

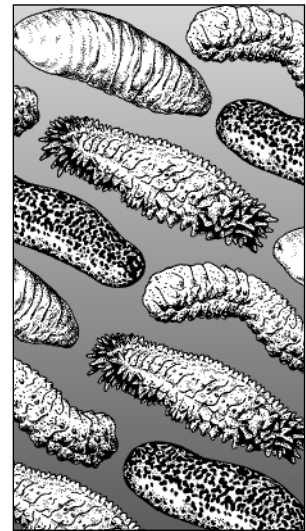


Secretariat of the Pacific Community

BECHE-DE-MER

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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

This is the 23rd issue of a nearly 16-year-old publication, and I believe the bulletin has now reached its cruising speed with two issues published every year for the last five years. I must thank here the many regular and occasional contributors who helped me make this happen, as well as the dedicated SPC Fisheries Information and Publication Sections' staff who work hard behind the scenes to maintain the quality of this publication. The important correspondence included in this issue proves that the bulletin serves well its goal of linking scientists, technicians, fisheries managers and all others with an interest in sea cucumbers, worldwide.

I draw, once again, your attention to the new database of all articles and abstracts published in the bulletin to date. This was put together by SPC's Fisheries Information Section, and is available on SPC's website at: http://www.spc.int/coastfish/news/search_bdm.asp. The database includes nearly 600 article and abstract titles that can be searched by title, author name(s), scientific name, region or country. Each search result is presented with a hyperlink that allows downloading in pdf format. We hope that it is useful and we would like to improve it through your suggestions.

This issue begins with a short article (p. 3) by Warwick Nash and Christain Ramofafia, from the WorldFish Center. The Solomon Islands Government decided to close its beche-de-mer fishery on 1 December 2005, for an indefinite period. A very difficult decision as the fishery was, as in many other countries, one of the rare cash-income opportunities for remote fishing communities. Nash and Ramofafia detail the reasons that led to this ban.

The number of topics covered by the articles in this issue, as well as the wide range of geographic places covered, proves that research on holothurians is alive and well: Mendes et al. have studied populations of *Holothuria grisea* in Brazil (p. 5); Therkildsen and Petersen describe the emergence of the cold-water *Cucumaria*

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frondosa fishery in Canada (p. 16); Pradina Purwati writes a brief description of the west Lombok holothurian fishery in eastern Indonesia (p. 26); Purcell and Tekanene report on the changes in colouration and morphology of white teatfish, *Holothuria fuscogilva*, juveniles in Kiribati, Pacific Ocean (p. 29); and Spalding tells us about an illegal sea cucumber fishery in the Chagos Archipelago, Indian Ocean (p. 32).

We continue to publish research findings about sea cucumber reproduction. Laxminarayana describes his observations in Mauritius of asexual reproduction by transverse fission of *Bohadschia marmorata* and *Holothuria atra* (p. 35); and Desurmont (p. 38) and Spalding (p. 32) briefly report on their observations of natural spawning in New Caledonia, Pacific Ocean, and the Chagos Archipelago, Indian Ocean.

A new regional multidisciplinary project, with collaboration between biologists and socioeconomists from five countries, and Swedish support has just started in the southwestern Indian Ocean. It is funded by grants from the Western Indian Ocean Marine Science Association (see: www.wiomsa.org) and will involve national and regional analyses to improve sea cucumber management (p. 11).

And if you are still doubtful about the variety of holothurian studies, please check the very wide array of topics and places covered in the abstracts we present on pages 39–46.

As usual, this and all previous issues of the bulletin are available in pdf format on SPC's website at: <http://www.spc.int/coastfish>.

Dr Sabine Stöhr, Chief of the Department of Invertebrate Zoology at the Swedish Museum of Natural History, informs us that the *Echinoderm Newsletter* has a new address (URL): <http://www.nrm.se/inenglish/researchandcollections/zoology/invertebratezoology/research/researchprojects/sabinestohr/echinodermata/echinodermnewsletter>. Authors wishing to contribute to the newsletter can contact her at: sabine.stohr@nrm.se.

Finally, please note that, following its usual three-year rhythm, the next Echinoderm Conference will be held in August 2006 on the campus of the University of New Hampshire, Durham, NH (USA) (more information can be found at: www.iec2006.unh.edu).

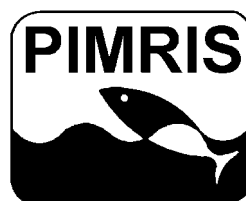
Chantal CONAND

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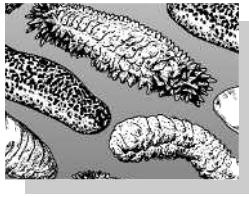


PIMRIS is a joint project of five international organisations concerned with fisheries and marine resource development in the Pacific Islands region. The project is executed by the Secretariat of the Pacific Community (SPC), the South Pacific Forum Fisheries Agency (FFA), the University of the South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



Pacific Islands Marine Resources Information System

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.



new info beche-de-mer

Recent developments with the sea cucumber fishery in Solomon Islands

Warwick Nash¹ and Christain Ramofafia²

In July 2003, the Regional Assistance Mission to the Solomon Islands (RAMSI) entered Solomon Islands — at the invitation of the national Solomon Islands government — to restore law and order following the outbreak of ethnic tension in the late 1990s and the coup in 2000. The return of generally peaceful conditions occurred within weeks. In late August 2003, the WorldFish Center was invited by the Australian Centre of International Agricultural Research (ACIAR) to develop an outline for a project, in the field of fisheries or aquaculture, that would provide benefits quickly to rural Solomon Island communities. In the language of aid and development, the “impact pathway” between the research project and the intended beneficiary (i.e. the village community) had to be short: benefits should flow to the communities during the life of the project, rather than after additional research and development.

One project emerged clearly as a high priority: implementation of sustainable fishery management practices for the sea cucumber fishery. This decision was made because it was evident, from both fishery export statistics and general knowledge, that sales of dried sea cucumber (beche-de-mer) were an important source of income to coastal communities in many parts of the country, and in some places virtually the only source of income. It was also apparent from analyses of export figures and anecdotal reports that sea cucumber stocks were declining in many parts of the country because of unsustainable fishing levels. This project satisfied ACIAR’s requirement of immediate returns because preventing further decline of sea cucumber stocks would contribute to sustainable levels of harvest indefinitely into the future (although at a lower level than current), and thereby continue to be an important source of income for local households. Failure to intervene would result in continued depletion of stocks, and negligible income from this resource, perhaps for many years. Chronic overfishing of sea

cucumbers, and failure of the resource to recover have certainly occurred in other countries, such as the Federated States of Micronesia (Chuuk) and Egypt on the Red Sea. When incentives to fish are high — such as high prices and few alternative sources of income — the rate of depletion may be very rapid, and to a very low level, as happened in several countries (Lovatelli et al. 2004).

Recognising that regenerating overfished stocks, either passively (with slow natural recovery from a low recruitment base) or actively (either by restocking with hatchery-reared juveniles or manually aggregating remnant adult stock to promote gamete fertilisation rates), is slow and costly, we concluded that by preventing further depletion of sea cucumber stocks, ACIAR’s directive to develop a project yielding benefits to rural communities in the short term could be met.

Preparing the project proposal to ACIAR included gathering evidence to confirm that overfishing was occurring. WorldFish Center marine scientist Dr Chris Ramofafia worked with Peter Ramohia of the Solomon Islands Department of Fisheries and Marine Resources (DFMR) to examine beche-de-mer fishery export statistics for evidence of overfishing. The trends were clear: beche-de-mer exports in the early/mid-1990s consisted of a small number of high-value species, but by 2004, the number of species exported had risen to 32, and the proportion of high-value species in the exports was small. This trend reflects the following: 1) a progressive depletion of species, over time; 2) the mean size of individuals within the exports, by species, declined steadily over the same period; 3) the use of destructive fishing methods including the use of “rocket bombs” and dredge nets has increased in the last couple of years; and 4) the number of export licenses issued by DFMR increased from 9 in 2001 to 22 in 2003, and then decreased to 17 in 2004. Dwin-

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ding export volume was the principal reason cited for the decrease in licenses in 2004. Collectively, this evidence of overfishing is at least as strong as that derived from trends in fishery catch rates over time, since fishermen can maintain their catch rates, even when stocks are declining, by moving further afield when stocks in one area decline. (Catch rate trends *can* sensitively track abundance changes if catch statistics are gathered at a small spatial scale.)

The awareness of overfishing raised by this analysis, as well as results of sea cucumber resource surveys by DFMR and other groups, led DFMR to announce an indefinite ban on the harvest and export of all species of beche-de-mer in Solomon Islands until further notice, effective 1 December 2005. DFMR also announced its intention to develop a Management and Development Plan for the fishery.

One of the objectives of our ACIAR-funded project is to develop sea cucumber fishery management plans at the provincial level in Isabel Province and Western Province. This now becomes the highest project priority, and is to be done in coordination with the national management plan. The scale of planning and consultation required to develop a national fishery management plan is beyond the scope or mandate of our project, and will require the efforts of other agencies and additional funds. DFMR is establishing a steering committee to guide the planning process.

The ACIAR-funded project on sustainable management of the beche-de-mer fishery started in January 2005 in the Kia community at the western end of Santa Ysabel (Isabel) Island, one of the major areas of beche-de-mer production in the country. We will describe the project in a future issue of the *Beche-de-Mer Information Bulletin*, but some of the findings to date are worth mentioning here because of their social, economic and resource management implications in relation to the recent ban.

- The importance of beche-de-mer as a source of income was confirmed.
- A shift in species composition in the harvests, from high- to low-value species, has occurred over the past few years.
- Local overfishing is indicated by decreasing catch rates over the last decade.
- Levels of personal debt of sea cucumber fishermen (among others), even in remote village communities, are quite high, mainly to local business entrepreneurs. These debts are serviced by the sale of beche-de-mer. The ban will,

therefore, make it difficult (or impossible if alternative sources of income are not available) to service these debts.

- Alternative sources of income are likely to be sought, and this may include increased harvests of other fished species. Reports of increased fishing for trochus and shark fin since the announcement of the beche-de-mer export ban have been made, but these have not been confirmed or their magnitude determined. If true, then an unintended consequence of the closure of this important source of income to remote coastal communities may be increased fishing effort — perhaps to unsustainable levels — on other species. Given their demographic characteristics (low fecundity and low natural mortality), many shark species are vulnerable to overfishing; the additional fishing pressure that may arise as a result of the sea cucumber export ban would be undesirable, and highlights the urgent need for alternative, sustainable livelihood options for rural communities in Solomon Islands.
- We note that, given the rapid rate at which sea cucumber populations can be depleted when economic incentives are sufficiently high (e.g. the Egypt fishery collapsed within five years after it started: Lawrence et al. 2004), income from sea cucumber fishing in Solomon Islands may have declined to very low levels in the near future even if the ban were not imposed — the difference in loss of income may well have been only a matter of time.

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Population patterns and seasonal observations on density and distribution of *Holothuria grisea* (Holothuroidea:Aspidochirotida) on the Santa Catarina Coast, Brazil

Fabricio M. Mendes¹, Adriano W. C. Marenzi^{2a} and Maikon Di Domenico^{2b}

Abstract

Seasonal population patterns of *Holothuria grisea* — the most abundant sea cucumber species on the Brazilian coast — were examined on intertidal areas in Armação do Itapocoroy Bay in southern Brazil during the winter and spring of 2003, and the summer and autumn of 2004. The study area was divided into three strata, which were defined by tide level: upper intertidal (stratum 1), lower intertidal (stratum 2) and subtidal (stratum 3). This study showed that *H. grisea* occurred more densely in subtidal stratum over all seasons, except autumn when the density was equal between subtidal and intertidal strata. Specimens were found to have an aggregated distribution pattern, but this pattern was limited to rocky sea bottoms, and this species seems to be adapted to areas with high rugosity. Finally, tide level variation seems to determine density patterns.

Introduction

Aspidochirotida are found in the intertidal zone down to the deepest trenches where, they may comprise up to 90% of the total biomass (Pawson 1970; Hendler et al. 1995; Hadel et al. 1999).

Although *Holothuria grisea* (Holothuriidae) are not commercialized in Brazil, they are the most abundant species along the Brazilian coast (Tommasi 1969) and have been consumed (in small quantities) in São Paulo State (Hadel et al. 1999) as well as in Rio de Janeiro State along with the sea cucumber, *Isostichopus badionotus* (Hadel et al. 1999; Lima et al. 2001).

Thus, *H. grisea* could play an important role in the Brazilian economy as a new seafood resource, although few studies on this subject in Brazil have

been conducted (Lima et al. 2001). It is, therefore, important to understand the ecology and biology of this species. This study attempts to understand the density and distribution patterns of *H. grisea* along the southern Brazilian coast.

Methods

Study location

Armação do Itapocoroy Bay is in Penha (Fig. 1), on the north-central coast of Santa Catarina State in southern Brazil (26°46'10" S and 48°49'10" W). This bay is sheltered from strong southerly winds, and is exposed to easterly and northeasterly winds, the latter two being the most frequent in the area. The site is an area of low-energy wave action, gently sloping bedrock, and a sandy substrate consisting of coarse grain-sized sediment.

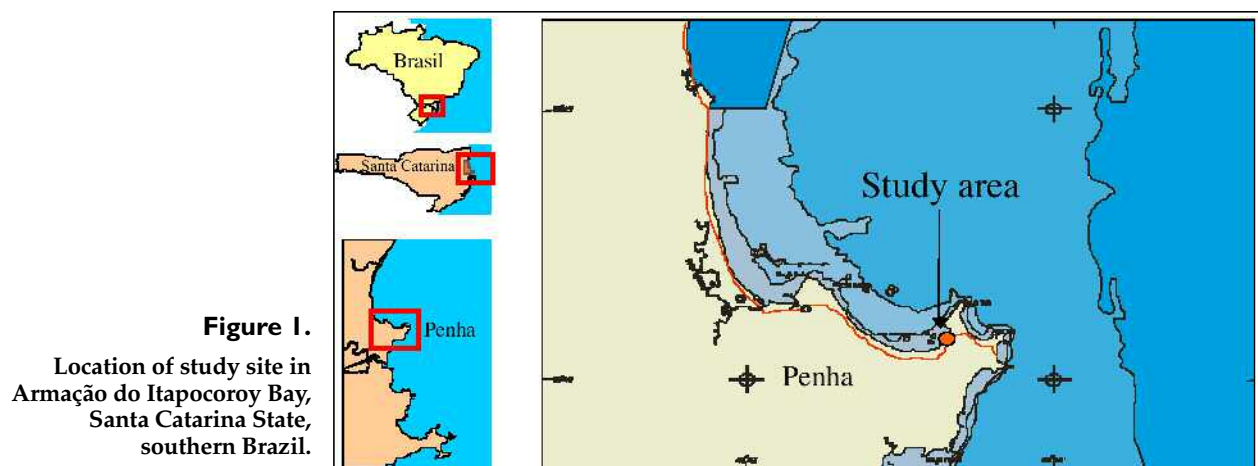


Figure 1.

Location of study site in Armação do Itapocoroy Bay, Santa Catarina State, southern Brazil.

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The study site is an area of 1200 m² (20 m X 60 m) and is divided into three strata defined by tide level: upper intertidal (inner – stratum 1), lower intertidal (middle – stratum 2) and subtidal (outer – stratum 3), following the classification proposed by Holme and McIntyre (1971). Each stratum is 400 m² (20 m X 20 m).

Density and spatial distribution

The seasonal variation in *H. grisea* density was determined during winter and spring 2003, and summer and autumn 2004. In each stratum *H. grisea* were counted in one-meter-square (1 m²) quadrats, and 25 quadrats per stratum, per season (n = 300) were recorded. In order to establish the spatial distribution, the standardized Morisita index (I_p) of animal dispersion and aggregation was used (Krebs 1989).

Rock covering and rugosity

To better understand *H. grisea* behavior, the percentage of rock cover was measured and recorded for each quadrat in order to relate the density and distribution of the holothurians with the amount and type of substratum.

Before counting the sea cucumbers, a quadrat was divided into four parts and the percentage rock cover was estimated visually, using a scale of 0–100% with intervals of 5%.

Rock rugosity was estimated by the rugosity index d (IRd), which is a variation of the chain link method³ (Luckhurst and Luckhurst 1978), where a chain with small links was laid on the substratum. In some quadrat recorders (n = 150), constituting 5 replicates of measures (border to border), the chain was positioned to follow the contours and crevices of the substratum as closely as possible. The mean ratios of quadrats length (stretched length) to contours length (border to border)(Rg) were used as a comparative index $IRd = [1 - (1/Rg)]$.

Data analysis

In order to test significant differences in seasonal and strata density, a parametric two-factor ANOVA (Underwood 2001) was used. Data normality were verified using the Kolmogorov-Smirnov test and the homoscedasticity was tested using the Bartlett test and, when necessary, data were transformed using the square root of the density values (Zar 1984).

The absence of homogeneity in the variances was caused by the null results in stratum 1, which was subsequently excluded from the analysis. Due to the high number of samples (n = 300), the demand for normality becomes secondary to using parametric analysis (Underwood 2001).

Pearson's coefficient r (Legendre and Legendre 1998) was used to correlate the density of *H. grisea* in strata 2 (lower) and 3 (subtidal) with rock rugosity and rock covering.

Results

Density

The density values of *H. grisea* (Table 1) differed significantly between strata 2 (lower) and 3 (subtidal) ($F = 36.2373$; $p < 0.0001$) except in autumn (Fig. 2), when stratum 3 was the most abundant. Holothurian densities did not differ significantly between seasons ($F = 0.7798$; $p > 0.5$).

Table 1. Density of organisms (Dt m⁻²) in both strata over the year; EP is the standard error of the mean.

