introduction

Townsley and Townsley (1973) reported the occurrence of small individuals of *Holothuria leucospilota* at Fanning Island. This led to the speculation that recruitment of this species is via spontaneous fission. This phenomenon was only confirmed in 1997 when Conand et al. (1997) reported fissiparity in *H. leucospilota* from Reunion Island, Indian Ocean, bringing the total of fissiparous holothurian species to 10 (Purwati 2001).

One common feature among fissiparous holothurians is that the fission potential is not expressed in all habitats. The factors that trigger fission (i.e. those that work locally or specifically) have been debated. When two or more fissiparous species share the same habitat, not all of them undergo fission. At Rongelap Atoll, *H. atra* is triggered to fission, but *H. leucospilota* is not (Bonham and Held 1963). At Heron Island, *S. chloronotus* undergoes fission, but *H. leucospilota* does not (Franklin 1980). This kind of phenomenon also occurs with *H. leucospilota*, *H. atra* and *S. chloronotus*, which share the same habitat at Fanning Island (Townsley and Townsley 1973) and *H. atra*, *S. chloronotus* and *H. edulis*, which were kept under laboratory condition (Uthicke 1997).

This paper aims to determine the seasonal pattern of *H. leucospilota* asexual reproduction at Darwin harbour, and to analyse the results of monthly observations of individuals resulting from fission. Because these *H. leucospilota* populations also undergo sexual reproduction (Purwati and Luongvan 2003), the relative importance of fission will also be evaluated.

Materials and methods

An investigation of *H. leucospilota* was made at Nightcliff (12°22'45 S and 130°50'45 E) and East Point (12°24'20 S and 130°50'49 E), in Darwin, northern Australia. These areas are dominated by a wet and dry season, and experience semi diurnal tides. Individuals of *H. leucospilota* inhabited intertidal areas of approximately 300 m x 500 m at Nightcliff, and 500 m x 700 m at East Point. Individuals showed patchy distribution over the intertidal reefs, small sandbars (mainly at Nightcliff), and rocky areas (mainly at East Point).

Population densities

Transect lines were established on Nightcliff's intertidal zone in November 1999. Eight 160-m-long transect lines were placed every 20 m, and each line contained eight circular quadrats (4 m in diameter). Within each circle, the number of individuals was recorded.

East Point reef is a rock formation with a lower area of silt and rubble. Because of this, it was necessary to estimate the population density separately. The lower area experiences two low and high tides a day. Five circular quadrats (4 m in radius) were randomly distributed.

During ebb tide on the rock, individuals were more likely to be trapped in tidepools as only high spring tides cover the entire area. During ebb tides, tidepools of varying size were exposed in the (or intervening with) dry rocky areas. This arrangement of tidepools prevented the use of transect lines. Instead, holothurians from seven standing

tidepools were counted to provide an estimate of the number of individuals per square meter.

Individual size and anatomy

The fresh body weight of 50 individuals was measured using a 500 g Pesola field balance every three months. Only individuals with stiff skin were sampled as they were considered to hold the optimum amount of water in their bodies. Any water expelled from the posterior end was weighed inclusively. As soon as a randomly chosen individual was taken from the water, it was placed in a plastic bag, suspended on the balance. This procedure was used in order to minimise disturbance.

Thirty individuals resulting from fission were dissected to examine the internal organs. Cut was made along the body on the ventral side after being drugged with 10 per cent magnesium sulphate for two to three hours.

Fission frequencies

Fission was monitored monthly from August 1998 to January 2000, during daytime low spring tides. Fifty individuals randomly collected were classified according to Conand and De Ridder (1990) into:

- normal individual (N);
- individual in process of fission (F);
- anterior end (A) or posterior end (P) individual;
- anterior individual with regenerating posterior complex (Ap) or posterior individual with regenerating anterior complex (Pa).

The fission and regenerating rate were then estimated based on formulas by Conand et al. (1997):

- Fission rate (F%):
$$\frac{(A + P)}{2 \times n} \times 100$$
- Regenerating rate (R%):
$$\frac{(Ap + Pa)}{n} \times 100$$
- Product of fission (%):
$$\frac{A + P + Ap + Pa + (2 \times \text{recently fission})}{n} \times 100$$

(n: total number = 50)

Results

Population densities and individual size

The tidepools at Nightcliff were comparatively shallow, with a mean depth at low tide of less than 30 cm. The substratum was silty, and provided numerous shelters due to the presence of dead corals

and rocks. At low tide, the water temperature of the tidepools ranged from 30–36°C in an exposed area, and 28–34°C in shaded crevices. Fewer individuals were found closer to the beach. During low tide on the rock platform at East Point, several pools had deeper (approximately 50–70 cm) and clearer water with relatively coarser sand grains and less silt on the bottom than those at Nightcliff. The water temperature at spring low tide ranged from 30–38°C. Otherwise, the water temperature varied between 30 and 36°C.



Figure 1. Individual undergoing fission at Nightcliff

The density of holothurians at Nightcliff was estimated to be 0.054 individual m⁻², while random sampling over the lower area of East Point gave an estimate of 0.077 individual m⁻², and within tidepools on rocky platforms, density was 0.290 individual m⁻².

At Nightcliff, the largest individuals were between 200 and 225 g in drained body weight, only rarely reaching 275 g. More than 50% of collected individuals were 50–125 g, and individuals less than 50 g were more common there than at East Point. The size range at East Point was greater than that at Nightcliff, with the maximum size of individuals exceeding more than 450 g. Small, up to 50 g, individuals appeared in May 1999, which coincided with a period following intensive fission (Fig. 2). A “T test” of mean individual sizes (measured in successive sampling sessions in the two areas) showed that individuals at Nightcliff were significantly smaller (test, $P < 0.05$). Exceptions occurred between June (at Nightcliff) and May (at East Point) ($P = 0.1514$). This coincided with a high fission rate at East Point.