	Stratum 2		Stratum 3	
	Dt	EP	Dt	EP
Winter	3.32	1.34	8.04	1.51
Spring	3.48	1.44	7.12	1.58
Summer	1.60	0.91	6.68	1.41
Fall	3.80	1.25	4.40	0.74

Considering the season and the stratum, the two-factor ANOVA analysis showed no significant density difference during the year in strata 2 and 3 ($F = 1.5482$; $p = 0.2034$), however, analyzing each stratum separately, there was a significant density variation of *H. grisea* over the seasons when densities decreased in the stratum 2 during the summer and in stratum 3 during the autumn (Fig. 2).

Spatial distribution

The standardized Morisita index showed an aggregated spatial distribution ($I_p > 0.5$, when: $I_d > I_{mc} > 1$) on both strata during all seasons (Table 2), but highest aggregating values were always associated with the stratum 2.

3. The chain link method was proposed by Luckhurst and Luckhurst (1978) and is commonly used to determine rock complexity on reefs, where a chain with small links is laid on the substratum as closely as possible along a transect. Afterwards, an index was calculated by establishing the ratio between the contour length and the stretched length. This index, in conjunction with the number of holes and crevices counted along the transect, measures the rock complexity.

A significant ($p < 0.5$) positive linear relationship was found between the density of *H. grisea* and the amount of rock covering ($r = 0.411$; $n = 150$) (Fig. 3), and also between the density of *H. grisea* and rock rugosity ($r = 0.665$; $n = 150$) (Fig. 4). Nevertheless, the highest values of rock rugosity occurred in intermediate levels of rock covering as shown by a parabolic relationship between the rock covering and rock rugosity ($r = 0.844$; $n = 150$) (Fig. 5).

There were no differences in rock covering and rock rugosity between strata 2 and 3 (Table 3). The correlation ($p < 0.01$) found in stratum 3 between the *H. grisea* density and IRd ($r = 0.7837$; $n = 50$) was higher than the correlation ($p < 0.01$) found in stratum 2 ($r = 0.6818$; $n = 50$). No correlation ($p < 0.01$) was found between *H. grisea* density and rock covering in stratum 2 ($r = 0.3130$; $n = 50$), however, this correlation was observed in stratum 3 ($r = 0.8059$; $n = 50$) (Table 4).

Discussion

Contiguous strata are useful for determining absolute weights of any species, especially in microtidal areas. Each stratum, however, should be clearly defined to avoid confusing or mixing two or more different strata (Raffaelli and Hawkins 1996). Strata 2 (intertidal) and 3 (subtidal) in this study are clearly delineated.

To determine the density of *H. grisea* with a high degree of precision, it was necessary to record a high number of quadrats, due to its distribution pattern.

Pawson (1966) showed that holothurians are often aggregated. Thus, *H. grisea* in Armação do Itapocoroy Bay were found with the same distribution pattern, but this pattern was limited to rocky bottoms; in sandy bottom areas there was a low frequency of isolated specimens.

The highest holothurians densities were found in areas with high rock covering and in areas with high rugosity in Armação do Itapocoroy Bay. Specimens of *H. grisea* have cryptic behavior (Cutress 1996), and numerous tube feet that give a tenacious grip on hard substrates (Deichmann 1930; Hendler et al. 1995).

According to density correlations analyzed for rock rugosity and rock covering, *H. grisea* possess a strong correlation with rugosity. The highest rugosity values were found in intermediate levels of rock covering, suggesting that *H. grisea* live on rocks. However, the rock itself is not the most important factor affecting their density. Also important is a highly irregular bathymetry, with holes and crevices where *H. grisea* can find shelter and sediment with deposited organic matter.

Table 2. According to standardized Morisita index, $I_p > 0.5$ means an aggregated distribution when $I_d > M_c > 1$. How highest is the I_p value, more aggregated were the specimens

	Stratum 2			
	Winter	Spring	Summer	Autumn
I_d	4.69	4.88	8.37	3.38
M_c	1.19	1.18	1.39	1.17
I_p	0.57	0.58	0.65	0.55
	Stratum 3			
	Winter	Spring	Summer	Autumn
I_d	1.73	2.05	1.94	1.45
M_c	1.08	1.09	1.09	1.14
I_p	0.51	0.52	0.52	0.51

Table 3. Rugosity (IRd) and rock covering mean values with no significant difference between the two strata (EP = Standard error of the mean).

	Rugosity	Rock covering
	Mean (\pm EP)	Mean (\pm EP)
Stratum 2	0.044 (± 0.011)	16.378 (± 4.531)
Stratum 3	0.049 (± 0.010)	12.400 (± 3.458)

Table 4. Correlation (Pearson's coefficient r) of *H. grisea* density in the strata 2 and 3 among the rock rugosity index d (IRd) and the rock covering (RC).

	Correl IRd	Correl RC
Stratum 2	0.68	0.31
Stratum 3	0.78	0.81

Although Rogers-Bennett and Ono (2001) attributed the patchy distribution pattern of *Parastichopus californicus* without any apparent seasonal aggregating, spawning, or feeding behavior, Graham and Battaglione (2004) suspected long-term movement patterns of *Actinopyga mauritana* due to a series of directed movements in response to patchy distributions of food and shelter.

There is a positive relationship between *H. grisea* density, percentage cover of rock, and the rock rugosity index; therefore, it would be expected that the highest *H. grisea* density would be found in the

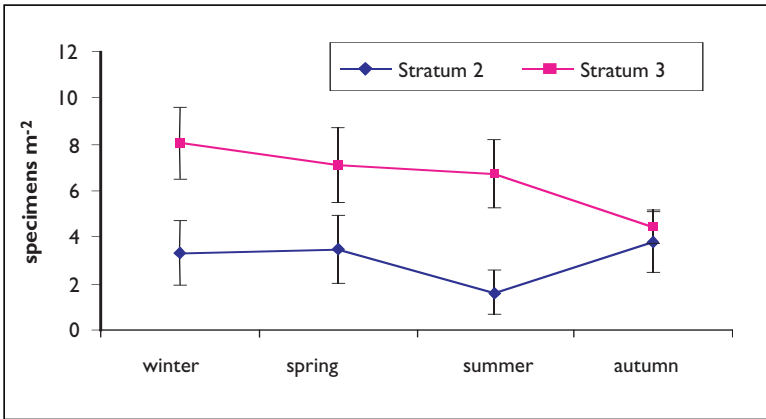


Figure 2.
Seasonal variation of *H. grisea* density (specimens m⁻²) in two strata.

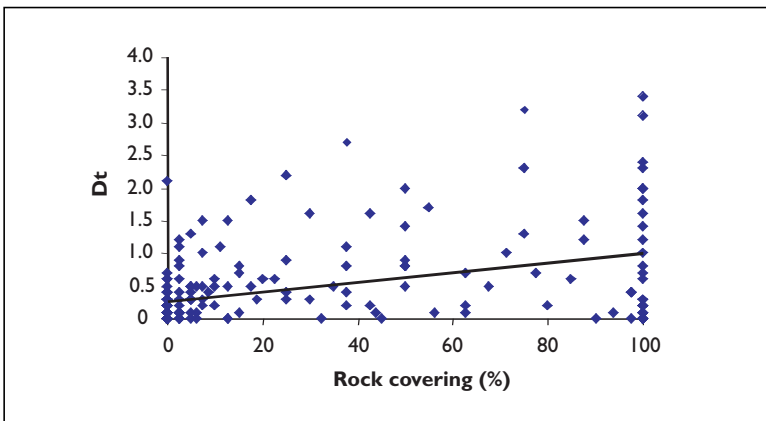


Figure 3.
Linear relationship between *H. grisea* density (Dt) and rock covering (%).

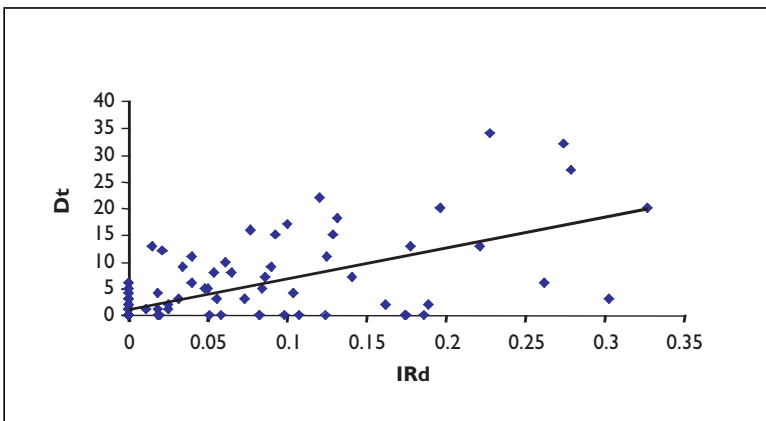


Figure 4.
Linear relationship between *H. grisea* density (Dt) and rugosity index d (IRd).

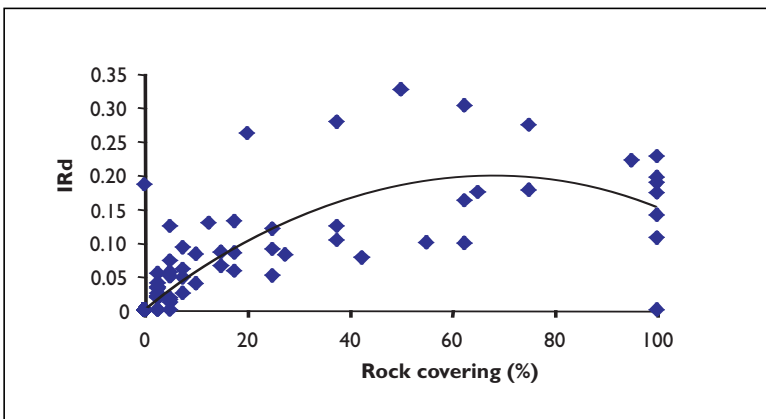


Figure 5.
Parabolic relationship between rock covering (%) and rugosity index d (IRd).

stratum with the highest rock rugosity. Rooker et al. (1997) observed that an increase in the total abundance of organisms coincides with increasing habitat rugosity. Sonnenholzner (2003) did not find *H. theeli* where the substrate was mainly sand with no shelter areas.

Zhou and Shirley (1996) divided a coastal area in Alaska into 3 strata and concluded that densities of *Parastichopus californicus* increased from the inner stratum to the outer stratum and differed significantly among the 3 strata. In Armação do Itapocoroy Bay, densities of *H. grisea* also increased from stratum 2 (middle) to stratum 3 (outer), although, between strata 2 and 3 there was no difference in rock covering or of rock rugosity, suggesting that the density variation among the two strata is determined by other ecological factors.

Tide level was the primary factor affecting density, since this species is not tolerant of long desiccation periods. Tommasi (1969) reported that *H. grisea* is the most frequently found and numerous sea cucumber species on the Brazilian coast and that it is found in high densities in subtidal zones. Sonnenholzner (2003) reported that *H. theeli* may occupy different intertidal and subtidal ecological niches and its habitat preferences may be linked to hydrodynamic characteristics such as tide level.

Significant differences in *H. grisea* densities were found among strata 2 and 3 over all the seasons, except autumn. In autumn, intense southerly winds and currents drive seawater onto the south coast of Brazil, frequently inundating the intertidal zone, and causing a mixture between strata 2 and 3. Thus, *H. grisea* were found in low aggregations in both strata during the autumn season.

This fact would also explain the significant density reduction in the autumn when analyzing only stratum 3. The intertidal zone inundation allowed a more widely spread distribution pattern of *H. grisea*, since this species occupied the two strata equally. Analyzing only stratum 2, there was a reduction in *H. grisea* density in the summer due, most likely, to the high summer temperatures (desiccate-inhibition). Highest aggregations were observed in stratum 2 suggesting an immersion response of *H. grisea* that was most concentrated in areas that had high humidity retention (e.g. tide pools) during low tide periods.

It is probable that the high summer temperatures also restricted the occupation of the most tolerant specimens to desiccation, thus forcing the least resistant ones to occupy more protected areas (subtidal). This behavior was also observed in Florida (USA) where individuals of the same species mi-

grated some distance offshore because of adverse environmental factors (Hendler 1995). An activity rhythm of *A. mauritana* related with tidal cycles was also observed in Solomons Islands by Graham and Battaglene (2004). Zhou and Shirley (1996) also aim an existence of seasonal migrations in *Stichopus variegatus* and *Cucumaria frondosa* specimens in a southeast Alaska Bay.

Generally, animals do not behave in the same way in different places. Ecological patterns can vary temporally and from place to place, so that behaviors and patterns are regulated by biotic and abiotic factors that act on the environment (Chapman, 2000). Thus, the *H. grisea* population in Armação do Itapocoroy Bay follows characteristic patterns of the species, although specific environmental factors and patterns of this habitat causes specific responses as particular behaviors.

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A three-year project on sea cucumbers in the southwestern Indian Ocean: National and regional analyses to improve management

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Introduction

This paper briefly outlines a new sea cucumber project in the southwestern Indian Ocean. The project is supported by the Western Indian Ocean Marine Science Association (WIOMSA) (www.wiomsa.org), a regional nongovernmental organisation, established in 1993 to promote and advance marine science in the Western Indian Ocean (WIO) region. The research project is funded under the Marine Science for Management grant (MASMA) of WIOMSA.

Despite their long history of consumption by Asian populations (Conand 1990, 2004a, 2005a, 2005b), sea cucumbers are a poorly understood coastal resource. Although the high demand for sea cucumbers has resulted in overexploitation in the main producing nations (Conand 1990, 2001, 2004a, 2005a, 2005b), there remains a high demand for this product worldwide, leading to the expansion of the fishery into new fishing grounds as well as the development of sea cucumber aquaculture (Lovatelli et al. 2004). Renewed interest for this fishery has risen recently in the region (Muthiga and Ndirangu 2000; Muthiga in review; Conand 2001, 2004a, 2004b, Conand et al. 2005; Rasolofonirina and Conand 1998, Rasolofonirina et al. 2004; Aumeeruddy and Skewes 2005, Aumeeruddy et al. 2005; Samyn et al. 2005).

Some sea cucumber studies have already been conducted in several countries in the WIO (Table 1), but there has been limited analysis of information relevant for fisheries management in individual countries and no attempt at a regional level.

Given that the WIO region has more than 106 species of sea cucumbers (Clark and Rowe 1971) — 20 of which are of commercial value — it is apparent that there is a great deal more information that is needed, especially studies focusing on reproduction, recruitment, growth and mortality. This information is crucial for fisheries management as recommended by FAO (Lovatelli et al. 2004) and the Convention on International Trade in Endangered Species — CITES (Conand 2004b, 2005a).

Coastal fisheries provide an important source of income for communities in the WIO region (McClanahan and Pet-Soede 2000; Cesar et al. 2002; Jid-dawi and Öhman 2003). However, the increasing need for finfish and other marine products is putting a great deal of pressure on the marine ecosystems, leading to overexploitation of species and habitat degradation (Jennings and Polunin 1996; McClanahan and Sheppard 2000; de la Torre Castro and Rönnback 2004). The opening up of international trade to China and the decline in the finfish fishery in the WIO have, in part, contributed to the current interest in alternative fisheries, such as sea cucumbers, which can divert fishing pressure away from traditional fisheries and improve incomes of coastal communities. Preliminary analysis of the sea cucumber fisheries and management systems in some countries of the region indicate rapidly developing and unregulated fisheries with some showing signs of overexploitation (Horsfall 1998; Muthiga and Ndirangu 2000; Marshall et al. 2001; Rasolofonirina et al. 2004; Mbaga and Mgaya 2004; Aumeeruddy and Skewes 2005; Uthicke and Conand 2005a). It is difficult, however, to make a thorough assessment of WIO fisheries at the present time because of inconsistencies with and poor collection and storage of catch statistics in most countries of the region.

Unfortunately, despite the potential importance of sea cucumbers to the livelihoods of coastal communities, few studies have taken into account the socioeconomic aspects of the fishery (Iida 2005). This is especially important because the characteristics of the fishery seem to vary from country to country and with different world biotic zones Conand 2001, 2004a. In addition, conservation implications (Bruckner et al. 2003) and marine protected areas have also not been addressed. The proposed project is timely because the issues of sea cucumber fisheries management, trade and conservation are increasingly being addressed at the global level as evidenced by the recent international FAO workshop in China (Lovatelli et al. 2004), at a CITES workshop in Malaysia, and at the 12th conference of parties meeting of CITES (www.cites.org). The global view of sea cucumber fisheries is similar to

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Figure 1.

Several species of dried sea cucumbers by a collector in Madagascar

issues in the WIO, where many fisheries are over-exploited and poorly managed due to poverty and lack of adequate information for fisheries management (Lovatelli et al. 2004, Conand 2004a, 2005b). Since WIO countries are signatories to CITES, it is imperative that appropriate management and reporting systems are instituted, and the proposed project has potential to contribute to this process.

Project overview

Marine resources are vital to the coastal peoples of the WIO region. Management of these resources must balance sustainable use with conservation of marine habitats containing these resources. Successful management cannot be achieved without key ecological and socioeconomic information. This project intends to address the conservation and management, and the information needs of the rapidly growing sea cucumber fishery in the region. Specifically, knowledge generated through this project will:

- Increase the understanding of the status of sea cucumbers and their management, including potential for aquaculture;
- Provide key skills and information for management, including identification skills and information on reproduction and recruitment of key commercial species that is crucial for fisheries management;
- Improve the knowledge of management systems and knowledge gaps, thereby helping to form the basis for any management plans; and
- Increase the knowledge of the fishery's impact on the socioeconomic status of coastal communities.

A general model describing the five levels of this fishery-system (Conand 2001, 2004b, 2005a) will be

useful for the analysis of the fisheries management programmes in WIO countries. The project will also use knowledge gained by different projects in the region: Madagascar — potential aquaculture of sea cucumbers (IH-SM and Belgian cooperation); Seychelles — FAO project on the biology, ecology, and socioeconomics of the fishery; Kenya — INCOFISH implemented by the Wildlife Conservation Society (WCS) mapping fisheries activity; Reunion — ECOMAR studies on ecology and biology.