Most successive sampling sessions at Nightcliff showed significant difference in mean individual size. This may be a consequence of a relatively stable fission rate. At East Point, there was no significant difference, except between January and

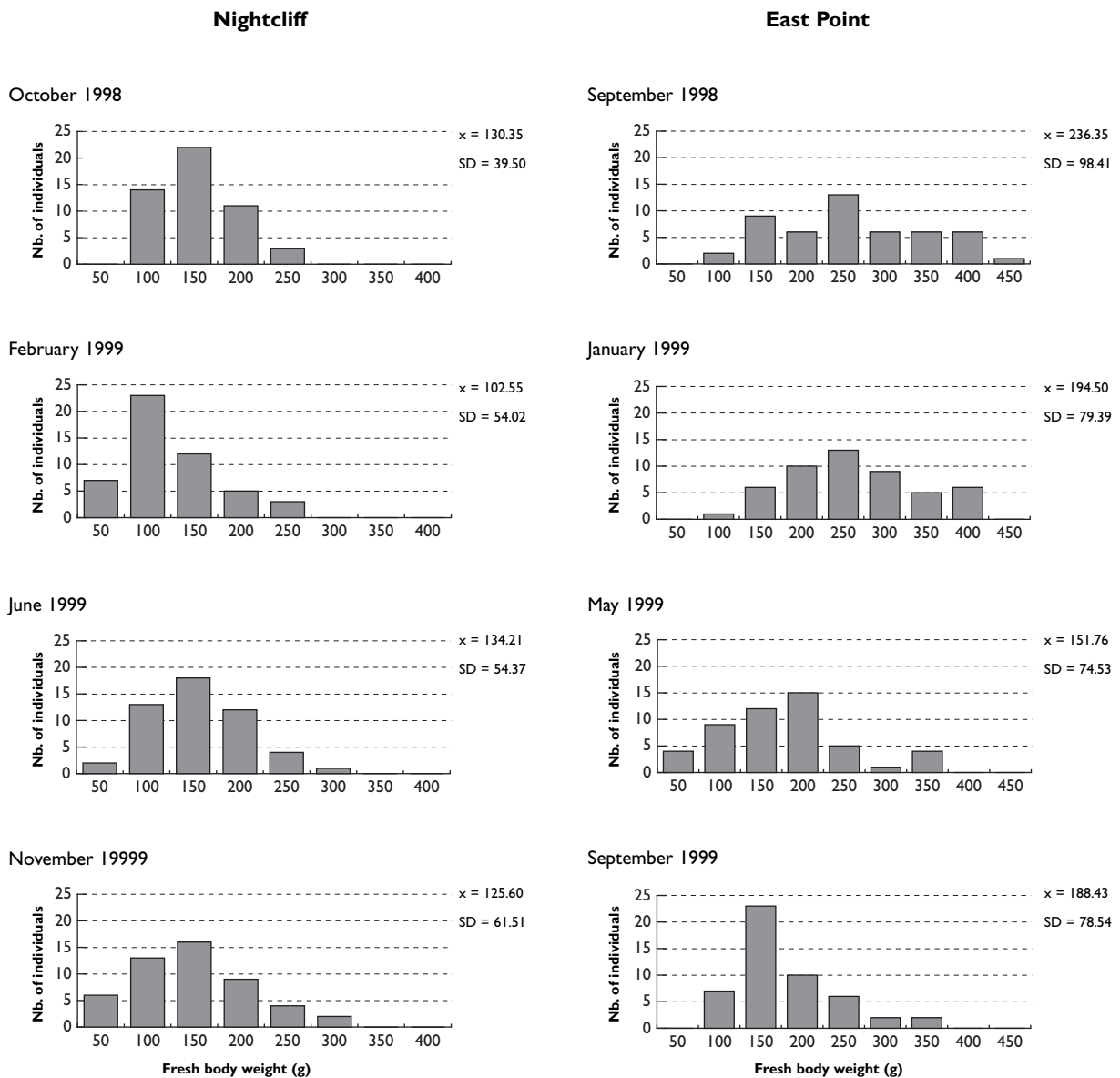


Figure 2. *H. leucospilota* size composition in Nightcliff and East Point

September 1999, which coincided with a pre- and post-intensive fission period (Fig. 2).

Ten out of 29 individuals kept in aquaria underwent fission from August–September 1998, March–April 1999, and January 2000. In order to estimate the position where the body split prior to division, the fresh body weight of these fission animals was recorded (Table 1).

Fission frequencies

All fission categories were present every month except July at East Point (Fig. 3). The average fission product was 8.33% of the sampled population, with

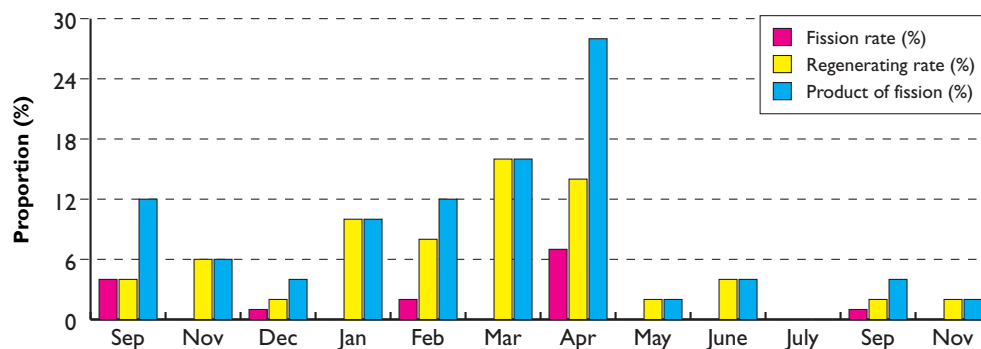
a maximum value of 28% at East Point, and 6% with maximum of 8% at Nightcliff. The frequency of the regenerating rate increased in January and reached a maximum in March and April at East Point. At Nightcliff on the other hand, the regenerating rate went up and down slightly, between 2 and 6%, with a maximum of 8% in March.

Recently fissioned individuals were always found to be less numerous than regenerating individuals. Between regenerating categories, the number of Pa was higher (2.0% at East Point and 1.6 at Nightcliff) than Ap (0.9% at East Point and 0.6% at Nightcliff), indicating a possible difference in survival rates between the two ends.

Table 1. Proportion, in fresh weight (g), of A and P individuals that divided transversally in the aquarium (n = 10).

Date	Mouth end A (g)	Anal end P (g)	A to P (%)	A/A+P (%)
Aug. 98	17.40	143.65	12.11	10.80
Sep. 98	61.14	101.05	60.50	37.70
	24.54	63.07	38.91	28.01
Mar. 99	30.39	87.04	34.91	25.88
	32.07	102.93	31.16	23.76
	29.74	98.72	30.13	23.15
	22.57	89.09	25.33	20.21
Apr. 99	29.43	73.49	40.05	28.60
	43.49	101.17	42.99	
	30.06			
Jan. 00	50.03	156.28	32.01	24.25
Average:	34.08	101.65	34.81	25.24
SD:	13.48	28.70	12.56	6.98

a) East Point



b) Nightcliff

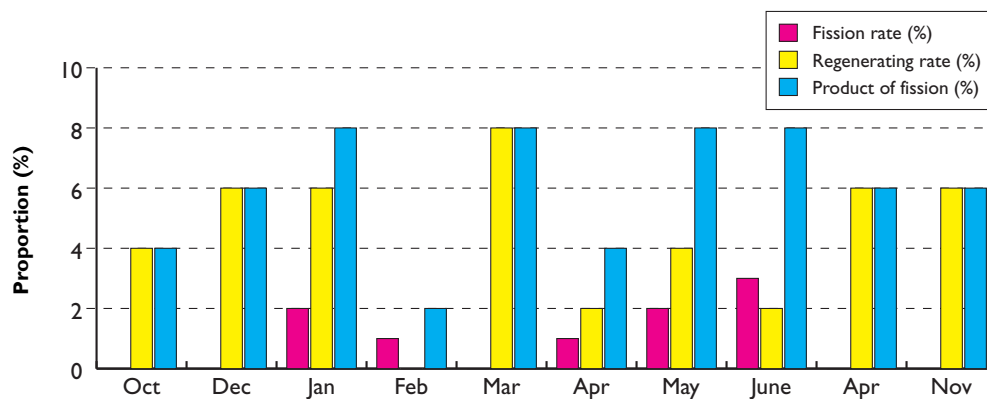


Figure 3. Proportion of fission products

Anatomical variations

Specimens that recently underwent fission showed no open wound on either body end. Mouth-part individuals (A and Ap) were always with an intact buccal complex, and anal-part individuals (P and Pa) with an intact anal complex. The intestines of most specimens were empty, indicating they had stopped feeding. Muscle bands and intestines appeared to grow earlier than other organs, both in anterior and posterior end individuals (Table 2).

Discussion

The phenomenon of fission

Multiple fission was not observed in the *H. leucospilota* populations studied. Likewise, it has not been found among other fissiparous species of Aspidochirota or Dendrochirota, even though six individuals of *H. parvula* resulting from fission have been reported without both anal and anal parts (Emson and Mladenov 1987). Fission in *H. leucospilota* did not seem to create an open-ended body, or spoil any internal organs. The mechanism of twisting and constricting occurring prior to fission was

suggested to promote tight closure of the fission area immediately after the body separated. In the laboratory, fission was not observed, although it was possible it occurred during the night, as has been suggested for *S. chloronotus* (Uthicke 1997).

Regeneration of internal organs began not long after the external wound healed. Muscle bands regrew in individuals of A and P, and together with the intestine reached a single point at the healed wound of either anterior or posterior ends. The empty intestines indicated no feeding activities. In Ap individuals of the same species inhabiting Reunion Island, the anus has been suggested to develop prior to the lengthening of the intestine, forming an “s” shape (Conand et al. 1997). This may take considerable time.

Anal end portions seem to have a better survival rate than mouth end individuals. The same was observed for *H. leucospilota* on Reunion Island (Conand et al. 1997), and other species including *H. atra* in Nanwan, Taiwan (Chao et al. 1993) and *S. chloronotus* on the Great Barrier Reef (Conand et al. 2002). However, in *H. parvula* from Fort St. Catherine, Bermuda, both portions of the body

Table 2. Anatomical condition of dissected individuals

Fission categories (morph)	Anatomical conditions
A 10 specimens in total	<ul style="list-style-type: none"> • Anterior complex intact. • Intestines empty with yellow or greenish colour; short with rupture at posterior end or running straight to posterior-blind-end, attached to inner body wall joining tips of five pairs of muscle bands while cloaca and anal aperture absent. One specimen was observed to have small amounts of fine-grained sand at distal portion of intestine, which were not attached to the inner side of posterior end of integument. Only on occasion did the muscle bands not reach the posterior blind end. • Respiratory trees: only distal portion of right side. • Haemal network: present in several individuals. • Gonad: proximal parts of tubules hanging on gonad basis observed in one individual
P 9 specimens in total	<ul style="list-style-type: none"> • Anal/posterior complex intact. • Intestines thin, yellow or greenish; long enough to create “s” shape with the end free and ruptured; or straight with posterior end in association with inner wall of integument at anterior-blind-end, joining muscle band ends; mouth and other buccal compartment not developed. • Gonad: not found with gonad basis. A single individual maintained distal parts of gonad tubules free in body cavity
Ap 5 specimens in total	<ul style="list-style-type: none"> • Calcareous ring and buccal area intact. • Intestine: always found reaching inner side of posterior-blind-end. Most with empty intestines. • Cloaca: membrane-like structure found in two specimens; absent in others • Gonad: not found. (One specimen found with complete visceral organs, except gonad.)
Pa 6 specimens in total	<ul style="list-style-type: none"> • Calcareous ring: might be absent or present, tentacles may not be obvious. • Intestines: distal portion always reached inner integument surface; relatively long, might be in “s” shape. • Haemal network: always present • Gonad: only one female and one male with fully-grown gonad (orange in female and creamy in male, but tubules relatively small in number and dimension). One specimen found with complete viscerae, except gonad (integument at anterior end was pale and print of tube feet arrangement remained).

have similar rates of survival (Emson and Mladenov 1987). Behaviours such as *H. leucospilota* anchoring its body using the posterior end (Bonham and Held 1963) may reduce the probability of anal end individuals (P and Pa) being washed away, while mouth end individuals may be more easily swept away and accessible to predators.