The project began in October 2005, and is intended to be multidisciplinary, with close collaboration between biologists, ecologists and social scientists. Training in sea cucumber taxonomy, biology and fisheries will provide capacity to regional scientists, fishery officers and managers for monitoring and evaluating the effectiveness of the management systems currently in place. The project will focus on Kenya, Madagascar, Reunion, Seychelles and Tanzania, although information on other WIO countries will be collated from the literature and ongoing studies for a more complete regional analysis.

Main objectives

Objective 1: Species inventories and distribution

Key questions are: 1) What species occur and where? 2) Which species are the most abundant? 3) Which habitats have the highest diversity? and 4) Is there a regional distribution pattern that provides information on biogeography? This will allow us to understand which areas are at risk, which resources are shared across the region, and which species need special attention in term of management.

Objective 2: Impacts of MPAs

The effectiveness of MPAs in protecting sea cucumber resources has not been evaluated. Assuming that fishing affects the population of commercial sea cucumbers, we can hypothesise that: 1) the numbers of species (including commercial species) will be less in fished areas, and more in unfished areas, and that 2) sea cucumbers in fished areas will have smaller body sizes than in un-fished areas. This information has implications for national fisheries management processes and requirements under CITES and CBD (Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), and the Convention on Biological Diversity CBD), and provides a better understanding of sea cucumber stocks.

Objective 3: Biology of the main species

Information on the reproduction and recruitment of sea cucumbers is crucial for the management of the fishery (Conand 1993, 1996, 2004c; Uthicke and Conand 2005). The main questions that will be explored are 1) What are the reproductive patterns and factors that control these patterns? and, 2) What are the recruitment patterns and environmental and ecological factors controlling recruitment of these species? This information will provide a better understanding of factors that control reproduction and recruitment, which are important for fisheries management and any potential aquaculture developments.

Objective 4: Socioeconomics

Sea cucumbers are highly valuable on the international market, yet the level and potential contribution of this resource to national economies, as well as to the livelihoods of coastal communities, is not known. Information under this objective should provide a comprehensive assessment of coastal fisheries and the current and potential contribution of sea cucumbers to the livelihoods, sociocultural and economic status of coastal communities and their ability to undertake potential aquaculture projects. The information could also serve to persuade fisheries authorities to pay closer attention to the management of sea cucumbers.

Objective 5: Management

While many WIO countries have sea cucumber fisheries, and while there is some basic information on the management systems, there has been no comprehensive analysis made. For example, information on management processes such as licensing, monitoring, collection of catch statistics, and fisheries policies are not readily available. Such infor-

mation should assist countries in improving the management of their sea cucumbers stocks.

Objective 6: Training

In order to manage any fishery, management authorities require some basic monitoring and assessment skills, as well as a basic understanding of the biology, ecology and taxonomy of the target fishery. Training practitioners and students, providing identification material on sea cucumbers, as well as producing guidelines for the collection of catch statistics should serve to increase this capacity in selected WIO countries.

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A review of the emerging fishery for the sea cucumber *Cucumaria frondosa*: Biology, policy, and future prospects

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Introduction

Sea cucumbers have been harvested for human consumption for more than a millennium. Over the past 50 years, global landings have increased steadily from about 5000 tonnes annually in the 1950s to nearly 30,000 tonnes in 2003 (Conand and Byrne 1993; FAO 2005). Originally, the fishery for these marine invertebrates were limited to a few species in the Indo-Pacific, but recently — in response to a market opening created by both depletion of traditional resources and an increasing demand for sea cucumber products — the exploitation of sea cucumbers has spread to many new regions and a number of new species are now being targeted (reviewed by Conand 1997, 1998, 2001, 2004; Conand and Byrne 1993)

One of the species that is new on the global market is the North Atlantic sea cucumber *Cucumaria frondosa*. A fishery for *C. frondosa* developed on the east coast of North America during the 1990s and has expanded so rapidly that according to FAO, as well

as national USA and Canadian statistics, the landings of this species alone in 2003 made the USA the world's second-largest producer of wild-caught sea cucumber, and Canada the fourth largest producer (Fig. 1).

Because of the global significance of these fisheries and because *C. frondosa* has become one of the most predominant commercial sea cucumber species on the world market in terms of landed weight, it is important to document and follow the developments in the exploitation of this species. Bruckner (2005) provided an overview of the *C. frondosa* fishery in the state of Maine (USA) as part of a larger summary of continental USA sea cucumber fisheries, but a fishery for this species outside the USA remains virtually undocumented in the literature. This paper aims to fill the information gap by providing an overview of the history and current status of fisheries for *C. frondosa* throughout its range, and discussing future prospects for these fisheries in the light of existing management experiences of sea cucumber fisheries in other places.

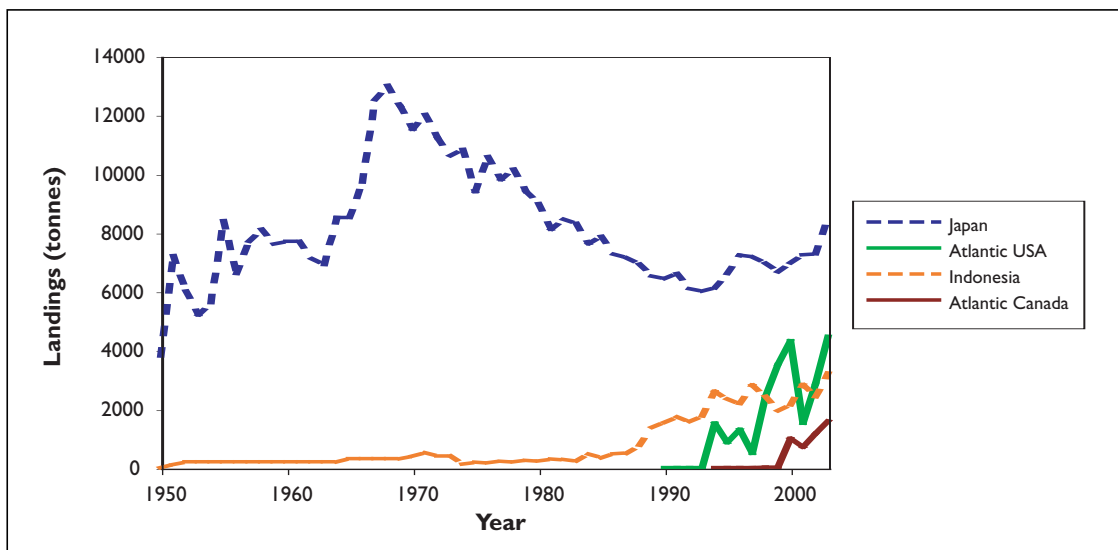


Figure 1. Total sea cucumber landings for the four countries or regions in countries producing the highest yields in 2003 (note that only landings from the Atlantic coast of the USA and Canada are included). Data source: FAO 2005 (for Japan and Indonesia), NMFS 2005 (for USA), DFO 2005 (for Canada). It should be noted that there is a reporting error in the FAO data for US Northeast sea cucumber landings in 2003. FAO reports a landing of ~9300 tonnes, but the correct figure, as reported from the Maine Department of Marine Resources and the NMFS is ~4500 tonnes.

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Cucumaria frondosa

Although several sea cucumber species exist in the North Atlantic and adjacent seas, only one, the orange-footed sea cucumber *Cucumaria frondosa* (Gunnerus 1767), is targeted in the current fishery. *Cucumaria frondosa* is the only dendrochirote sea cucumber that is harvested for human consumption on a significant scale globally; all other commercial species belong to the order Aspidochirota (Bruckner et al. 2003). As is typical for sea cucumbers, the biology and ecology of *C. frondosa* is still incompletely understood, but in recent years, a number of extensive studies of the growth and reproduction of this species have been carried out (e.g. Gudimova et al. 2004; Hamel and Mercier 1995, 1996a, 1996b, 1998, 1999; Medeiros-Bergen and Miles 1997; Organesyan and Grigorjev 1998; Singh et al. 1999, 2001).

Cucumaria frondosa reaches a length of 35–50 cm and has a wide distribution in the North Atlantic and Arctic Ocean including the Norwegian, Barents, and North Seas. The southern range in the western Atlantic extends to Cape Cod; in the eastern Atlantic it ranges from the far north, to south of Scandinavia and the British Isles (Jordan 1972). *Cucumaria frondosa* occurs from the intertidal zone down to 300–400 m (Brinkhurst et al. 1975), but is most common in shallower depths (Jordan 1972; Singh et al. 2001).

The main products derived from *C. frondosa* are the muscle bands that are vacuum packed and flash frozen, and the dried body wall that is boiled and dried (Feindel 2002). The dried product is about 5–10% of the wet weight (Ke et al. 1987; Feindel 2002).

Most *C. frondosa* products are sold in Asian markets. Although *C. frondosa* is smaller than most commercial species and has a thinner body wall, a market acceptance for this species has developed over the past decade. However, *C. frondosa* remains a lower-grade species that yields much lower prices than most commercial sea cucumbers. Generally, fishermen are paid about 0.1 US dollars (USD) per kilogram and the dried product yields only about USD 6–10 kg⁻¹ (Feindel 2002). This price range is clearly much lower than that for other sea cucumber species that typically yield USD 30–40 kg⁻¹ of dried body wall and more than an order of magnitude lower than certain high-value species that may fetch up to USD 110 kg⁻¹ of the dried product (Ferdouse 2004).

***Cucumaria frondosa* fisheries**

Information on fisheries for *C. frondosa* was collected from published and unpublished literature as well as personal communication with fisheries

officials in all North Atlantic countries (the affiliations of all individuals cited in the following sections are listed in the Appendix). The information was mainly collected between January and May 2005. We always attempted to obtain the most updated data, but we emphasize that all information presented in the following sections is highly time-sensitive because exploitation of *C. frondosa* is evolving and changing quickly.

Although there had been sporadic attempts to start a fishery for *C. frondosa* in Atlantic Canada since 1980, the state of Maine (USA) was the first place to develop a substantial fishery for this species (M. Lundy, pers. comm.). This fishery started in earnest in 1994 (Chenoweth and McGowan 1997) and Maine is currently the only state on the US east coast where sea cucumbers are harvested. (For a review of the history and current status of this fishery, see Bruckner 2005).

Two years after the onset of the Maine sea cucumber fishery, Canadian government agencies began assessing the feasibility of starting a fishery for *C. frondosa*; in 2000, a sea cucumber fishery had developed in several locations. Since this onset, trends in annual landings have varied between provinces (Fig. 2).

The Scotia-Fundy sector (Nova Scotia and New Brunswick) has had the highest sea cucumber landings in Canada. In this region, fishers with an urchin license were allowed to take sea cucumbers prior to 2004, but now, only people holding an experimental sea cucumber license are authorized to land this species (DFO 2005a). Currently the region has issued five such exploratory licenses, and a number of regulations are in place, including a closed season from April to December, and a series of closed areas (V. Docherty, pers. comm.). As in Maine, these regulations have partly been put in place to avoid gear conflicts. In addition, no nighttime fishing for sea cucumbers is allowed in the Scotia-Fundy region, and simple gear restrictions are in place as well as a minimum size (10 cm length) for landings (DFO 2005a).

The other region where sea cucumbers are being fished include the provinces of Newfoundland and Labrador where the governments have there have issued eight exploratory licenses and have set an exploratory annual quota of 4500 tonnes (L. Barrett, pers. comm.). There is no sea cucumber harvesting and none being planned or anticipated in the near future in the province of Prince Edward Island; all attempts to establish a fishery in this region have failed due to limited stock supply (B. MacPhee, pers. comm.). Similarly, although Hamel and Mercier (1999) reported promising prospects for a sea cucumber fishery in Quebec, it has not yet been

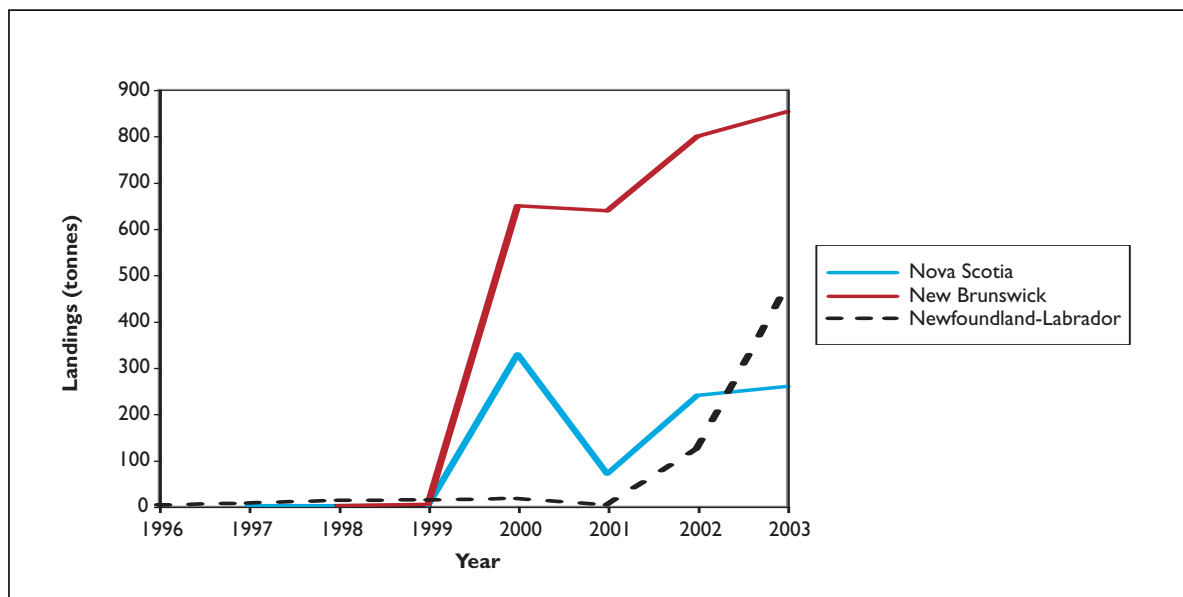


Figure 2. Sea cucumber landings in Atlantic Canadian provinces.
Data source: DFO unpublished database.

possible to establish an economically viable fishery. However, while there is presently no commercial sea cucumber fishery in Quebec, studies to assess the possibility for developing one in the future are ongoing (J. Lambert, pers. comm.).

All Canadian fisheries use drags similar to the ones used in Maine. As in Maine, a scallop drag was initially used, but was replaced by the modified urchin drag that appears to produce less bycatch and has a lighter impact on the seabed than the heavier scallop drag (DFA 2002a). The mean fished depth is 13–20 m and fishermen never drag below 65 m (Feindel 2002; P. Collin, pers. comm.). Initial surveys in Newfoundland suggested that diving might be a possible alternative harvesting method, and exploratory trial dives yielded up to 2700 kg day⁻¹ in certain areas. However, experimentation with this harvest technique in the Scotia-Fundy region indicated that the value of *C. frondosa* is too low to make diving a viable harvest technique (DFO 2005b).

The only European country that harvests sea cucumbers is Iceland. Although a three-month trial study several years ago suggested that *C. frondosa* could not sustain a viable fishery in Iceland, a private company is currently making another attempt at developing a fishery (A. Möller, pers. comm.). One boat has been fishing *C. frondosa* for about one year in Breidarfjordur Bay on the west coast of Iceland. So far about 80 tonnes of *C. frondosa* have been landed (K. Olafsson, pers. comm.). The future of this fishery is uncertain as the resource appears to be more dispersed and less abundant than antic-

ipated, and catch per unit of effort (CPUE) has been variable and small (A. Möller, pers. comm.).

Most other European countries have never considered exploiting their sea cucumber resource (R. Redant: Belgium, H. Geene: Netherlands, C. Stransky: Germany, E. Morgan: UK, D. McGabhann and P. Comisky: Ireland, A. Lindquist and D. Valentinsson: Sweden, A. Skak: Greenland pers. comms.). However, although there is no current activity, interest in sea cucumber fisheries is developing in several places. In Norway there is now a small-scale attempt to start both fishing and farming sea cucumbers (E. Slinde, pers. comm.). In Denmark there is no current exploratory fishery, but the Institute of Fisheries Research is initiating a project to explore the potential of a future harvest of *C. frondosa* that is currently common bycatch (J. Astrup, pers. comm.). Finally, in Ireland, the fisheries authorities receive occasional requests regarding the harvesting of sea cucumbers. *Cucumaria frondosa* appears to be rare in Irish waters, but there are several other species that potentially could be harvested in the future (D. McGabhann, pers. comm.).

In the Barents Sea, fishermen recently began harvesting *C. frondosa* (Gudimova 1998; Organesyan and Grigorjev 1998). So far there is no directed fishery for this species; all landings are bycatch from the scallop fishery. Previously, this bycatch was simply discarded at sea but since 2000, fishermen have been able to sell the sea cucumbers for processing (Gudimova et al. 2004). Thus far, landings have not exceeded 200–250 tonnes per year (Gudimova et al. 2004) and because sea cucumbers are

harvested only as bycatch, there are no regulations governing this resource.

In general, all fisheries for *C. frondosa* are still in early exploratory stages, and it is difficult to predict whether the available stock can sustain long-term exploitation. While there are several full-time sea cucumber fishermen in Maine, reports from Canada indicate that *C. frondosa* may not be able to sustain a stand-alone fishery, but that it can provide a supplement for urchin or groundfish fishermen (DFA 2002a, b, c; DFO 2005a). All surveys and reports from fishermen suggest that the distribution of *C. frondosa* is highly scattered and localized (DFA 2002c).

Prospects

Cucumaria frondosa seems to hold promise for the fishing industry in the North Atlantic and adjacent seas — a region that has previously not exploited their holothurian resources but where overexploitation and depletion of many traditional stocks have left fishing communities eager to find new target species. However, even though *C. frondosa* has quickly become one of the world's most important commercial sea cucumbers, it is obvious that fisheries for this species in most areas are still in a very early exploratory stage, and at this point it is difficult to make predictions about their future sustainability.

Sea cucumbers tend to be highly vulnerable to overfishing, and sea cucumber fisheries throughout the world are generally characterized by overexploitation and boom and bust cycles (Conand 2004; Uthicke and Conand 2005). Nevertheless, there are several examples of sea cucumber fisheries that appear to be well-managed and have produced relatively stable yields over decades. Examples of such fisheries are found on the Pacific coast of North America in the states of Alaska (Woodby and Larson 1998; Woodby et al. 2000), Washington (Bradbury 1994; 1999), and California (Schroeter et al. 2001; California Department of Fish and Game 2001), and in British Columbia, Canada (Muse 1998; DFO 2005b). It is important to note, however, that all these fisheries are much smaller in volume than the current *C. frondosa* fisheries on the east coast of Canada and the USA (Bruckner 2005).

The low value of *C. frondosa* requires harvesting to be in enormous bulk to be cost-effective, creating a real concern for the sustainability of fisheries for this resource. At this point, there is no information on the size of the virgin biomass for this species, so managers do not know what fraction of the population has been or is harvested. Although *C. frondosa* is extremely abundant in some areas, the distribu-

tion may be patchy, and lack of a clear pattern of decreasing CPUE throughout the range of the fishery is not a safe indication that the resource is not being depleted. Especially for developing fisheries that target spatially structured stocks such as sea cucumbers, CPUE can be a very misleading measure of abundance because fishermen may continue to move to unexploited areas. For example, in both Washington and California, CPUE for sea cucumbers remained stable over a series of years, whereas direct assessment surveys showed severe population declines (Bradbury 1994; Schroeter et al. 2001).

Because CPUE is probably not a good measure of resource abundance, it is entirely unclear whether the abundance of sea cucumbers in the North Atlantic has already decreased in response to exploitation. The large quantities of *C. frondosa* currently landed in North America may not be sustainable, considering the slow growth of this species and the slow rate of resource renewal typically observed in sea cucumber fisheries (Conand 1989; Bruckner et al. 2003; Uthicke and Conand 2005). In general, the global experience with overexploitation in many sea cucumber fisheries may suggest that a highly precautionary management strategy should be adopted for *C. frondosa*.

However, the extent to which the global sea cucumber fishery experience will be relevant to the management of *C. frondosa* depends on a number of factors including the degree of similarities and differences in the biology and the fishing regime between *C. frondosa* and other species.

Comparative vulnerability of *C. frondosa* fisheries

Recent work on marine fish suggests that comparisons of life history parameters may be used to predict differences in how related species respond to exploitation (Jennings et al. 1998, 1999; Reynolds et al. 2001). According to theory, species that attain large sizes, grow slowly, and mature late, suffer greater population declines for a given mortality rate than smaller, faster-growing species that mature early. Phylogenetic comparisons of life history patterns have shown that this pattern is true for fish stocks from the North Atlantic (Jennings et al. 1998). It seems likely that this pattern applies across taxa (Jennings et al. 1998), so an examination of how the life history traits of *C. frondosa* compare with those of other sea cucumbers may suggest whether this species will be more or less vulnerable to exploitation than those that have been exploited for decades or centuries. Although life history traits notoriously are difficult to determine in sea cucumbers due to their lack of hard parts, low tag retention, and flexible body shapes, the magnitude of the variation in reported parameters between

species is so great that a rough inter-specific comparison can be meaningful.

Hamel and Mercier (1996a) found that the maximum size reached by *C. frondosa* after five years of growth was 10.7 cm at 20 m depth and less than 5 cm at shallower depths. These figures are much lower than reported growth estimates for any other species. *Holothuria scabra*, for example, is reported to grow to 15 cm in only one to two years (this is larger than *C. frondosa* grew in 5 years at its maximum growth-rate; Skewes et al. 2000) and *Isostichopus fuscus* is reported to grow to 21 cm in four to five years (Herrero-Perezul et al. 1999; Reyes-Bonilla and Herrero-Perezul 2003). although to some extent growth rate is correlated with water temperature, tropical sea cucumbers are not the only species that appear to grow faster than *C. frondosa*. Temperate species such as *Stichopus japonicus* and *Parastichopus californicus* also grow to larger sizes faster; *S. japonicus* typically grow to 20 cm in four years (Izumi 1991), and *P. californicus* reaches 4–10 cm after only two years and is thought to reach a commercial size of 30–50 cm at the age of four years (Boutillier et al. 1998).

Hamel and Mercier (1996a) found that *C. frondosa* reached sexual maturity when the animals were about five years old at 20 m depth. Shallower populations of *C. frondosa*, however, did not reach sexual maturity during their experimental period of five years, and considering the significantly lower growth rate at those locations, it is probable that maturation occurs much later than age five (Hamel and Mercier 1996a). The minimum estimate of age at maturity of five years for *C. frondosa* is similar to that reported for *P. californicus* (Cameron and Fankboner 1989) and only slightly later than *Holothuria fuscogilva*, which is reported to mature at four years (Reichenbach 1999), and *I. fuscus*, which matures at four to five years (Herrero-Perezul 1999). Other species, however, such as *H. scabra* and *S. japonicus* mature considerably earlier, at one to two and two years respectively (Skewes et al. 2002; Chen 2003).

The available data suggest therefore that especially at shallow depths, *C. frondosa* matures later and grows considerably slower than several commercial species. *Cucumaria frondosa*, with a maximum size of 50 cm, is intermediate in size among commercial sea cucumbers that range from 5 cm to more than 1 m (Bruckner et al. 2003). According to theory and the analysis of Jennings et al. (1998) a smaller maximum length should make *C. frondosa* less vulnerable to exploitation than other species, but its considerably slower growth and late maturity may make it more vulnerable. Certainly the estimate of 10–15 years required for growth before re-

cruitment to the fishery is much higher than reported for any other holothurian species (Hamel and Mercier 1996a; Gudimova et al. 2004).

To contrast the findings of the life history comparison, which may suggest that *C. frondosa* is less resistant to exploitation than other species, there are several factors that could indicate that *C. frondosa* may actually have greater potential as a sustainable fisheries resource than other sea cucumbers. First, the density of *C. frondosa* appears to be much higher than that reported for other sea cucumbers. Typical densities for tropical holothurians rarely exceed a few hundred per hectare, although some species such as *Actinopyga echinites*, *Actinopyga mauritiana*, and *Holothuria atra* have been observed in aggregations of several 1000s per hectare (Conand 1994; Hamel et al. 2001). The density of the most common temperate sea cucumber on the west coast of North America, *P. californicus*, is reported to be as much as 19 individuals per meter of coastline (Boutillier et al. 1998). However, density estimates for *C. frondosa* off the east coast of North America are commonly around 5–15 individuals per square meter (ind. m^{-2}) with local densities up to 50 ind. m^{-2} (Singh et al. 2001). No density estimates are available for *C. frondosa* in other parts of its range, but the extremely high density of *C. frondosa* in the western North Atlantic suggests that, at least in this region, a greater virgin biomass is available. This means that greater yields may be supported over time than for more sparsely distributed species. However, although a large virgin biomass may allow for a greater absolute amount of resource extraction before the future viability of a stock is impacted, it certainly in itself does not safeguard a stock from overfishing.

One factor that may directly help protect adult *C. frondosa* from overfishing is habitat use and depth range. Hamel and Mercier (1999) suggested that because *C. frondosa* is found on underwater steep cliffs and rough terrains that are inaccessible to fishermen, such areas serve as natural refuges that will ensure that a portion of the sea cucumber population remains untouched. In addition, with current technology, fishermen do not dredge below 60 m, whereas *C. frondosa* are found down to >300 m. This means that only the top fifth of *C. frondosa*'s depth range is currently being fished so that unless harvesting behavior and technology is considerably altered, depth provides a natural refuge that would protect part of the *C. frondosa* spawning stock even in highly fished regions. Such a depth refuge has proven to be a very successful tool in the management of the red abalone in California (Karpov et al. 1998). It is uncertain, however, at what densities *C. frondosa* is found in areas currently inaccessible to fishing gear (both because of depth

and bottom topography), and whether individuals in these areas have a reproductive output that is sufficiently high to supply the more shallow and accessible fishing grounds. The reproductive cycle of echinoderms has in some cases been found to vary between depths (Keats et al. 1984; Nicholas et al. 1985).

Hamel and Mercier (1996b) reported that in the Gulf of Saint Lawrence, the gonadal index of *C. frondosa* individuals at 10 m remained slightly lower than that observed at 110 m, whereas Singh et al. (2001) found that in Passamaquoddy Bay, individuals at shallow depths had higher dry gonad weights than deepwater individuals. Because of the small difference in both sets of measurements, the inverse results of the two studies and the fact that both studies found that the seasonal reproductive patterns were roughly similar at both depths, it appears that *C. frondosa* may have similar reproductive potential at all depths.

One factor indicating that reliance on natural refuges may be a viable management strategy for *C. frondosa* is its relatively long planktonic larval duration of 48–49 days (Hamel and Mercier 1996a). Although *P. californicus* has an even longer larval stage of 65–125 days (McEuen 1987), most other sea cucumber species are planktonic for much shorter periods before they settle (e.g. *S. japonicus* 12–13 days, Chen 2003; *H. scabra* 13 days, Hamel et al. 2001; *H. fuscogilva* 14–21 days, Friedman 2005; *I. fuscus* 22–27 days, Hamel et al. 2003; and *H. nobilis* 28 days, Martinez and Richmond 1998). The longer larval stage of *C. frondosa* may facilitate recovery of depleted areas because broodstock can be imported from locations that are protected from fishing. Although dispersal is dependent on a number of factors, including local oceanographic conditions, planktonic larval duration has been shown to be at least partly associated with the connectivity of marine populations on a regional scale (Doherty et al. 1995) and may therefore make refuges a viable option.

In addition to these ecological considerations, it appears that current economic forces may also help protect *C. frondosa* against overfishing because, paradoxically, the factor that is, perhaps, the greatest threat to the fishery's sustainability — the low economic value that necessitates the capture of enormous biomass for the fishery to be economically viable — may at the same time help maintain *C. frondosa* populations at moderate population densities. For more valuable sea cucumber species, it is worthwhile for fishers to search out individuals even when they are at extremely low densities. For example, Boutillier et al. (1998) reported that in British Columbia, Canada virtually all sea cucum-

bers have been removed in areas that have been searched by a dive harvester. However, because *C. frondosa* yields such a low value per landed kilogram, it is not economically viable for fishermen to keep fishing a given area until all sea cucumbers have been harvested. As soon as CPUE drops below a certain threshold, fishers will either move to a new area or stop fishing altogether because they will lose money by continuing. Thus, while economic extinction of the *C. frondosa* fisheries is a real possibility, it seems that unless extremely severe Allee effects occur (Courchamp et al. 1999; Stephens and Sutherland 1999; Petersen and Levitan 2001), it is unlikely that fishing will endanger *C. frondosa* with biological extinction risks, as has occurred for other sea cucumber species as a result of fishing (Bruckner et al. 2003). It is important to note, however, that although *C. frondosa* may not become extinct, the loss of the fishery due to overfishing could cause significant economic hardship to fishermen. Furthermore, the ecological impacts of a great reduction in the biomass of sea cucumbers are unknown.

Potential future changes in the market price for *C. frondosa* may considerably alter the dynamics of fisheries for this species and the risk of biological overfishing. Price increases seem possible as suggested by Ferdouse (1999, 2004). The market is virtually insatiable, and supply from other areas may dwindle due to overexploitation, but for now the low value of *C. frondosa* may offer some protection for the species. Although the apparent slow growth rate and relatively late maturity suggest that *C. frondosa* could be more vulnerable to exploitation than other sea cucumber species, the high density and the potential for natural harvest refuges that would protect a portion of the spawning stock indicate great potential for developing and maintaining sustainable fisheries for this species. It remains to be seen whether 1) this potential is realized through prudent management, 2) whether *C. frondosa* remains one of the world's most important commercial species in terms of landed weight, or 3) whether fisheries for this species will follow the cycle of most sea cucumber fisheries globally: that of boom and bust.

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Souvenir from west Lombok, eastern Indonesia

Pradina Purwati¹

Holothurians in Lombok, Indonesia have not been sufficiently studied. The few publications that exist include Prahoro and Suprpto (1991), Aziz and Sugiarto (1994) and Yusron (2004), who reported on the presence of holothurian species in Batu Nampar, Kuta and Teluk Gerupuk, and Sekotong, respectively. The latest data from the office of National Statistics in 2002 indicates that 84 metric tonnes (mt) of beche-de-mer (trepan), comes from West Nusa Tenggara Province where Lombok is located. The total national harvest is 3057 mt. The Indonesian provinces of Sulawesi, Maluku and Papua are still the country's major producers of beche-de-mer, accounting for more than two-thirds of the national total (BPS 2002 Report).

When I visited Lombok in late July to early August 2005, a collector at Medana village in west Lombok had 12 huge holothurian individuals. The size was believed to be more than 1.5 kilograms when alive, and sold for 35.000–100.000 Indonesian rupiah (IDR) each (USD 1 = IDR 9000). Most of the holothurians were salted with a long cut on either the ventral or dorsal side. The collector has been buying fresh holothurians from local and Madurese fishermen

(who dive in nearby waters) since early 1990. A compressor is used by the Madurese fishermen who dive mostly at night in depths of up to 30 m.

Approximately 30 species of holothurians are known by local fishermen in west Lombok, while a review of the national records indicate that 26 holothurian species have been involved in the Indonesian trepan fishery (Purwati in prep.). Nowadays, trepan prices are IDR100,000 individual⁻¹ for *Holothuria nobilis*; IDR 30,000–35,000 individual⁻¹ for *Thekenota ananas* or *Actinopyga* sp.; IDR 5000 for species of *Bohadschia*; IDR 300,000 kg⁻¹ for *H. scabra* (5 fresh individuals kg⁻¹); and IDR 1000 per large individual of *H. fuscogilva*.

In general, holothurians are called *bantun* in west Lombok, although one local name may be given to different species (Table 1).

In general, species composition of trepan in the local market is believed to be the same, although the volume has decreased. In the 1990s, as many as 30 individuals of *bantun batu* (*H. nobilis*) could be gathered from the fishermen in less than 15 days, which is rarely the case nowadays.



Figure 1. Sea cucumber species from Medana village.
a: *Holothuria scabra*; b: *Thekenota ananas*; c: *T. anax*; d: *Bohadschia marmorata*; e: *B. similis*

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Table 1. Local names of holothurians in west Lombok.

Local names	Scientific name	Possible misidentification
Talengko	<i>Holothuria coluber</i>	<i>H. leucospilota</i>
Bantun batu	<i>H. nobilis</i>	<i>A. miliaris</i>
Bantun kunyit	<i>H. fuscopunctata</i>	<i>H. scabra</i>
Cara hitam	<i>H. atra</i>	
Bantun beras / buang kulit	<i>H. scabra</i>	
Karido polos / bantun getah	<i>Bohadschia vitiensis</i>	
Karido getah bintik / laos	<i>B. similis</i>	<i>B. marmorata</i>
Karido bintik	<i>B. argus</i>	
Kapuk	<i>Actinopyga lecanora</i>	
Bantun kasut	<i>A. miliaris</i>	
Gamat order	<i>A. echinites</i>	
Koro coklat	<i>A. mauritiana</i>	
Bantun donga karang/jepun	<i>Pearsonothuria graeffei</i>	
Bantun capung	<i>Stichopus chloronotus</i>	
Gamat biasa	<i>S. hermanni</i>	
Gamat kacang	<i>S. horrens</i>	
Donga/duyung	<i>Thelenota anax</i>	
Bantun nanas	<i>T. ananas</i>	

**Figure 2.** Boiled trepang from Batu Kijuk village

In another part of west Lombok, Batu Kijuk village, Sekotong, a collector had small, boiled holothurians that were 7–8 cm in length, and these were likely to be *Stichopus*. Collecting holothurians is best in the rainy season at night, during a low tide. In the late 1990s when the fishery began in this village, the collector was able to process 300 kg of fresh holothurians per day, which were harvested by local villagers from the seagrass beds in front of the village.

Local collectors sell *bantun beras* (*H. scabra*) to the larger collectors or exporters for IDR 200,000 kg⁻¹ (35–37 individuals kg⁻¹), and IDR 420,000 kg⁻¹ (8 individuals kg⁻¹). *Gamat* (*Stichopus* spp.) prices range between IDR 150,000 and IDR 350,000 kg⁻¹ (for those that are 15 cm long). The collector at Sekotong reported that the gamat group of sea cucumbers has been harvested for the past three years, following

bantun koro, beras and *nanas*. Unlike in Medana, people at Sekotong consume *H. scabra* (*bantun beras*). After being boiled twice, *H. scabra* is dried to be used as crackers or cooked with spices and vegetables.

At both villages, as well as in other areas of Indonesia, including Maluku, processed trepang has never been kept for long periods of time. Most species of all sizes are sold immediately, demonstrating their high market demand. It is unfortunate that most holothurians sold by fishermen are low quality and sell for low prices. This encourages them to collect as many as they can, so they can compensate for expenses they incur while they are sailing.

Indonesian fishermen have been involved in the trepang fishery for more than 500 years. People of Makassan, Bugis, Bajo, Buton and Madura are well

known as trepang hunters. Their hunting areas reach as far as Australian waters (Dwyer 2001; Macknight 1978; Fox 2000; Stacey 2001). Such a long history does not draw enough attention from the government, the standard quality of processed holothurians has not been acknowledged/introduced, and there is no sustainable harvest strategy. The government and researchers have considerable work ahead of them in addressing conservation issues.