This study confirms that the body area where fission occurs is specific to each fissiparous species. Fission produced smaller mouth end individuals, similar to that found at Reunion (Conand et al. 1997) and Fanning islands (Townesley and Townesley 1973). In *H. atra*, the mouth end part is smaller (44%) than the anal end portion (Chao et al. 1993; Conand 1996), whereas in *S. chloronotus* the mouth end part is slightly larger than the anal end portion (Conand et al. 1998). In *H. parvula* (Kille 1942; Emson and Mladenov 1987), and *H. surinamensis* populations (Crozier 1917), the area of constriction is in the middle of the body.

In the present study, the gonadal base belonged to the mouth end individual (A), which differs from Conand et al. observations (1997). The anal end individual (P) held the distal parts of gonad tubules, which were located freely within the body cavity. Interestingly, the gonadal tubule at both ends was blind and retained full-grown oocytes. It seemed that gonadal tubules had been somehow prepared to break down before the body divided morphologically into two different portions. Whether these tubules were absorbed later remains unknown.

Fission frequency

Fission occurred throughout the year in populations of *H. leucospilota* at both sites. Compared with the continuous fission of the *H. parvula* population in Bermuda (Emson and Mladenov 1987) or to the seasonal fission of *S. chloronotus* at Reunion Island (Conand et al. 1998), the fission period for *H. leucospilota* was shorter. Higher frequencies of fission in East Point coincided with high rainfall, from December to March. During this period, low spring tides totally exposed the reef between 1100 and 1600 hr (the same was true for Nightcliff), which confirmed Ferns' (1995) observations. During these months, desiccation is more intense, direct solar radiation and water temperature are greater, while salinity is lower. One or a combination of these conditions may trigger fission.

Spontaneous fission of *H. leucospilota* also occurred at the laboratory where the above environmental conditions were absent. Two other fissiparous species, *S. chloronotus* and *H. edulis* have been reported to divide under laboratory conditions (Uthicke 1997). Unless unknown stimulating fac-

tors were present at the laboratory, it is possible that the individuals have been naturally stimulated before being transferred to the laboratory. In this case, triggers would require an "incubation time" before individuals act on the stimuli. However, it is unlikely, as fission still occurred two to three weeks after the individuals had been kept in the laboratory. Under-nourishment may also be considered as one of the possible fission stimulators, as food was not given during rearing. Again, it was unlikely to be the fission triggering factor for *H. atra*, a species usually living in eutric areas (Conand 1996), during experiments where more food was made available for sediment feeders (Uthicke 1997). The empty intestines and blind ended fractions of gonadal tubules in recently divided individuals may offer evidence that internal organs prepared for division before the body splits.

Role of fission in the population

Current investigation conforms to general characteristics of fissioning populations: high-density populations of mostly small individuals (Chao et al. 1993; Conand et al. 1998; Uthicke 1997). When fission produces small individuals, the habitat is able to accommodate larger numbers, because biomass is related to habitat capacity (Uthicke 2001). In comparison, the population of *H. leucospilota* at Heron Island, in which fission is absent, has been reported to have wet body weight between 10 and 1200 g, with a density of 0.031–0.245 ind. m⁻² (Franklin 1980).

Several researchers agree that a high rate of fission, and a low recruitment of juveniles produced through gamete fertilisation, may indicate that fission is important in sustaining local populations. Fission may play a role in either maintaining population density (Emson and Mladenov 1987; Conand et al. 1998) or increasing it (Chao et al. 1993; Chao et al. 1994). This seems to be the case with the Nightcliff and East Point populations, where small, normal individuals less than 10 cm long or weighing less than 10 g of fresh body weight were hardly found.

Fissiparous species use their asexual reproduction ability only in certain habitats. But, there is no report of a fissiparous population that does not develop gonads (that are not able to reproduce sexually). This may demonstrate that fission is a secondary strategy, operating when sexual reproduction fails.

Naturally, every population attempts to reach optimum density in its habitat (Uthicke 1997). In fissiparous holothurians, both asexual and sexual reproductions may occur simultaneously in order to

maintain population. When sexual reproduction is incapable of attaining the optimum population density (because of insufficient number of breeders or failure during embryonic and larval stage), then perhaps, fission potential would be generated to function. In this case, fission would act to compensate unsuccessful sexual reproduction. Indeed, this hypothesis requires further investigation. However, if the dual role of fission in population maintenance is acceptable (as a replacement for and as supplemental to sexual reproduction), then it is unlikely that fission reduces sexual reproductive activity as suggested by Emson and Mladenov (1987), Chao et al. (1994) and Conand (1996).

Sexual reproductive efficiency may decrease when individuals become smaller in size due to self-division. And, development of gonads in the population may not guarantee success of sexual recruitment, as failure may occur after the gametes are released. When the environment becomes risky for sexual recruitment, fission seems to have the potential to compensate the failure, as individuals produced by fission have already adapted to the parent habitats, as well as to predatory avoidance (Emlet et al. 1987). In such cases, fission becomes more effective in population upholding.

Unlike *S. chloronotus* populations on the Great Barrier Reef and Reunion Island, for which fission and spawning occur at different periods (Conand et al. 2002), *H. leucospilota* populations showed a limited spawning activity (Purwati and Luong-van 2003) and an important fission activity taking place during the same month. Does it indicate that fission is the main strategy of population upholding in the local habitat of Darwin harbour? Whatever the importance of asexual reproduction in this *H. leucospilota* population, it maintains a population with a sex ratio of 1:1 (Purwati and Luong-van 2003). This means that fertilisation can still be accommodated, or, in other words, that the ability for this *H. leucospilota* population to reproduce sexually is not affected by fission. In *S. chloronotus*, a high fission rate produces a population with more males than females (Conand et al. 2002) — which may imply that males have a higher potential to undergo fission. As a consequence, during spawning events, there is a limited number of eggs in the water column and chances of a successful sexual reproduction are limited. Therefore, it is true that fission reduces the sexual reproductive ability in this population, as is the case with *H. atra* (Conand 1996).

The possible usage of fission potential

The beche-de-mer trade involves 15–20 holothurian species, including at least four fissiparous species. Fission potential of these species could be

used to accelerate restocking and population enhancement. Reichenbach and Holloway (1995) have conducted an interesting fission experiment on several commercial holothurian species. Rubber bands were put around specimens to induce fission. The technique successfully stimulated binary division, but only *S. chloronotus* and *Thelenota ananas* had a high survival rate for both ends. *A. miliaris* and *S. variegatus* were able to develop the anterior part of anal end individuals, despite the fact that the last three-mentioned species are not known to divide naturally in the wild. Since each fissiparous species has a particular fission point, rubber bands placed correctly may increase the survival rate of both portions. This, in turn, may increase the chances of success of a sea cucumber stock enhancement programme based on reproduction by induced fission.

Acknowledgement

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Valuation of sea cucumber attributes through laddering¹

Timothy H. Lo

Purchasing dried sea cucumber and rehydrating it for cooking has always been a time consuming process. This study aims to provide direction for the development of more convenient products. Specifically, this research will:

- identify and rank the importance of quality attributes used by restaurants to judge the quality of dried sea cucumber; and
- produce a “hierarchical value map” linking sea cucumber attributes with consequences and values.

This research uses the laddering technique to identify important sea cucumber characteristics and to link them to consequences. Laddering uncovers product characteristics and consequences by following the means-end theory (Grunert 1995). Consequences are important; as Bredahl et al. (1998) found with respect to product design, it is necessary to translate consumer demands into product specifications that can be met by producers. With regard to sea cucumbers, however, it is especially complicated because the majority of restaurant owners’ perceptions of dried sea cucumber differ from the quality of cooked sea cucumber as perceived by consumers. Olsen and Reynolds (2001) mention that the key to the means-end approach is understanding consequences. Hence, this research focuses on how restaurants judge the quality of dried sea cucumber and the consequences of selecting sea cucumber, based on certain attributes. The study employed a sample of 10 chefs and 4 wholesalers/retailers in Singapore. Selected respondents were well acquainted with sea cucumber products, and were willing to talk about them. The information collected in the interviews was coded, and frequencies were analysed in an implication matrix. The hierarchical value map (Fig. 1) presents a summary of the most frequent attribute–consequence relationships.

Moisture content

Moisture content influences the shelf life of dried sea cucumber (Fig. 1). Moisture is gauged by judging how heavy a sea cucumber is relative to its size, feeling how hard the sea cucumber is, and smelling for “off” odours. The lighter the sample, the drier it is, although numerous factors affect sea cucumber weight. The presence of salt, sand, calcium powder,

as well as flesh thickness affect weight; therefore, experience is needed when using weight as an indicator of moisture. The harder the sea cucumber, the drier it is, but each species is unique with some being softer than others. A sea cucumber that is not dried properly will rot and give off bad odours. The majority of respondents suggested that the implications of moisture content are mainly economic. The implication matrix, however, shows that a minority of respondents linked moisture content with rehydration, cooking processes, and eating quality. This suggests that the moisture attribute may have both economic and eating quality implications.

Exterior appearance

It is important that dried sea cucumber not to be damaged as it causes disintegration during cooking (Fig. 1). This is particularly important for sea cucumber dishes served whole. For example, whole sea cucumber stuffed with meat would fall apart if there were cracks in the flesh. This affects the presentation of the dish, which consequently impacts on the reputation of the restaurant. Some respondents mentioned that for certain unspecified species, smooth skin is an important attribute as it indicates that the sea cucumber was still alive when it was caught. According to these respondents, skin texture influences the eating quality of the sea cucumber. However, what constitutes smooth or rough skin could not be confirmed as skin texture varies widely between species. Furthermore, only two respondents mentioned skin texture; therefore, it is not thought to be an important attribute. The term exterior appearance also describes a uniform round shape. Exterior appearance is one attribute that producers can focus on to enhance value without modifying the inherent characteristics of the sea cucumber. Producers who are aware of dishes requiring whole sea cucumber, can focus on exterior appearance when processing sea cucumber destined to be cooked whole. Subasinghe (1992) details sea cucumber processing to obtain acceptable exterior appearance.

Size

The size of the sea cucumber influences the type of dish and the cooking process (Fig. 1). Different

1. Summary of a document submitted for the Honours Degree in Bachelor of Agribusiness (Aquaculture) at Curtin University of Technology.