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Ontogenetic changes in colouration and morphology of white teatfish, *Holothuria fuscogilva*, juveniles in Kiribati

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Abstract

Little is known of the appearance or ecology of white teatfish (*Holothuria fuscogilva*) juveniles, which are very rarely found in the wild. In this study we use juveniles cultured in Kiribati to describe their ontogenetic changes in colouration and morphology, which differ strikingly from those of the adults. Juveniles are mostly yellow and up to ~15 mm in length, then gaining more black blotching on the body and becoming brown with black blotches around 20–30 mm in length. At this size they have stout, spike-like, dorsal protrusions on the body. When they reach ~50 mm in length, the body becomes progressively smoother and often cream-coloured with dark blotching. We present a length–weight relationship ($r^2=0.95$) from hatchery produced juveniles, which allows conversion of these measures among future studies. Our observations should assist in the identification of white teatfish when they are small, and shed light on suitable habitats for releasing them into the wild for restocking.

Introduction

The white teatfish, *Holothuria fuscogilva*, is one of three high-value sea cucumbers in the tropics. It is widely distributed across the Indo-Pacific and, apparently, in parts of the Indian Ocean (Uthicke et al. 2004). The adults can be off-white or light brown coloured, sometimes with dark mottling, and sometimes almost entirely dark brown (but light brown ventrally).

Despite its value, the life history of white teatfish is poorly known. In particular, little is known of the juvenile phase, which is rarely recorded in field surveys and field studies (Conand 1981, 1989). Moreover, small juveniles of holothurian species may be quite different in appearance from adults, preventing their identification in the field. Correct identification will enable reliable sightings in the field to expand our knowledge of their habitat association and ecology.

In Tarawa, Kiribati (Gilbert Islands group), white teatfish have been produced by the Ministry of Fisheries and Marine Resources Development since 1997. The sea cucumber production was supported, both technically and financially, by the government of Japan through the Overseas Fisheries Cooperative Foundation (OFCF). Thousands of the juveniles have been released into the wild to try to restock breeding populations in Kiribati, which have been depleted by overfishing (Friedman and Tekanene 2005). Here, we use individuals produced in a hatchery to document the colour patterns and morphology of *H. fuscogilva* so they can be reliably identified in the field. In addition, we

present a length-weight relationship for converting length measurement to body weight.

Colouration and morphology

Marked ontogenetic changes in colouration and morphology of white teatfish mean that juveniles bear little resemblance to adults. Juveniles of <15 mm (i.e. <0.2 g) are mainly yellow, with some patches of black (Fig. 1). They have a few prominent spike-like protrusions on the dorsal body wall. When they are 15–30 mm in length (i.e. 0.2–1 g), juveniles gain more dark blotches on the body and still have yellow colouration and possess anterior horn-like protrusions that are usually black. At this size, they have numerous broad, spike-like protrusions on the dorsal body wall. When they are 20–30 mm in length (i.e. ~0.4–1 g), the yellow colouration is replaced by beige, brown and black blotches. Once they reach about 50 mm (i.e. ~5 g), the juveniles progressively lose the prominent spike-like protrusions, becoming smoother on the dorsal surface. The colouration becomes generally lighter, often beige or cream in colour, but still with dark brown blotches.

We recognise the possibility that the hatchery environment could either modify colour patterns or the rate at which these change ontogenetically. For example, hatchery-reared juveniles of the topshell (*Trochus niloticus*) undergo ontogenetic changes in shell morphology at a smaller size than wild juveniles (Purcell 2002). That is, the hatchery-reared juveniles are morphologically precocious. Therefore, the colouration and morphology of white teatfish juveniles produced in the hatchery may well reflect

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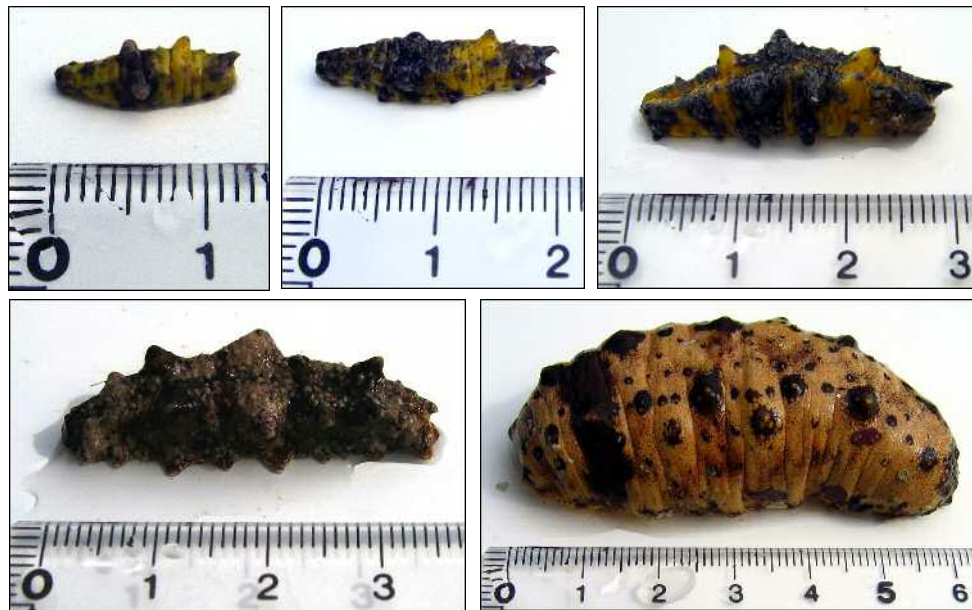


Figure 1. Photographs of white teatfish (*Holothuria fuscogilva*) juveniles cultured in the Kiribati Fisheries Department Hatchery at Tarawa, showing ontogenetic changes in morphology and colouration.

those of wild white teatfish juveniles, but the sizes at which those changes occur may be different.

The colour patterns of juveniles provide some clues to the ecology and likely nursery habitats for *H. fuscogilva*. The yellow and black banded colouration of small juveniles (<15 mm) could camouflage them in a specific microhabitat, but we note that this is a typical warning colouration in animals that are toxic or unpalatable when eaten (Brodie and Brodie 1999). Whether small juvenile white teatfish are toxic, or simply mimicing toxicity, is not known but this would be an interesting topic for future research.

In the Maldives, Reichenbach (1999) found that white teatfish (*H. fuscogilva*) juveniles occurred predominantly in shallow seagrass beds. Gentle (1979) reported to have found white teatfish juveniles, <20 cm in length, among turf-like "seaweeds" in Fiji. He hypothesised that their patchy brown colouration could act as camouflage in this microhabitat. Our study shows that the dark, blotchy, colour pattern occurred in hatchery-produced juveniles of 15–30 mm in length. We believe that dark coloured surfaces such as hard reef substrata with epilithic algae, or among certain seagrasses, may indeed allow this juvenile phase to be camouflaged. Releases of juveniles into these habitats could provide protection from predation, and be more suitable than sand or coral rubble for releasing juveniles for restocking. This hypothesis

will be examined in a restocking experiment in Abaiang, Kiribati.

Length–weight relationship

Hatchery produced juveniles ($n = 38$) were weighed to ± 0.01 g, and their body lengths measured ventrally to ± 1 mm. The length–weight relationship for juveniles 10–90 mm is given in Figure 2. The function explained 95% of the variation in body weight by measurement of length of the juvenile white teatfish. Since the exponent (slope of the curve) $2.629 (\pm 0.298, 95\% \text{ CI})$ is significantly less than 3, growth is allometric, with white teatfish becoming progressively thinner (or flatter) for their length as they grow longer.

The relationship should be useful when converting these measurements between studies or for rapid conversion to weight from length measurements taken in the field. The range in juvenile sizes examined here mirror those used for restocking in Kiribati (see Friedman and Tekanene 2005). The curve from our morphometric equation for *H. fuscogilva* is steeper than that determined by Conand (1989) principally from adults (i.e. $\text{weight} = 0.0011 * \text{weight}^{2.407}$). Our results, therefore, present a function to estimate weights of juvenile white teatfish from length measurement, whereas Conand's (1989) function should be used for conversion of length to weight in adult specimens.

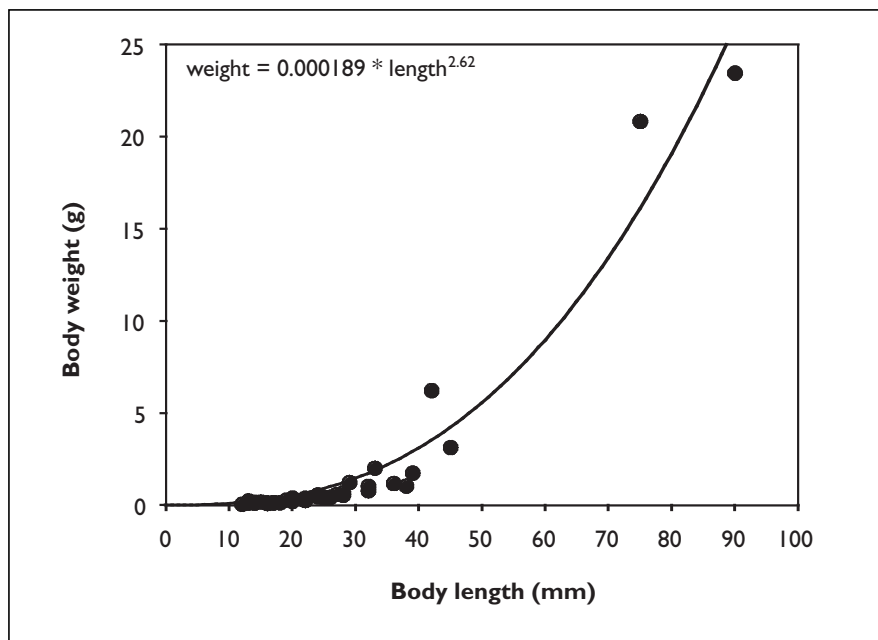


Figure 2. Length–weight relationship of hatchery produced white teatfish juveniles, using the general morphometric equation, $y = a * \text{length}^b$.

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Illegal sea cucumber fisheries in the Chagos Archipelago

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The Chagos Archipelago

The Chagos Archipelago, in the central Indian Ocean, includes about 50 small islands with a total land area of only 53 km². These islands are distributed across a vast complex of shallow banks and atolls with nearly 11,000 km² of waters above 50 m depth (Sheppard and Seaward 1999) and some 1.3% of the world's coral reef area (Spalding et al. 2001).

The islands were first settled in the late eighteenth century. By the mid-twentieth century there was a small economy, based around copra, but the resident population was removed, mostly against their will, by the British in the early 1970s (legal challenges from the Chagossian people are still ongoing). With the exception of Diego Garcia, where there is now a large US military base, the islands have remained uninhabited for over 30 years (Curtis 2004; Edis 2004). Surveys of the coral reefs during the 1970s revealed a remarkably pristine reef fauna although overfishing had likely taken a toll on marine turtles. The island biota on the formerly inhabited islands was of course significantly altered, however a number of islands remain rat-free and offer some of the most important seabird nesting colonies in the Indian Ocean.

Fisheries patrols, largely to monitor the licensed tuna fishery, began in the 1990s, and a small licensed demersal fishery from Mauritius has also been ongoing. At the same time, the first observations of illegal fishing were made and since that

time, an unquantified number of vessels have been observed, mostly from South Asia and Indonesia (Mees et al. 1999; and pers. comm. with various UK government and fisheries officials). An expedition in 1996 revealed that reef shark populations had declined by some 85% and, given that sharks had not been a target for the licensed fisheries, this collapse was firmly linked to the illegal fisheries (Anderson et al. 1998).

UK government efforts to police these waters have increased since 1996 and the waters are now patrolled year-round by a Fisheries Protection Vessel while regular sorties to the islands are made by British military personnel. This has led to increases in capture of illegal fishing vessels and crew (Fig. 1), although rates of arrival of new illegal vessels remain high (Cdr. C. Davies, British Representative, Diego Garcia, pers. comm.). It seems likely that, as fish stocks become increasingly impacted elsewhere around the Indian Ocean margin, then the risks associated with illegal fishing in Chagos waters will become increasingly worth taking.

Illegal sea cucumber fisheries

Reports point to an illegal sea cucumber fishery in Chagos that has been operating out of Sri Lanka for several years. This is supported by direct observations and discussions with fishers. We were first informed of large quantities of sea cucumbers from Chagos waters in Sri Lankan ports in about 1999 (pers. comm. Arjan Rajusuriya; Sheppard et al. 1999). Meanwhile, Terney Pradeep Kumara et al.

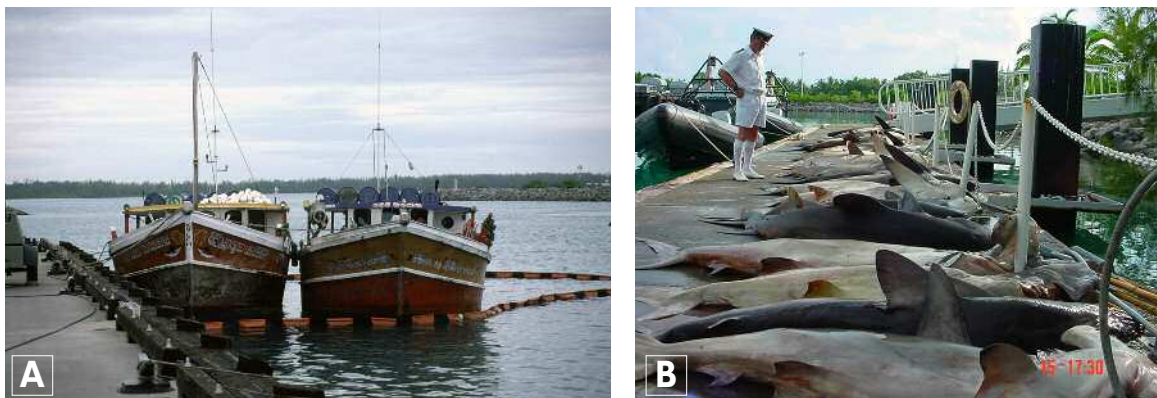


Figure 1. Intercepted illegal fisheries impounded in Diego Garcia. A: Sri Lankan vessels (photo: M. Spalding); B: shark catch (photo: N. Hinch)

(2005) have recorded sea cucumber imports of some 23,609 kg in 2000 and list Chagos as a major source. The start of the fishery in the years leading up to 2000 would tie in well with the recorded decline in national stocks in Sri Lanka that began around this time (Terney Pradeep Kumara et al. 2005)

Given that many illegal fishers of other fish stocks have been caught, it is perhaps surprising that the first direct observations and arrests of sea cucumber fishers by the Chagos authorities are from 2005 (pers. comm, Tony Humphries, BIOT Administrator).

Fisheries regulations within Chagos do not allow for any unlicensed vessels to take fish from Chagos waters. The only exceptions are for recreational and personal consumptive uses by personnel on Diego Garcia and the few private vessels (mostly yachts) that pass through these waters (Sheppard and Spalding 2003). Additional restrictions are imposed to prevent damage within the existing fisheries. There are limits on the gear and total number of licences, with temporary closures, for example, of spawning aggregations, which are imposed on the Mauritian commercial fishery. A number of Strict Nature Reserves have also been declared. These are closed to all fishing, although a legal loop-hole prevents this being applied to the Mauritian fishery at the present time.

In April 2005, a camp of illegal Sri Lankan fishers was observed on the northern end of Eagle Island, a Strict Nature Reserve. About 10 fishermen were pre-



Figure 2. Part of the haul of sea cucumbers on Eagle Island, April, 2006. Although not positively identified, it seems likely that the species include: **A:** some valuable teat fish *Holothuria (nobilis?)* and **B:** probably *Actinopyga* or *Bodaschia* spp. (Photos: M. Spalding)

sent. They had arranged a series of drying platforms on a wide sandy beach area at this end of the island, with strong black plastic sheeting to cover the sea cucumbers when it rained. An estimated 5000–7000 sea cucumbers were observed drying. These were not identified to species, although it would appear that there are several species present (Fig. 2). The mother vessel was not seen, but there was a small boat with an outboard. There was also no sign of diving equipment, although again it should be noted that this may have been held elsewhere.

These observations were reported to the British officials on Diego Garcia and the Fisheries Protection Vessel, with military personnel, was sent to intercept. The fishers were arrested, duly tried and fined, and on payment of the fine were allowed to return (without their catch) to Sri Lanka.

Since then, over a period of five months, a further three vessels and crew have been caught and each fined amounts ranging from USD10,000–17,000. Some, but not all vessels, were found with diving equipment, which would greatly extend their harvesting capability and would allow them to access some of the higher value species. To be added to the cost of these fines must be considered the costs of mounting an expedition to fish in Chagos waters. The journey is made in relatively small vessels, using considerable quantities of fuel. An expedition would take on the order of one to two months.

Such an expedition is clearly worth undertaking when the chances of success are high. This is heightened by the growing market value of sea cucumbers. The total value of the haul observed drying in April could have been as much as USD 60,000–80,000, and this by no means represents the complete intended catch. Perhaps the capture of four such ventures in the last five months will begin to have a deterrent effect.

Impacts on the natural population

There have been no surveys of sea cucumbers in the Chagos Archipelago and the author is unaware of any species lists. Figure 3 includes photos taken in the northern atolls of Chagos, including two spawning observations, as requested by Conand in her editorial in the SPC *Beche-de-Mer Information Bulletin* #22. Natural population sizes for the archipelago are unknown, which present a challenge to any efforts to assess the impacts of the fishery. Given the geography of the region, it is likely that most effort would have been focussed around the islands of Peros Banhos, the Great Chagos Bank and perhaps Egmont. Visitors to Solomon, and military on Diego Garcia, would likely prevent intensive collection in these places, while the very re-

mote and exposed nature of some of the non-islanded banks and atolls would likely reduce collecting pressure on these.

Nonetheless there is reason for concern. The Chagos archipelago represents one of the few remaining wilderness areas of the Indian Ocean. It provides an invaluable reserve of natural reef communities, and may well play a wider regional role in the movements of species and genetic material to other reefs across the ocean. It will be extremely valuable to maintain these reefs in healthy and near-pristine conditions in order to have a baseline, both for scientific study and, perhaps, to support recovery of damaged ecosystems elsewhere across the region. There is a considerable additional concern that the presence of persons onshore in the nature reserve islands could have consequences on their ecology. The accidental introduction of alien invasive species would have a devastating impact on some of the last vestiges of oceanic island hardwood forests as well as on the vast seabird nesting colonies that use the islands. The UK government has expressed its concern to the author and will be further seeking to halt this fishery through improved detection and arrest as well as through diplomatic approaches with other Indian Ocean countries.

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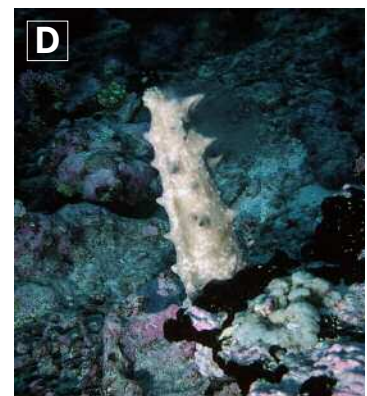


Figure 3. Underwater images of sea cucumbers in Chagos. A and B: probably *Pearsonothuria graeffei*; C: *Thelonota ananas*; D: unidentified. Both spawning observations were in early March 2001. (Photos: M. Spalding)

Asexual reproduction by induced transverse fission in the sea cucumbers *Bohadschia marmorata* and *Holothuria atra*

A. Laxminarayana¹

Introduction

Although holothurians are known for their ability to reproduce asexually by fission, specific data on this subject is scarce. Approximately 10 species of sea cucumbers have been reported from field and laboratory observations to reproduce asexually (Emson and Wilckie 1980; Conand 1989, 2004; Uthicke 2001a,b). Some of the species that reproduce asexually in the field are: *Holothuria atra*, *H. parvula*, *H. edulis*, *H. leucospilota*, *Actinopyga mauritiana* and *Stichopus chloronotus*. Other studies present experimental induction by constriction (Reichenbach and Hollway 1995). In the present study, the sea cucumbers *Bohadschia marmorata* and *H. atra* were induced to reproduce by transverse fission by cutting them slightly anteriorly to the middle portion (45%) of the body.

Materials and methods

This study was carried out at the Albion Fisheries Research Centre in Mauritius. The sea cucumbers *B. marmorata* and *H. atra* were collected from the wild during low tide or by free diving from August to December 2004. The sea cucumbers were maintained in one-tonne tanks containing about 15 cm of sand. The tanks were aerated with an air-blower. Water in the tanks was changed every day and the sand was changed once every two weeks. The sea cucumbers were fed with seaweed powder.

Two experiments were conducted. In the first experiment, 6 *H. atra* and 4 *B. marmorata* were studied, and in the second experiment, 10 *H. atra* and 20 *B. marmorata* were examined. The total initial weights of *H. atra* were 1387.0 g in the first experiment, and 961.0 g in the second experiment. The total initial weights of *B. marmorata* used for the first and second experiments were 440.0 g and 2609.9 g, respectively. The mean weight of *H. atra* for the first and second experiments were 216.7 g and 96.1 g, and the mean weights of *B. marmorata* were 110.0 g and 130.5 g in the first and second experiments.

The sea cucumbers were cut into two after making a constriction slightly anterior (45%) to the middle portion of the body. The total weights of the anterior and posterior parts were recorded immediately after induced transverse fission. The mean

weights of the anterior parts of *H. atra* were 86.7 g and 39.5 g in the first and second experiments. The mean weights of posterior parts of *H. atra* in the first and second experiments were 120.2 g and 52.5 g. The mean weights of anterior parts of *B. marmorata* were 42.8 g and 50.5 g in the first and second experiments, respectively. The mean weights of posterior parts of *B. marmorata* in the first and second experiments were 61.7 g and 72.8 g. All anterior and posterior halves were introduced into one-tonne fiberglass tanks provided with about 15 cm of sand. The sea cucumbers were fed daily with seaweed paste/powder.

Figure 1 shows the area of constriction before cutting *H. atra* into two, slightly anteriorly (45%) to the middle portion of the body. Figure 2 shows the process of cutting *H. atra* into two halves; Figure 3 shows the two cut portions after they regenerated.

The survival and weight of the sea cucumbers were monitored up to 373 days in the first experiment, and up to 288 days in the second experiment. The mean weights of sea cucumbers were calculated from the total final weights of the sea cucumbers at the end of the experiments. The results of the growth of asexually reproduced sea cucumbers are summarised in Tables 1 and 2.

The experiments were conducted from October 2004 to October, 2005. The water temperature variation during the period of study was 24.5–28 °C. Salinity varied from 34–36 ppt and pH varied from 8.1–8.4.

Results

In the first experiment, all the posterior and anterior halves survived in both species. The mean weights for *H. atra* were 447.6 g and 280.4 g in the first and second experiments, respectively. The mean weights of *B. marmorata* were 304.0 g and 286.0 g in the first and second experiments. The growth per day was 0.62–0.64 g for *H. atra* in the first and second experiments, and growth per day for *B. marmorata* was 0.52 g–0.54 g in the first and second experiments. In the second experiment, survival rates after 288 days were 95% and 92.5% for *H. atra* and *B. marmorata*. In the second experiment, initial mortality was noted during the first two days after duplication of the sea

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Figure 1. Area of constriction before cutting *Holothuria atra*



Figure 2. Process of cutting *H. atra* into two halves



Figure 3. The two cut portions.

cucumbers. All of the four pieces that died were the anterior portions of the cut ends of the body. After two days of duplication, the body wall had its normal consistency and wounds at both the ends were healed and entirely closed.

Discussion

Asexual reproduction in sea cucumbers by fission has been studied by several researchers (Emson and Wilkie 1980; Emson and Maldenov 1987; Conand 1989, 1993, 1996; Conand and Ridder 1990; Chao et al. 1993; Reichenbach and Hollway 1995; Boyer et al. 1995; Reichenbach et al. 1996; Uthicke 1997, 1998, 2001a, b; Conand and Uthicke 2001; Howaida et al. 2004). Asexual reproduction in nature is a seasonal event mainly occurring in winter in natural populations. Most holothurian species with asexual reproduction follow the "twisting and stretching" mode (Emson and Wickie 1980; Uthicke 2001a, b); the anterior and posterior sections rotate in opposite directions, resulting in a constriction in the holothurian. In the second step, the two halves slowly move in opposite directions until the body wall tears at the constriction and the two halves become completely separated. This process of asexual reproduction by transverse fission was noted in natural populations of *H. atra* by Chao et al. (1993), Conand and Ridder (1990), Boyer et al (1995), Conand (1996) and Uthicke (1997, 1998, 2001a, b). Reichenbach and Hollway (1995) described the asexual propagation potential of several commercially important species of sea cucumbers. Asexual reproduction was observed in *H. edulis* and *Stichopus chloronotus* (Uthicke, 1997, 1998, 2001a, b). Howaida et al. (2004) conducted experiments on the asexual reproduction of *Actinophyga mauritiana* by placing rubber bands in the midbody of *A. mauritiana*. Immediately after this, the animals started to constrict slightly in the middle and showed some swelling in

Table 1. Asexual reproduction in *H. atra*

Expt. no.	No. used	Initial total wt. (g)	Initial mean wt. (g)	Mean wt. (g) anterior part	Mean wt. (g) posterior part	Final total wt. (g)	Final mean wt. (g)	Growth / day (g)	Survival (%)
1	6	1387.0	216.7	86.7	120.2	2687.8	447.6	0.62	100.0
2	10	961.0	96.1	39.5	52.5	2701.8	280.4	0.64	95.5

Table 2. Asexual reproduction in *B. marmorata*

Expt. no.	No. used	Initial total wt. (g)	Initial mean wt. (g)	Mean wt. (g) anterior part	Mean wt. (g) posterior part	Final total wt. (g)	Final mean wt. (g)	Growth / day (g)	Survival (%)
1	4	440.0	110.0	42.8	61.7	1215.8	304.0	0.52	100.0
2	20	2609.9	130.5	50.5	72.8	5291.0	286.0	0.54	92.5

the posterior section. After one hour, the constriction became slightly more distinct, giving a heart shape to the posterior half. The anterior and posterior ends slowly rotated in opposite directions resulting in a more distinct constriction. The entire process of fission lasted for an entire day. After two days, the body wall had its normal consistency and wounds at both ends were healed and nearly closed. Howaida et al. (2004) also observed a survival rate of 65% for anterior parts and 85% for posterior parts.

In the present work, all the cut pieces survived in the first experiment whereas in the second experiment, survival was 92.5–95%. The mortality that occurred was for the anterior parts during the first two days after duplication. There was initial weight loss immediately after the induction of transverse fission in the sea cucumbers, but thereafter, there was a gradual increase in weight once the sea cucumbers fully regenerated. The growth rate was slightly better for *H. atra* (0.62–0.64 g day⁻¹) compared with *B. marmorata* (0.52–0.54 g day⁻¹). So far, there are no experimental studies on the growth rates of sea cucumbers after asexual reproduction. Therefore, the present study provides some useful information on this, although more studies are needed in this important area of sea cucumber research.

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Observation of natural spawning of *Bohadschia vitiensis*

Observer: Aymeric Desurmont¹

Date: 11 June 2005
 Observation time: 16:30–16:45
 Location: Baie des Citrons, Noumea, New Caledonia
 Depth: 2–5 m
 Tide: Low tide
 Moon phase: 4 days after new moon
 Species: *Bohadschia vitiensis* (2 specimens spawning)

Description

As already described in several past issues of this bulletin,² the Baie des Citrons in Noumea, New Caledonia is host to many species of sea cucumbers, including *Bohadschia vitiensis*, which is mostly found on the soft sandy-muddy bottom in the middle of the bay.

On the day of the observation, many sea cucumber tracks could be seen on the soft bottom, and all visible *B. vitiensis* specimens were clearly on top of the sediment and not half buried as they usually are. Two specimens were in the classical upright spawning position, releasing a very thin dribble of white gametes while slowly swaying. These were the only two *B. vitiensis* specimens showing signs of spawning activity among the 50+ individuals visible during 15 minutes of observation.

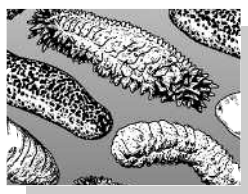
Other sea cucumber species visible in the surrounding area (*B. argus*, *H. atra*, *H. coluber*, *H. edulis*, *H. scabra*, *H. scabra versicolor*, *Stichopus chloronotus* and *S. hermanni*) showed no sign of spawning behaviour.

It is interesting to note that this observation was made in June during the austral winter while another observation of mass-spawning of the same species had been made³, in the same location, in November 2004 during the austral summer.



Bohadschia vitiensis

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 2. SPC Beche-de-mer Information Bulletin, Issues: #18, p. 38; #20, p. 37; and #21, p. 28. (<http://www.spc.int/coastfish/News/BDM/bdm.htm>)
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Abstracts & publications

beche-de-mer

SPC translates two chapters of Chantal Conand's 1989 thesis: "Aspidochirote holothurians of the New Caledonia lagoon: Biology, ecology and exploitation"

SPC's Reef Fisheries Observatory has organised the translation of two chapters of Chantal Conand's seminal thesis on the ecology and biology of sea cucumbers. Although this thesis was published in French in 1989, a long time ago, many results were never made available to the wider audience of non-French speakers. Since the initial publication of this work, interest on holothurian resources and their management has only increased, and SPC hopes this translation will be of use to fishers, researchers and managers alike.

Chantal Conand is now Professor Emeritus at La Reunion University. Her PhD was undertaken at the ORSTOM (now IRD) Center in New Caledonia, and the Laboratory Océanographie Biologique of the University of Bretagne Occidentale in France. She is still involved in sea cucumber research, as the scientific editor of this Beche-de-mer Bulletin published by SPC and several programmes of regional and international interest.

The translated parts of the PhD thesis are listed below:

Part of Chapter two:

Ecology of the aspidochirote holothurians

4. Autoecology
 - 4.1 Analytical methods
 - 4.2 General results on distribution, density and biomass
 - 4.3 Ecology of main species
 - 4.4 Discussion of results
5. Taxocoenoses
 - 5.1 Methods
 - 5.2 Richness of the various biotopes
 - 5.3 Main taxocoenoses
 - 5.4 Discussion
 - 5.5 Factors of the distribution
6. Conclusion

Chapter three :

Biology of the main commercial species

1. Introduction
 - 1.1 Purpose of the study
 - 1.2 Materials
2. Biometrics
 - 2.1 Introduction and methods
 - 2.2 Distribution of length and weight frequencies
 - 2.3 Biometric relationship
 - 2.4 Discussion

The document is available on CD, in pdf format. For more information, please contact: Kim Friedman, Senior Reef Fisheries Scientist, SPC, BP D5, 98848 Noumea Cedex, New Caledonia. Email: KimF@spc.int

Abstracts

Long-term changes in reproductive patterns of the holothurian *Oneirophanta mutabilis* from the Porcupine Abyssal Plain

E. Ramirez-Llodra, W.D.K. Reid and D.S.M. Billett

Source: Marine Biology (2005) 146: 683–693

Time-series studies (1989–2002) in the NE Atlantic have shown large-scale changes in the composition and structure of the benthic community on the Porcupine Abyssal Plain. Radical changes in the abundance of some species in 1996 led to a significant shift in the way in which organic matter was reprocessed at the seabed. This article examines the reproductive processes of the holothurian *Oneirophanta mutabilis* collected during the time series. The reproductive biology of *O. mutabilis* is reviewed. No males were evident in any of the samples. The sex ratio (females: 'no gender') was biased significantly towards no-gender individuals. The maximum egg size was 650 μm and there was no evidence of synchrony in reproduction. Significant changes in the oocyte-size distribution and the fecundity of *O. mutabilis* were noted through time, coinciding with the time of greatest faunal change in the benthic community. There was an increase in the proportion of previtellogenic oocytes and a decrease in the proportion of mature vitellogenic oocytes in 1997 and 1998, in parallel with a significant decrease in fecundity of the post-1996 samples. Samples from 2002 showed a reversal in the reproductive trends, with an increase in the proportion of mature vitellogenic oocytes and fecundity. The results are discussed in relation to large changes in abundance of the epibenthos on the Porcupine Abyssal Plain. It is suggested that the superabundance of certain megafaunal species on the abyssal seafloor affected the availability of trophic resources for *O. mutabilis*, leading to the changes in its reproductive effort.

Feeding rate and impact of sediment reworking by two deposit feeders *Holothuria leucospilota* and *Holothuria atra* on fringing reef (Reunion Island, Indian Ocean)

P. Mangion, D. Taddei, P. Frouin and C. Conand

Source: Echinoderms: München - Heinzeller & Nebelsick (eds), Taylor and Francis Group, London, 311–317

To investigate the quality and the quantity of sediment ingested by deposit-feeding holothurians, experiments were conducted with the common species *Holothuria atra* and *Holothuria leucospilota* at two stations on Reunion fringing reefs. A relation has been established between enrichment level of the area and holothurian densities: holothurians are abundant (densities up to 3 ind m^{-2}) in eutrophic areas whereas low densities characterize oligotrophic areas. During field observations, *H. atra* and *H. leucospilota* consumed an average of 79.7 g dw ind⁻¹ d⁻¹ and 88.8 g dw ind⁻¹ d⁻¹ of sediment respectively in both stations. We showed that a mixed population of both species in a eutrophic area can rework 82 kg dw m^{-2} y^{-1} whereas in the oligotrophic area 3 dw m^{-2} y^{-1} only are reworked. There was no significant difference in sediment organic matter between the stations, nevertheless the high densities found in the eutrophic area indicate a higher benthic production. Gut content analysis showed that the organic matter ingested from the sediment was used with 10% efficiency for both species. C/N ratio decreased along the gut showing organic matter degradation. This shows the ability of these holothurians to break down the organic matter from the sediment and to make it easily available for other organisms

Reproductive biology of *Holothuria leucospilota* in the Cook Islands and the implications of traditional fishing of gonads on the population

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Source: New Zealand Journal of Marine and Freshwater Research, 2005, Vol. 39:141–156

This study describes the reproductive biology of *Holothuria leucospilota* in Rarotonga, Cook Islands and assesses the effect of traditional fishing on survival and reproduction. Monthly collections of *H. leucospilota* from January 1998 until March 1999 revealed that gametogenesis and spawning were synchronous be-

tween the sexes and spawning occurred annually during the summer months. Spawning during the first year had already started at the beginning of the study in January and lasted until April, whereas in the second year, spawning started in November and finished in February, possibly because of higher water temperatures in this year. Our data indicate that the incision of the body-wall and gonad removal had no impact on the survival of *H. leucospilota* in cages. However, their body weight, general sheltering and feeding behaviours were affected by gonad removal. Although the body-wall of fished animals healed within 7–14 days, the gonads had just started to regenerate after 41 days, suggesting that the spawning of fished individuals would have been greatly delayed, possibly until the following year.

Population dynamics of the exploited sea cucumber *Isostichopus fuscus* in the western Galapagos Islands, Ecuador

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Source: Fisheries Oceanography 14: 377. (2005)

Long-term density data for the sea cucumber, *Isostichopus fuscus*, from Canal Bolivar (separating eastern Isabela and eastern Fernandina Islands), Galapagos, were compared with catch statistics and used in a stock depletion model to determine the extent of the effects of the fishery on the existing population and the potential for the population to recover after each fishing season. Recruitment indices were found to be low from 1994 until mid-1999, when a mass recruitment event was registered and numbers of small individuals increased dramatically. The increase in density of juveniles peaked in 2001 and has declined since. Recruitment in this species of sea cucumber appears to be highly sporadic and may depend on intense climatic events such as the warm El Niño. Current levels of fishing activity are unsustainable. The management implications of pulse recruitment in this fishery are discussed.