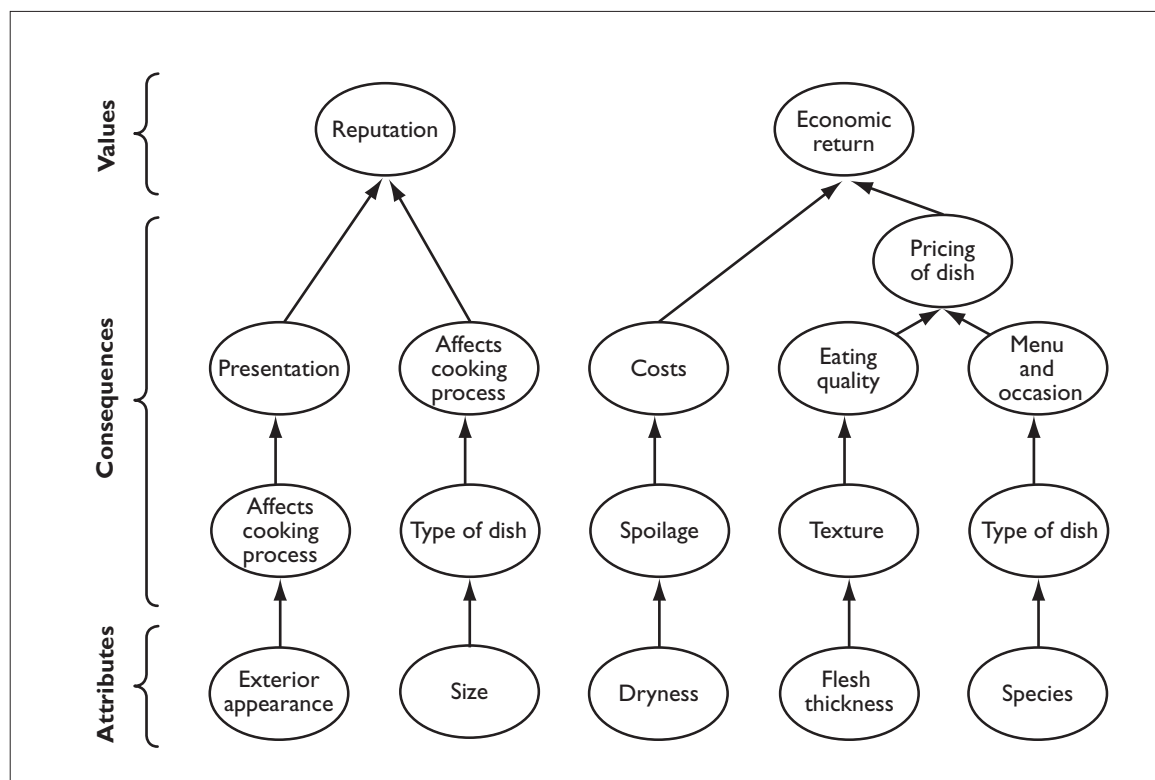


Figure 1. Hierarchical value map of sea cucumber attributes

dishes require different cooking times and unless the correct size of sea cucumber is selected, the sea cucumber may not be cooked to perfection. An overcooked sea cucumber becomes “mushy”, affecting the reputation of the restaurant. Chefs at Huat Kee’s Teochew restaurant and Quan Xiang Yuan Seafood restaurant mentioned they preferred to purchase a sack of ungraded sea cucumber at an inexpensive price instead of graded sea cucumber. This is because it is important for restaurants to have a range of sizes so that a variety of sea cucumber dishes can be prepared. Bigger sea cucumbers are worth more but they are also cooked differently: larger sea cucumber taking longer to cook. Larger sea cucumbers may be worth more because dishes that use larger sea cucumber are often served on special occasions (e.g. sea cucumber roasted with a whole duck served at weddings). When purchasing ungraded sea cucumber, size and exterior appearance varies, although the purchasing decision is determined by economic return. Lower priced cucumbers with poor exterior appearance are chopped up and used in dishes requiring sea cucumber pieces. Restaurants’ preference for ungraded sacks of sea cucumber is likely to continue; therefore, sea cucumber grading may be more suitable for retail markets or for processors that sell rehydrated sea cucumber.

Flesh thickness

Texture is the most important characteristic when judging sea cucumber, as the product itself has no flavour of its own. As a result, sea cucumber consumers focus on texture to gauge quality. Good texture is described as flesh that has some springiness without being tough or soft. Generally, thicker flesh results in better texture but each sea cucumber species has unique texture characteristics. The ultra premium species, Qi Sam (*Apostichopus japonicus*), is noted for a “crunchier” or firmer eating texture. Large sea cucumbers usually have thicker flesh, therefore flesh thickness is more important in smaller and medium sized sea cucumbers. Respondents use flesh thickness as an indicator of texture and eating quality. Eating quality influences the pricing of dishes and economic return.

Species

Different species are used for different dishes and different dishes are served on different occasions (Fig. 1). Prices are adjusted according to the dish thereby influencing economic return (Fig. 1). Cooking style is influenced by the cooking traditions of different Chinese regions, which are known for using specific species of sea cucumber.

Therefore, when marketing sea cucumber to restaurants, it is important to match the correct species to the restaurant's cooking style. It should be noted that each species of sea cucumber has its own attributes. Dried sea cucumber is classified by species and certain species are only found in specific countries. Therefore, country of origin is another indicator of quality and consistency. Consistency is important because chefs become accustomed to utilising sea cucumber in a certain manner to obtain particular eating qualities. The ability to purchase sea cucumber from the same region repeatedly is a reason why relationships between restaurants and suppliers are valued.

Discussion

Relationships between restaurants and suppliers are also important because the true quality of sea cucumber can only be judged after it has been rehydrated (i.e. after purchasing occurs). This suggests an element of trust between suppliers and restaurants. Sea cucumber producers who have strong relationships with suppliers may be able to provide restaurants with a more consistent supply of sea cucumber from the same region. Walter (2003) finds that close supplier relationships also result in faster development of new products at a lower cost. Building strong relationships with suppliers is therefore mutually beneficial for sea cucumber producers, suppliers and even customers. While this research focused on restaurants as users of sea cucumber, it is just one of four distinct segments of customers for sea cucumber producers. Restaurants, retailers, wholesalers and processors represent different sea cucumber market levels and Zucker and Anderson (1998) suggest that different market levels have different preferences. As mentioned, some restaurants prefer to purchase sacks of ungraded sea cucumber at a cheaper price. Therefore, in creating value for customers, it may be wise to differentiate between segments of customers. A trend toward the purchase of already rehydrated sea cucumber by restaurants became evident through the course of this study. This suggests that the processing sector that produces rehydrated sea cucumber may be increasing in importance. Da Dong Restaurant, Marriot Hotel and Sheraton Towers stated that processing sea cucumber is a time consuming and labour intensive task. Sorensen et al. (1996) found that convenience in buying, preparing and eating fish was perceived as important to consumers of seafood. Therefore, in the development of new products, sea cucumber producers could focus on creating value through convenience. Innovation in research and development is also an important factor for the future of traditional food industries (Jordanna 2000). Restaurant chefs mentioned that seafood products

such as lobster, abalone and fish maw have overtaken sea cucumber in popularity. If the sea cucumber industry fails to innovate, it could lose greater market share.