To split or not to split? A study of fission in tropical holothuroids and the carrying capacity of the environment

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Source: Poster presentation made at AMSA 2005, 11–13 July 2005, Darwin, N.T., Australia

Asexual reproduction by transverse fission of four species of aspidochirotida holothuroids (*Holothuria atra*, *H. hilla*, *H. difficillis* and *Stichopus chloronotus*) will be monitored in One Tree Island on the Great Barrier Reef and fission products will be surveyed for the duration of the study (March–September). *Holothuria atra* were translocated to patch reefs (micro-atolls) within the lagoon at 2 density treatments (low density and high density) with unmanipulated patch reefs as controls. The *H. atra* were measured and weighed before being placed into the patch reefs. Their weight and length and reproductive response (fission) will be monitored throughout the study. These experiments will test the hypothesis that holothuroids can adjust their reproductive strategy in response to the carrying capacity of their environment. Aspidochirotids are deposit feeders and ingest the top 5 mm of the substratum. The nutritional value of the sediment in all treatments will be assessed during this study and analysed for any nutritional changes potentially resulting from the presence of holothuroids. Presently the demand for holothuroids as beche-de-mer has increased drastically and has led to the overharvesting of species of high market value. There is now an urgent need for better management strategies for fisheries to maintain sustainable populations of holothuroids as a food resource whilst maintaining their role in coral reef ecology. This depends on an increased understanding of the biology and ecology of holothuroids.

Impact of holothurian nutrition on microbenthic communities in coral reefs and evaluation of toxicity biomarkers (La Réunion, Indian Ocean)

J. Kolasinski

Source: 2005 - Masters report, University of Metz and Marine Ecology Laboratory of La Réunion University, 50 p.

The first objective of this study was to assess the microbenthos ingestion and absorption by two holothurian species *Holothuria atra* and *H. leucospilota* of La Reunion fringing reefs. Nine individuals of each species were sampled in three stations located along an eutrophication gradient. Microbenthic communities were assessed by chlorophyll *a*, phaeopigments, phospholipids and glycolipids contents. Holothurians from the oligotrophic reference station appeared to discriminate soft bottom patches with high nutritional value. In contrast, no selectivity was observed in the two other eutrophicated stations. Then oligotrophic and dystrophic zones seemed to differ by the extent of selectivity. *H. atra* show a significantly higher assimilation than *H. leucospilota*. Data also suggest that efficiency of assimilation decrease with the eutrophication gradient. Thus, investigations on holothurian nutrition may be considered as reliable bioindicators of enrichment. The second objective of this study was to assess toxicity biomarkers, acetylcholinesterase activity (AChE) and ethoxyrufin-O-deethylase activity (EROD), to elucidate any correlation with the eutrophication gradient. AChE is the functional target of insecticides, nematicides and chemical nerve agent. EROD activity is the main biotransformation process concerning the organic xenobiotics and then inform on any physiological induced stress. Significant variation was measured in AChE activity for *H. leucospilota*. The lowest value was found at the reference station ($293,9 \pm 72,4$ nmoles $\text{mgP}^{-1} \text{min}^{-1}$) compared with the values in eutrophicated areas (548.0 ± 84.1 and 607.3 ± 72.2 nmoles $\text{mgP}^{-1} \text{min}^{-1}$), what represent a 48% inhibition in the reference station. The EROD activity was measured for the first time on *H. leucospilota* and *H. atra*, and showed no significant difference between stations with 27.73 ± 25.19 to 68.73 ± 52.20 pmoles $\text{mgP}^{-1} \text{min}^{-1}$ for *H. leucospilota* and 10.78 ± 7.55 to 20.33 ± 24.56 pmoles $\text{mgP}^{-1} \text{min}^{-1}$ for *H. atra*.

Reproduction of the commercial sea cucumber *Holothuria whitmaei* [Holothuroidea: Aspidochirotida] in the Indian and Pacific Ocean regions of Australia

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Source: Marine Biology 2005 (on line)

Seasonal trends in the gonad index (GI) of two widely separated populations of black teatfish, *Holothuria whitmaei* (formerly included in *H. nobilis*), were investigated between Pacific (Great Barrier Reef) and Indian Ocean (Ningaloo Reef) coral reefs of Australia. Reproductive activity followed a similar annual trend, with the GI of both populations peaking typically between April and June. Macroscopic and histological analysis of Ningaloo Reef specimens revealed that large germinal tubules, positioned centrally on the gonad basis, progressed through four maturity stages: growing (II); mature (III); partly spawned (IV); and spent (V). Growing tubules dominated the central region of the gonad basis between January and March, followed by an increase in the number of mature tubules throughout the GI peak (April–June). The progressive appearance of partly spawned and spent tubules between June and October suggests that spawning in *H. whitmaei* continues intermittently over an extended period throughout the austral winter. Examination of the gonad structure of sexually mature male and female specimens identified five tubule size classes in total (C₁ to C₅), each of differing physical and gametogenic status. In females, smaller C₁ tubules, located at the anterior edge of the gonad basis, contained pre to early vitellogenic oocytes. Larger C₂ and C₃ tubule cohorts, positioned centrally on the gonad basis, contained mid to late stage vitellogenic oocytes. Smaller C₄ and C₅ tubules, located at the posterior edge, contained only relict oocytes. Similar physical and gametogenic differences were apparent between tubule cohorts in male specimens. We propose that these results, together with evidence of incomplete gonad resorption over the austral summer, indicate that gonad development in *H. whitmaei* conforms to the predictions of the Tubule Recruitment Model (TRM). The TRM is reported rarely among tropical aspidochirotes, and results presented here (1) provide the first direct evidence of this model in *H. whitmaei*, and (2) confirm that this species is one of the few winter-spawning tropical invertebrates.

Zoogeography of the shallow-water holothuroids of the western Indian Ocean

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Source: Journal of Biogeography (J. Biogeogr.) (2005) 32, 1523–1538

Aim to analyse the zoogeography of the shallow-water holothuroids of the western Indian Ocean (WIO). Based on this analysis we ask to what extent differences in species' ability to disperse across potential barriers provide an explanation for holothuroid zoogeography. Location Shallow-waters (50 m isobaths) of the WIO, extending from Suez to Cape Town and from the coastline of East Africa east to 65°E. Methods Data for the analysis were obtained from Samyn's (2003) monograph on the shallow-water sea cucumbers of the WIO. A species presence/absence matrix with a resolution of 1° latitude/longitude was constructed. These cells were assigned to eight coarser operational geographical units, which were delimited on the basis of published faunistic and geological borders. The analytical zoogeographical methods employed were cluster analysis on several b-diversity coefficients and parsimony analyses of endemism. The influence of life-history strategies on the distribution pattern was analysed through examination of latitudinal and longitudinal gradients, and by plotting cumulative curves for species number against range size. Results The shallow-water holothuroid fauna of the WIO can be split into several biogeographical units. To the north, we found evidence that the northern Red Sea holothuroid fauna differs from that of the southern Red Sea. The latter has closest affinity with south-east Arabia and the Persian Gulf, and thus the biogeographical barrier of Bab-el-Mandab nowadays seems to be of minor importance. The cold upwelling at the east coast of Somalia forms an effective barrier for holothuroids and especially those with lecithothrophic (short-lived) larvae. Even though the circumtropical biogeographical pattern is not well resolved, important taxonomic turnovers suggest that it is composed of several distinct subprovinces. Taxonomic turnover is at least partially dictated by the dispersion capacity of the different orders. Main conclusions This study concludes that the WIO is best split into at least three biogeographical realms: (1) the Red Sea and associated Arab Basin, (2) the asymmetrical circumtropical region stretching from the horn of Africa to southern Mozambique, and (3) southern Africa. Conspicuous differences in dispersal abilities of the three dominant orders are identified. The biogeography of the WIO is best explained by: (1) species' dispersion ability, (2) the prevalent current patterns, and (3) to a lesser, geographically limited extent, recent geological history. As a serendipitous discovery, we found that Rapoport's rule does not hold in the WIO.

Commercial sea cucumbers and trepang markets

Chantal Conand

Source: Encyclopedia of Life Support Systems (EOLSS), Developed under the Auspices of the UNESCO, Eolss Publishers, Oxford, UK, [<http://www.eolss.net>] [Retrieved November 9, 2005], in Fisheries and Aquaculture

Characteristics of the morphology, anatomy, and biology of the sea cucumbers, particularly the commercial species, used to prepare trepang or "beche-de-mer," a delicacy for Asiatic people, is presented in the introduction, before an overview of the complex fishery system. The main commercial species are then listed, and summary described, according to the fishery zones and traditions. The harvesting, processing, and grading methods for trepang are traditional and help maintain high grade, valuable products. The main world fisheries, tropical and temperate, traditional and recent, and their recent catches are analyzed, and show an increase of interest; many recent fisheries raise conflicts in relation with conservation needs. The processed product generally passes from the producer country to the main world markets, Hong Kong, Singapore, and Taiwan, before being imported in the consumer countries. From diverse indices, over-exploitation is more and more often evoked worldwide, as the demand for trepang increases; durable management should become a priority, and regulations should be adapted for these fisheries. In conclusion, further studies should develop on the fishery biology of the commercial species, on stock assessments, on improving the statistics on catches and markets, and on alternative measures for conservation based on mariculture. Despite an increasing interest, all these fields are still poorly known; they yet deserve more attention, as their social value in small artisanal activities is high.

Molecular phylogeny of coral-reef sea cucumbers (Holothuriidae:Aspidochirotida) based on 16S mitochondrial ribosomal DNA sequence

Alexander M. Kerr, Daniel A. Janies, Ronald M. Clouse, Yves Samyn, Jeni Kuszak and Junhyong Kim

Source: Marine Biotechnology 2005 7:53–60

Members of the Holothuriidae, found globally at low to middle latitudes, are often a dominant component of Indo–West Pacific coral reefs. We present the first phylogeny of the group, using 8 species from the 5 currently recognized genera and based on approximately 540 nucleotides from a polymerase chain reaction–amplified and conserved 3' section of 16S mitochondrial ribosomal DNA. Parsimony and likelihood analyses returned identical topologies, permitting several robust inferences to be drawn. Several points corroborated the Linnean classification. *Actinopyga* and *Bohadschia* each appear monophyletic and *Pearsonothuria* is sister to *Bohadschia*. Other aspects of our phylogeny, however, were not in accord with the taxonomy of Holothuriidae or previous speculations about the group's evolutionary history. Most notably, the genus *Holothuria* appears paraphyletic. *Actinopyga* and *Bohadschia*, sometimes held to be closely related to one another because of certain morphologic similarities, are only distantly related. The morphologically distinct *Labidodemas*, even thought to warrant separation at the family level, is nested well within *Holothuria*. A maximum parsimony reconstruction of ancestral ossicle form on the phylogeny indicated that, in addition to a probable bout of elaboration in ossicle form (the modification of rods or rosettes to holothuriid-type buttons), at least 2 rounds of ossicle simplification also transpired in which buttons reverted to rods or rosettes. Cuvierian tubules, defensive organs unique to numerous members of Holothuriidae, were probably present before the initial radiation of the family, but the reconstruction is ambiguous as to their ancestral function.

Further insight on carapid–holothuroid relationships

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Source: Marine Biology 146(3) 2005: 455–465

Carapidae (or pearlfish) are eel-like fishes that live inside different invertebrates, such as holothurians, sea stars, or bivalves. Those of the genus are commensal and use their host as a shelter, while species are parasitic and eat the hosts gonads. In areas where they live in sympatry and are able to inhabit the same host species. Infestation is considered as monospecific when several conspecifics are observed in the same host. However, many aspects of this particular relation remain obscure, e.g. communication between carapids and the defence systems of the different protagonists (carapids and hosts). Experiments have been conducted in the field and laboratory to investigate several aspects of the carapids relationships with their hosts. Sampling carried out in the Bay of Opunohu (Moorea, French Polynesia) determined the sex ratio of (3:1) and (1:1) and their distribution rate within different Echinodermata. Our study showed that neither species was capable of determining whether a heterospecific already occupied a sea cucumber or not. They were, however, able to locate the sea cucumber's cloaca, due to the excurrent resulting from respiration. The sea cucumbers defence system (Cuvierian tubules) minimises predator attacks, but is not effective against carapid intrusion. The Carapidae defence system is twofold. Due to a passive system related to the sea cucumbers low cloacal position, the Cuvierian tubules are not expelled when fish enter the cloaca. Moreover, carapids resist sea cucumber toxins better than other reef fish. Their increased resistance might be related to their gills rather than to their mucus coating; however, the latter may assist the fish in resisting the sticky substances emitted by the Cuvierian tubules.

Economics and management strategies for restocking sandfish in Vietnam

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Source: NAGA, WorldFish Center Quarterly 27(3 & 4) July–Dec 2004

This paper assesses the costs and benefits of a proposed project for restocking sandfish (*Holothuria scabra*) in Khanh Hoa Province, Vietnam. It identifies the key stakeholders, institutional framework, management and financing required for its implementation. The recommended management strategy includes a 50 per cent harvest at optimum size. Limiting the number of boats fishing an area, possibly through licensing, can

control the number of sandfish removed. The easiest way to prevent harvesting of undersized sandfish is to control the size of processed sandfish from processors. The potential benefits of restocking are shown by the rapid changes in selected indicators, particularly the net present value, the internal rate of return, and the benefit-cost ratio. Probability analysis is used to estimate the uncertainties in the project calculations. Based on a conservative estimate, the restocking of sandfish is expected to be profitable, although cost-benefit analyses are sensitive to the survival of restocked sandfish and their progeny, and the number of boats fishing for sandfish in the release area.

The population dynamics and some aspects of the fishery of sea cucumbers (Holothuroidea) along the Kenyan coast

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Source: Fourth WIOMSA Intern Scientific Symposium, Mauritius, September 2005

The Holothurian or sea cucumber fishery is a potentially highly valuable fishery, with features including low technological requirements for capture and processing that make it easily accessible to local communities. However, despite the relatively long history of this fishery in Kenya, key information required for management is lacking. This study investigates 1) the spatial and temporal distribution of sea cucumbers along the Kenyan coast in order to ascertain the availability of commercial species 2) the catch composition and fishing effort at two major landing sites and 3) the mode of fishing and historical trends of the sea cucumber fishery in Kenya. The abundance and distribution of sea cucumbers was investigated using belt transects, timed counts and quadrat surveys that were laid in different habitats from Malindi to Shimoni as well as inside and outside MPAs. Catch data was collected at Gazi and Shimoni and included records of the species caught and measurements of sizes (wet weights, lengths) as well as the number of fishers for a period of four months. Historical catch data were compiled from fisheries catch statistics. A total of 31 species were recorded (from Kiunga to Shimoni) and a new species, *Holothuria (Mertensiothuria) arenacava* was described from the Mombasa marine reserve. Seventeen species were of commercial value including the high value species *H. fuscogilva*, *H. nobilis* and *H. scabra* but the most common species were *H. atra* and *H. leucospilota* that are of low value. The abundance of sea cucumbers was highly variable ranging from 0.5 to 7.75 sea cucumbers 250 m⁻². Sandy channels and hard substrate sites had the highest abundance of sea cucumbers (5–15 individuals 250 m⁻²) and seagrass areas the lowest (2 individuals 250 m⁻²). When similar sites were compared, marine parks did not have a higher diversity but had statistically higher abundances of sea cucumbers than unprotected sites. *Holothuria fuscogilva*, a high value species contributes 49% and 63% of the catch at Gazi and Shimoni, respectively. *Holothuria nobilis*, *Actinopyga miliaris*, *Thelenota ananas*, *Bohadschia marmorata*, and *B. argus* contribute between 7–13% of the catch. The catch ranged between 12–30 pieces man⁻¹ day⁻¹ at Gazi and 20–24 pieces man⁻¹ day⁻¹ at Shimoni. Approximately 20% of *H. fuscogilva* in the catch at Gazi and ~5% of *H. scabra* collected in Shimoni were sexually immature. Fisheries department catch data indicate that catches have declined from 90 metric tons yr⁻¹ in 1988 to less than 20 metric tonnes yr⁻¹, in 1999. In addition, interviews with fishers indicated that large, high value species are becoming more difficult to collect and the catch is increasingly dominated by mid to low value species. All these indicate that the fishery is in urgent need of intervention. The study recommends a moratorium on new licenses, improved collection of catch data especially of the top 5 species and biological studies including reproduction and recruitment of the key species that are crucial for fisheries management.

Resource assessment of the holothurian populations of the Seychelles

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Source: Fourth WIOMSA Intern Scientific Symposium, Mauritius, September 2005

The holothurian fishery in Seychelles has developed rapidly recently due to the high demand for bêche-de-mer. By 1999 there were already signs of population depletion, and concerns were raised regarding the sustainability of the fishery. Lacking baseline data on the holothurian population, the Seychelles Fishing Authority started a resource assessment project with funding from the FAO. The study area was limited to the Seychelles Bank and the Amirantes Plateau which represented 96.3% of the 50,396 km² of shallow (<100 m) habitat in the Seychelles. We stratified the study area by depth and type of substrate to produce a total of

14 strata. These were used as the basis for the sample design where 329 sampling sites were optimally allocated using pilot density data and expert knowledge. The surveys were done either by divers collecting data along a 100 m long x 8 m wide belt transect or by a towed video camera for a 15min period. During 3 cruises, a total of 250 sites were surveyed. Twenty three species of sea cucumber were found during the surveys. The total stock estimate of holothurian for the study area stands at 98,579.8 t (88,214.7 t for the Seychelles Bank and 10,365.1 t for the Amirantes). The overall population density (no/ha) ranges from 19.4 for the Seychelles Bank to 23.6 for the Amirantes. The data obtained during these surveys will be used to formulate different options for managing the fishery, which will be then discussed with the stakeholders. It is expected that a management plan for the holothurian fishery will be implemented by the end of 2005.