Sea cucumber is commonly coated in calcium powder to protect against insect infestation and moisture absorption. However, there is conflicting evidence on the preference of calcium coating. Hong Kong consumers prefer calcium coated sea cucumber (Ferdouse 1997), while Huat Kee's Teochew Restaurant claimed it was a tactic employed by producers to add weight. Furthermore, Chef Chan's Cantonese Cuisine explained that if calcium powder was not washed off properly, it could give a bitter taste to the food. Quantitative studies are needed to determine where the bias lies for this attribute, although packaging could also be used to protect sea cucumber from insect infestation and moisture absorption. Protective packaging may even enhance convenience as less labour would be involved in scrubbing the calcium off.

If market orientation is to improve company performance, it implies the continuous adaptation of the company's products to the market (Grunert et al. 1996). Therefore, most of this discussion has centred on the creation of value for sea cucumber customers through new products or closer relationships. The food industry however, evolves slowly and incrementally, rather than through sudden technological revolution (Grunert et al. 1996). This is probably true for the actual sea cucumber product itself but not necessarily true for the value-added product. For example, packaging that allows supermarkets to stack punnets of strawberries more efficiently, can create value without modifying the actual product. Therefore sea cucumber producers should focus on creating value for specific segments through the creation of convenience.

Additionally, this research did not focus on the pharmaceutical prospects for sea cucumber. Chen (2003) highlighted the trend toward sea cucumber extracts as nutritional supplements and functional foods. Product development in this area could occur more quickly as compared with the food industry. Therefore, pharmaceutical applications for sea cucumber should be a priority for future research.

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Natural spawning observations

Bohadschia marmorata

- Observer: Michael Rard, Ecomar, La Reunion University
- Location: La Saline-les-Bains, Petit Trou d'Eau, Reunion Island, Indian Ocean. Observed in the back reef in 1 m depth.
- Date: 24 April 2004, 17:00.
- Moon: 5 days after new moon
- Tide: Low tide
- Note: Two male individuals have been observed in the classical upright posture.

Bohadschia similis

- Observer: Aymeric Desurmont, SPC
- Location: Baie de Tembia, New Caledonia. On sandy-muddy bottom. 3-4 m depth.
- Date: 20 December 2003, 17:00.
- Moon: 3 days before new moon
- Tide: High tide
- Note: Other specimens of the same species nearby showed no sign of reproductive behaviour.



Spawning
Bohadschia similis

(Image: A. Desurmont)

Stichopus chloronotus

- Observer: Aymeric Desurmont, SPC
- Location: Baie des Citrons, New Caledonia. Bottom with rocky surfaces covered with crustose and sparse filamentous algae, and sparse *Cymodocea* seagrass areas. 3 m depth.
- Date: 11 December 2003, 18:30.
- Moon: 2 days after full moon
- Tide: 2.5 h after low tide
- Note: Other specimens of the same species nearby showed no sign of reproductive behaviour.



Spawning
Stichopus chloronotus

(Image: A. Desurmont)



Abstracts & publications beche-de-mer

Advances in sea cucumber aquaculture and management

Alessandro Lovatelli, Chantal Conand, Steve Purcell, Sven Uthicke, Jean-François Hamel and Annie Mercier (eds).

Source: FAO Fisheries Technical Paper. No. 463. Rome, FAO. 2004. 457p.

This FAO Technical Fisheries Paper collates all the technical papers presented at the international workshop on “Advances in Sea Cucumber Aquaculture and Management” (ASCAM) held from 14 to 18 October 2003 in Dalian (Liaoning Province), People’s Republic of China, and organized by the FAO Fisheries Department. The publication is divided in four sections. The first part includes the introduction and recommendations made by the participants on issues concerning sea cucumber resource management and aquaculture. The next three sections contain the technical papers presented and discussed at the three sessions, namely (i) on the status of resources and utilization (Session I), (ii) on resource management (Session II), and (iii) on aquaculture advances (Session III).

Up-to-date information on the present status of world sea cucumber resources and utilisation is presented with special focus on those countries such as the People’s Republic of China, Ecuador, Indonesia, Japan, Malaysia and the Philippines, which have been heavily engaged in the industry for decades. Information from other countries such as Cuba, Egypt, Madagascar and Tanzania, relative new comers to the sector, is also provided indicating to some extent the growing interest with regards to the exploitation of holothurians for the demanding Asian markets.

The session on resource management focuses on the experiences of countries, highlighting progress made as well as identifying the constraints and knowledge gaps that need to be addresses to ensure adequate management of these multi species fisheries. Issues raised include whether restocking and stock enhancement should be used to manage sea cucumber fisheries.

Information on technical advances made in the artificial reproduction and farming of selected commercial species, particularly for the Japanese sea cucumber, *Apostichopus japonicus*, is presented. Furthermore, the workshop in Dalian provided the opportunity to share findings from ongoing research activities on a variety of other sea cucumber species including the Galapagos sea cucumber, *Isostichopus fuscus*. The interest in holothurian aquaculture is growing. This is evident from the number of countries that are engaged in sea cucumber aquaculture research, possibly as a result of declining natural resources or national aquaculture species diversification programmes.

The workshop recommendations were formulated and agreed during discussion sessions and are designed to help international and regional development organizations and national governments prioritize their activities concerning sea cucumber conservation and exploitation.

To receive a copy of the proceedings of the “Advances in Sea Cucumber Aquaculture and Management” (ASCAM) workshop in China, please contact: Alessandro.Lovatelli@fao.org

Preservation of genetic diversity in restocking of the sea cucumber *Holothuria scabra* investigated by allozyme electrophoresis

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2. WorldFish Center, BP D5, 98848 Noumea Cedex, New Caledonia

Source: Canadian Journal of Fisheries and Aquatic Sciences 61:519–528.