A comparison of sea cucumber population dynamics in protected and unprotected habitats near Chumbe Island, Zanzibar, Tanzania

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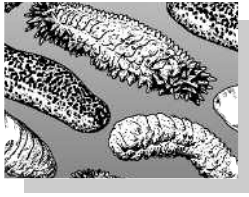
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Source: Poster presented at the Benthic Ecology Meeting 2005, 6–10 April 2005, Williamsburg, Virginia, USA. (<http://www.vims.edu/bem2005/index.html>)

Chumbe Island is located 10 km southwest of Stone Town, Zanzibar, off the coast of Tanzania. The west side is a protected reserve; the east side is subject to commercial fishing pressure. In order to examine the population dynamics of sea cucumbers in the protected and unprotected waters of Chumbe Island, an 18-day study was conducted between 14 November and 1 December 2004. A total of 138 belt transects, each with an area of 80 m², were conducted in four habitats of each side of the island: intertidal zones, reef flats, seagrass beds, and reefs. In each habitat, distribution, size, density and diversity of the sea cucumbers were determined. Of 858 total individuals, 87% were found in the protected habitats. Twenty-eight species of sea cucumbers were identified in the protected area, while only 8 of these were present in the unprotected area. Although *H. cinerascens* was the most abundant species (>200 individuals, but most in one transect), *H. atra* and *H. leucospilota* were the most widely distributed. In seagrass beds, the average length of *H. atra* was significantly larger in the unprotected area. With the exception of the intertidal areas, the populations in the protected habitats were significantly denser than in the unprotected (t-test, $p < 0.001$). Also with the exception of the intertidal areas, the protected habitats were more diverse than the unprotected. The most diverse habitat was the protected reef ($H' = 2.16$) and the least was the unprotected seagrass beds ($H' = 0.95$). The differing population dynamics between the protected and unprotected habitats indicates that sea cucumbers are most likely being overharvested on the unprotected side of Chumbe.



Correspondence beche-de-mer

I. Exchange of emails and documents on GMSA and IUCN Red list, about sea cucumbers between Professor Kent E. Carpenter¹, and Pr Chantal Conand²

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Note from the Editor: It is hoped that the readers can contribute sending replies to both, as their opinion would be helpful on these matters.

Professor K. Carpenter wrote:

I am now coordinating an initiative to assess marine species for the IUCN Red List. I am hoping to get some advice from you about which species to prioritize and some suggestions about echinoderm specialists that may be able to help with this. I see that you considered for Beche-de-Mer for CITES listing.

Reply from C Conand:

I shall include your mail on this subject in the BDM Bulletin #23. Could you give us some details on GSMA and Red List.

Professor Kent Carpenter:

Appendix 1 (see below) gives some background and status on the Global Marine Species Assessment. As I mentioned in my previous email, we are trying to identify priority groups of echinoderms that we could potentially assess for the IUCN Red List. We cannot hope to complete Red List assessments for all species of echinoderms so are looking for taxa that most need assessments and can feasibly be completed. We are interested in completing whole taxa of groups that may meet the following criteria:

- A. Heavily utilized, or of high economic value
- B. Experiencing severe habitat deterioration
- C. Likely to include threatened species
- D. Important in community structure and/or function
- E. Reasonably feasible to do (i.e., not too many species worldwide, taxonomy in reasonable shape data likely to be available, etc.).

Likewise, can you tell me how many species in the Order Aspidochirota and the families Holothuridae and Stichopodidae? Are these the only families that may meet the criteria A-E above? These are the only ones I am familiar with because they are the ones you included in the FAO Western Central Pacific guide.

Reply from C. Conand:

Yes sea cucumbers fill the followings:

- A. Heavily utilized, or of high economic value
- C. Likely to include threatened species
- D. Important in community structure and/or function
- E. Reasonably feasible to do (i.e., not too many species worldwide (hundreds much better than thousands!), taxonomy in reasonable shape, data likely to be available, etc.).

Commercial species are mostly in the families Holothuridae and Stichopodidae, but new fisheries for Cucumariidae (order Dendrochirota) (*Cucumaria frondosa*) in USA and Canada (look at Beche-de-mer bulletin #22 for synthesis on USA and #23 for Canada). The number of species varies — even in La Reunion a tiny island, a new *Aspidochirota* quite large, is being described — with some recent new species from Kenya, Madagascar... Anyway I shall try to reply soon.

Appendix I:

Status of the Global Marine Species Assessment (GMSA). November 2005

The Global Marine Species Assessment (GMSA) has been discussed over several years and listed as a priority action by both the IUCN - World Conservation Union and Conservation International (CI). The GMSA began in 2005 through limited donor support secured through CI. The operational goal of a fully supported GMSA is to complete Red List assessments for around 20,000 marine species in five years. In addition to the intrinsic value of Red List assessments for highlighting threatened species that need special conservation attention, the basic ecological, distribution, and threat information generated by these assessments is intended to form the basis for a global marine hotspot analysis and subsequent development of key biodiversity areas for conservation action. The GMSA is now actively seeking broader donor contributions to support the work of existing and future planned marine Red List Authorities (RLAs). Initial work on the GMSA included compilation of basic Red List information for almost 4,000 Indo-Pacific coral reef fishes and support for the IUCN/SSC Shark Specialist Group (including all cartilaginous fishes). The GMSA coordinator position was established in August 2005 through agreements between CI and IUCN, and IUCN and Old Dominion University (ODU). The GMSA intends to take advantage of a university base, similar to what is currently in place for the Global Mammal Assessment at the University of Virginia. In addition to a wide academic community to draw from, the economics of donor contributions are more efficient through the involvement of students and lower costs associated with residence outside major metropolitan areas. The GMSA is operated as part of IUCN's Biodiversity Assessment Unit (BAU) housed in the Center of Applied Biodiversity Science at CI. A GMSA strategy meeting was held during the first week of November 2005. Participants included representatives from IUCN/SSC Specialist Groups and Red List Authorities for various marine groups, CI, BAU, and the Fisheries Department of the Food and Agriculture Organization of the United Nations. A vision, goals, and objectives for the GMSA were agreed upon during this meeting, and criteria were developed to identify the priority taxa for the first phase of the GMSA. These criteria include: factors such as heavy utilization, high economic value, severe habitat deterioration, importance in community structure and function, intrinsically vulnerable life history regime, and feasibility of successful completion of a comprehensive Red List Assessment for the entire taxonomic group in question. Under these criteria 17 major taxa of fishes were listed as priorities, comprising approximately 8,000 species (out of a total of about 15,000 species of marine fishes). Important marine primary producers such as kelps, seagrasses, and mangroves will also be evaluated under these criteria, in addition to some important invertebrate groups such as corals, marine molluscs, and **echinoderms**. The IUCN Habitat Authority File for marine and coastal habitats was also reviewed and revised during the GMSA strategy meeting. An important recommendation from this meeting was to complete a marine mapping workshop as soon as possible to work out consistent criteria for mapping of marine species in the GMSA.

The following text is straight from the IUCN Red List web site (<http://www.iucnredlist.org/info/introduction.html>).

"IUCN - The World Conservation Union, through its Species Survival Commission (SSC) has for four decades been assessing the conservation status of species, subspecies, varieties and even selected subpopulations on a global scale in order to highlight taxa threatened with extinction, and therefore promote their conservation. Although today we are operating in a very different political, economic, social and ecological world from that when the first IUCN Red Data Book was produced, the SSC remains firmly committed to providing the world with the most objective, scientifically-based information on the current status of globally threatened biodiversity. The taxa assessed for the IUCN Red List are the bearers of genetic diversity and the building blocks of ecosystems, and information on their conservation status and distribution provides the foundation for making informed decisions about preserving biodiversity from local to global levels. The IUCN Red List of Threatened Species provides taxonomic, conservation status and distribution information on taxa that have been globally evaluated using the IUCN Red List Categories and Criteria. This system is designed to determine the relative risk of extinction, and the main purpose of the IUCN Red List is to catalogue and highlight those taxa that are facing a higher risk of global extinction (i.e. those listed as Critically Endangered, Endangered and Vulnerable). The IUCN Red List also includes information on taxa that are categorized as Extinct or Extinct in the Wild; on taxa that cannot be evaluated because of insufficient information (i.e. are Data Deficient); and on taxa that are either close to meeting the threatened thresholds or that would be threatened were it not for an ongoing taxon-specific conservation programme (i.e. Near Threatened)."

2. Ecuador lifts Galapagos sea cucumber fishing ban (Ecuador)

Communicated by Jean-Paul Gaudechoux

Fisheries Information Adviser, Secretariat of the Pacific Community

Source: <http://www.planetark.com/dailynewsstory.cfm/newsid/31047/story.htm> (June 2005)

Ecuador on Tuesday lifted a ban on the fishing of lucrative sea cucumbers from the Galapagos Islands in a move that environmental groups have said could threaten conservation efforts. The authorization by the Galapagos reserve management authority will permit fisherman from the islands to capture up to three million sea cucumbers in 60 days from June 12. The decision ends a prohibition on fishing of sea cucumbers — spiny tubular creatures that are widely sought after in Asia for their supposed aphrodisiac effects — put in place for 2005 and 2006. “We decided to open fishing of sea cucumbers, mainly due to social and economic considerations,” Ecuador’s Environment Minister Ana Alban told reporters. The decision comes after local fishermen threatened to stage a strike in the world-famous islands, which inspired 19th century British naturalist Charles Darwin’s theory of natural selection. Environmental organizations have warned sea cucumbers need to be protected from overfishing. Sea cucumber and lobster fishing are one of the main income sources for the 18,000 residents of the Galapagos, considered one of the most important biological reserves in the world. Last year, an Ecuadorean judge overturned a cap which allowed fishermen to catch 4 million sea cucumbers during a 60-day period. In the past, sea cucumber fishing had been seasonal and prohibited for much of the year, but authorities had banned it for 2005-2006. Fisherman have frequently asked for unlimited fishing rights for the sea cucumber, a species threatened by a growing illegal market fed by massive consumer demand in Asia. The islands, located 625 miles (1,000 km) west of Ecuador’s coast, are facing growing tensions between fishermen seeking to make a living and environmentalists struggling to protect the island from overdevelopment.

3. “Rolling sandfish”

Communicated by Dr Colin Shelley BSc (Hons) MSc PhD

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Talking to a beche-de-mer collector recently I was told an interesting story. In relation to sandfish, *Holothuria scabra*, he believed that they can deliberately puff themselves up into a round form, so that they can more easily roll around with wave action on shallow sand/mud flats as a strategy to move themselves into deeper water. Have you heard of this before, with this or other species of sea cucumber?

4. Solomon Government to ban export of beche-de-mer¹

Source: www.solomonstarnews.com 11 July, 2005 - 11:27am. Headlines

From Dr Simon Foale, Resource Management in Asia-Pacific Program, Dept of Anthropology, RSPAS, Australian National University, Australia ACT 0200. Email: simon.foale@anu.edu.au; <http://rspas.anu.edu.au/rmap/>

Communicated by Dr. Sven Uthicke, Postdoctoral Scientist, Biofilms and Molecular Biomarkers, Australian Institute of Marine Science, PMB No. 3, Townsville MC, Q 4810, Australia

The government will bring in place an indefinite ban on the export of beche-de-mer as of 1 August 2005. Permanent Secretary of the Department of Fisheries and Marine Resources, Tione Bugotu, said the ban would apply to all species of beche-de-mer. From now on until 31 July, we are giving all buyers and exporters to export all their beche-de-mer products in their possession. No beche-de-mer will be allowed to leave the country as from 1 August, Mr Bugotu said. He explained that the decision was reached in a review of the beche-de-mer fishery in the country by Dr Christain Ramofafia of the World Fish Centre. Mr Bugotu said the review revealed that the country’s beche-de-mer stock is in serious problem and faces an uncertain future. The review also found that catches and exports have fallen since peaks of 615 tonnes and 715 tonnes were achieved in 1991 and 1992 respectively. It said catches and exports have declined to less than half these amounts in subsequent years and remained low until now. The review also found that in

1. Note from the Editor: See also the more recent article by Warwick Nash and Peter Ramohia on page 3 of this issue.

contrast to declining catches and exports, the number of sea cucumber species exploited for beche-de-mer production has increased from 22 in 1994 to 32 currently, with 50 per cent of the species have low market value. This contrasting trend suggests dwindling sea cucumber resources, especially of high value species and local over-fishing. It is likely that current fishing levels are unsustainable, the review concluded. Mr Bugotu said it is obvious from these results that the beche-de-mer fishery in the Solomon Islands needs proper management strategies to be in place or else the fishery is well on track for a collapse. My department believes that putting this ban in place now is not only in the best interest of the resources, but also of the country. The department would rather receive praise in future for taking this action now than be blamed for a collapse beche-de-mer fishery, Mr Bugotu said. He added that putting in place this indefinite moratorium will give more time for the department to come up with a proper management and development plan for the fishery as required by the Fisheries Act 1998. Developing a good management plan for this fishery is expected to take time. It will also involve the time for adopting this plan as required under current fisheries law. We have to ensure that sea cucumber resources are still there to be managed and not be seen developing this Management and Development Plan for managing a resources that no longer exist. This indefinite moratorium is therefore not only necessary for ensuring we will have sea cucumber resources to be managed but also so that the department has amply time for coming up with the best Plan for the management of this important fishery, Mr Bugotu said. Beche-de-mer has been a major source of income for rural dwellers in the country.

5. Sea cucumbers in Zanzibar, Tanzania

Communicated by Jen Blaine (4 August 2005)

Email: s06.jblaine@wittenberg.edu

My name is Jen Blaine. I am a senior Biology major and Marine Science minor at Wittenberg University in Ohio, and I am conducting research this summer at the Duke University Marine Lab in North Carolina. I spent last fall semester abroad in Zanzibar, Tanzania with the School for International Training (SIT). During the last month of my program, I completed an independent research project on Chumbe Island (about 12 km SW of Stone Town, Zanzibar) comparing the sea cucumber populations of the protected and unprotected sides of the island. The Chumbe Island Coral Park is a privately-managed marine protected area, but only the western side of the island is protected; the eastern side is open to local fishermen. During my study, I conducted belt transects in seagrass bed, intertidal, reef flat, and reef habitats on both sides and identified (attempted to, at least) and measured the sea cucumbers present. I did my best to identify the species, but I had limited references. Overall, I found 28 different species present on the unprotected side, and only 8 of these were present on the protected side. I have attached my abstract¹ that includes other data, such as differences in densities. I also took several underwater pictures of some of the species that I encountered. Based on my results and my discussions with local fishermen in Swahili, I suggested that the sea cucumbers were being overharvested on the unprotected side (which, after doing a literature search, I realized wasn't very surprising).

Before my experience, I had never heard of the beche-de-mer international industry. I don't believe that there are any restrictions on the sea cucumber fishery in Zanzibar, and I don't know of many studies that have examined aspects of the fishery in Zanzibar. While writing my paper, I discovered the SPC Beche-de-mer Information Bulletins online, which were an excellent resource and opened my eyes to the global issue of this industry. I have become extremely interested in this field of study and the goal of managing sea cucumber fisheries sustainably. I presented my sea cucumber study at the national Benthic Ecology Meeting in April, and have since become even more driven to stay involved and interested in this field. I am currently considering applying for a Fulbright Scholarship to return to Zanzibar for a year and investigate the fishery in more detail. I have written this email in response to your call for local cases or information of the fishery in less-studied areas that was in the February 2005 issue of the Information Bulletin. I am not sure if you would be interested in an undergraduate study, but I would be happy to discuss mine or share it with you if you are interested. I am just getting introduced to the field of marine biology, and I am very interested in this topic and in raising awareness of the beche-de-mer industry in Zanzibar. If you are interested, my abstract is attached. I would greatly appreciate any feedback or advice.

1. See page 45 this issue for the abstract: "A comparison of sea cucumber population dynamics in protected and unprotected habitats near Chumbe Island, Zanzibar, Tanzania", written by Jen Blaine et al.

6. Information on PhD available

Alexander Kerr and Gustav Paulay have received funding from the National Science Foundation PEET program to train graduate students in the systematics of aspidochirotid holothurians. The grant will support three graduate students (one M.S. and two Ph.D. or three Ph.D. students) at the University of Guam and University of Florida. Students will study field, morphological, and molecular systematics of holothurians, pursue the revision of one clade of aspidochirotids for their dissertation, explore the evolution of that group using phylogenetic techniques, and help with the development of varied resources for holothurian systematics and biology. The project is focused on the families Holothuriidae and Stichopodidae, groups that reach their greatest diversity in the tropics, especially on coral reefs. We are looking for talented applicants interested in pursuing a professional career in invertebrate systematics. Please circulate this announcement widely and encourage prospective students to contact Alex or me. Graduate applications are due in early January at the University of Florida and March at the University of Guam. These positions are open to both US and international applicants.

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SPC Beche-de-mer Information Bulletin database

All articles and abstracts published in the first 23 issues of this Bulletin have been entered into a database searchable on SPC's website at:

http://www.spc.int/coastfish/news/search_bdm.asp

The database can be searched through any of the five following fields:

- species' scientific name
- article's title
- name of author
- country
- region

The results are given in a table indicating issue and page numbers in which the article or abstract has been published, year of publication, complete title of article/abstract, author(s) name(s), and the species, country and region concerned, if any. A hyperlink allows direct downloading of the article (or the complete bulletin) in pdf format.

Don't hesitate to send your comments and suggestions on how to improve this database and its access to SPC's Fisheries information Section (cfpinfo@spc.int).

Reducing mailing costs

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Therefore, we will now limit the mailing of printed copies to subscribers from Pacific Island countries and territories and to those, from outside the Pacific Island Region, that have contributed articles or news to the bulletin in the past. However, the *Beche-de-mer Information Bulletin*, as well as all other SPC fisheries-related information bulletins and newsletters, will still be available, in pdf format, free of charge on our website from the following address:

<http://www.spc.int/coastfish/News/news.htm>

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Yours sincerely

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