Population genetics analyses should be considered when releasing hatchery-produced juveniles of *Holothuria scabra* when spawners from non-local populations are used. In New Caledonia, within-region genetic heterogeneity of *H. scabra* populations, examined through allozyme electrophoresis of 258 animals, indicated high gene flow between nine sites and FST values did not deviate significantly from zero. However, exact tests indicated that populations at two sites with limited water exchange in the southern

location were significantly different from populations at three other locations on the west coast. Inclusion of *H. scabra* sampled in Bali (n = 90) and Knocker Bay, Australia (n = 47), and comparisons with existing data from the west Pacific (Torres Strait, Solomon Islands, Upstart Bay, Hervey Bay) showed that populations were significantly different (using exact tests), and samples partitioned distinctly using UPGMA (Unweighted Pair Group Method with Arithmetic mean) clustering. Rogers' genetic distance values between populations were significantly related to geographic distances, showing a pattern of isolation-by-distance. The rapid increase in genetic distance over the first few hundred kilometres supports the view that the spatial extent of any translocation needs to be carefully considered on the basis of knowledge of variation in allele frequencies within the target area.

The genus *Labidodemas* (Holothuroidea:Aspidochirotida) revisited, with description of three new species and with re-positioning of *Holothuria* (*Ireothuria*) *maccullochi* Deichmann, 1958

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Source: Journal of Natural History 38:1811–1847.

Prior to the present revision the taxon *Labidodemas* comprised *Labidodemas americanum*, *L. pertinax*, *L. rugosum* and *L. semperianum*. An up-to-date reevaluation of the group proved that at least four additional species need to be assigned to it. Three of these are new to science: one has recently been discovered in the shallow waters of KwaZulu-Natal, Republic of South Africa; one originates from Low Island, Australia, and was erroneously identified as *L. semperianum*, and one stems from South-West Sulawesi, again erroneously identified as *L. semperianum*. In addition, *Holothuria maccullochi*, classified in the monotypic subgenus *Ireothuria*, and *Holothuria proceraspina* are assigned to *Labidodemas*; the former as a valid species and the latter as a synonym of *L. semperianum*. Annotated taxonomic descriptions, distribution maps and an identification key are given. The new observation that *L. americanum* possesses Cuvierian tubules suggests that its rank remains at generic level rather than at family level as was recently proposed.

Development of three commercial sea cucumbers, *Holothuria scabra*, *H. fuscogilva* and *Actinopyga mauritiana*: larval structure and growth

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Source: Marine and Freshwater Research 54:657–667.

Development of the tropical sea cucumbers *Holothuria scabra*, *H. fuscogilva* and *Actinopyga mauritiana* was investigated. *Holothuria scabra* developed through the feeding auricularia, the non-feeding doliolaria and the pentactula larval stages in 14–17 days at 26–28°C. *Holothuria fuscogilva* and *A. mauritiana* were reared to the auricularia and doliolaria stages respectively. The auricularia stage was reached by 40–70 h and the larvae developed lateral processes and a prominent ciliated band. Transformation to the doliolaria stage took 10–12 h and occurred on Days 9–12 in *H. scabra* and Days 12–22 in *A. mauritiana*. During this transition the ciliated band fragmented into ciliary rings, the location of which coincided with the lateral processes in the auriculariae. In *H. scabra*, metamorphosis to pentactulae (13–15 days) was marked by development of five primary tentacles and a ventroposterior podium. This podium was used to attach to the substratum. Development of a second podium marked the development of juveniles (14–17 days). Hyaline spheres were conspicuous in late auriculariae of *H. scabra* and may be an indicator of larval competence. The disappeared in the doliolaria stage, which suggests that they may function as nutritive reserves to sustain *H. scabra* through the non-feeding perimetamorphic period. Absence of these spheres in *H. fuscogilva*, and their poor growth in *A. mauritiana*, suggests the feeding protocol used may not be sufficient to support complete development in these species. Determination of food and culture conditions that promote hyaline sphere formation and control bacteria may be essential for successful culture of *H. fuscogilva* and *A. mauritiana*.

An adaptive rotational harvest strategy for data-poor fisheries on sedentary species: application to the giant red sea cucumber (*Parastichopus californicus*) in British Columbia

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Source: Simon Fraser University website: <http://www.rem.sfu.ca/fishgrp/research.html>

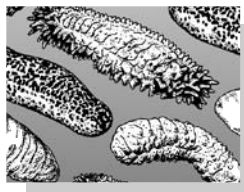
New hope for sea cucumber fisheries - research may help depleted stocks

Steve Purcell

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Source: PACIFIC ISLANDS.CC, the Website of Pacific Magazine and Islands Business, March 2004.

<http://www.pacificislands.cc/pm22004/pmdefault.php?urlarticleid=0032>



Correspondence
beche-de-mer

A call for information from Panama

I am from Panama (Central America), and am researching the possibility of growing sea cucumbers in ponds. I came across your webpage on sea cucumbers on the Internet. I would appreciate immensely, therefore, if you could provide me with any information you may have regarding farming sea cucumber. Having the Pacific and the Atlantic only fifty miles apart, I am certain the sea cucumber could be exploited in Panama, but our seas are so intensely exploited as it is that I would rather contemplate the option of farming it.

Juan Mendez S. (mendezj@sinfo.net)

Reply from C. Conand:

Farming is a difficult task; look at SPC *Beche-de-Mer Bulletin* #19 (2004) and the FAO report when it is available. Preliminary knowledge on the species' taxonomy, distribution and biology is a prerequisite. This is an important task!

Request for information from Dr Kim Friedman, SPC

The PROCFish project, under the auspices SPC's Reef Observatory is collating electronic and paper copies of "grey" literature and regional studies while comparing the status of inshore marine resources in 11 countries of the Pacific. During this five-year EU-funded study, the invertebrate scientist Dr Kim Friedman is collecting sea cucumber survey reports and theses, as well as information on fishing, processing and beche-de-mer prices.

This search will hopefully result in a library of useful information. Articles presently being sought or worked on are Colin Shelley's MSc thesis from PNG, and a translation (from French) of the ecology chapter of Chantal Conand's PhD thesis from New Caledonia. Readers are requested to send electronic or paper copies of any unusual but relevant sea cucumber literature to Kim Friedman at:

Dr Kim Friedman
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