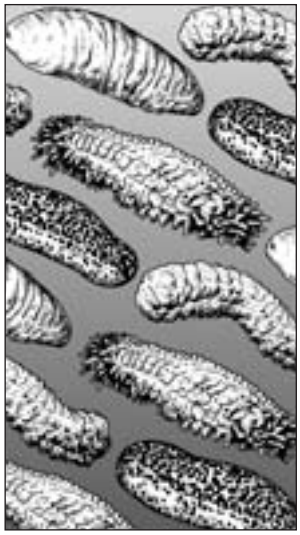
ISSN 1025-4943

Secretariat of the Pacific Community

BECHE-DE-MER

Number 19 — January 2004

INFORMATION BULLETIN



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Editorial

The great event in sea cucumber research and development this year was the workshop on Advances in Sea Cucumber Aquaculture and Management (ASCAM) held Dalian, Liaoning Province, China. Organised by the Fishery Department of the Food and Agriculture Organization (FAO) and held from 14–18 October, the workshop gathered experts from all over the world. Abstracts and some information on the workshop and the visit to two sea cucumber hatcheries are presented on page 4. Workshop proceedings will be published in early 2004 by FAO as: A. Lovatelli, C. Conand, S. Purcell, S. Uthicke, J.-F. Hamel and A. Mercier (eds). Advances in sea cucumber aquaculture and management.

In this issue, we also present several original articles:

J. Graham and S. Battaglene present observations on periodic movement and sheltering behaviour of *Actinopyga mauritiana* in Solomon Islands (page 23).

In Kosrae, Federated States of Micronesia, S. Lindsay and S. Abraham conducted a resource evaluation of the populations of two commercially harvested sea cucumber species, *Actinopyga mauritiana* and *Stichopus chloronotus* (page 31). On Jaluit Atoll, Marshall Islands, J. Bungitak and S. Lindsay conducted a marine resource survey and assessment. The article on page 33 provides the data collected on the commercially targeted holothurians.

The first data on the sea cucumber fishery in Mayotte, Indian Ocean, is presented by A. Pouget on page 35.

R. Pitt has left Vietnam, but uses data collected there to present, with his colleague Dinh Quang Duy, length–weight relationships for sandfish (*Holothuria scabra*) (page 39)

Inside this issue

Following the questionnaires on spawning observations and fission, still occuring, we set up a new questionnaire on juvenile occurrence. The information gathered will add to the knowledge on this obscure life cycle phase of most holothurian species (page 41).

You will also find our regular features on abstracts, publications and meetings. The 11th International Echinoderm Conference was held at the Ludwig-Maximilians-Universität, Munich, Germany, from 6–10 October 2003. The abstracts of the oral presentations and posters on holothurians (page 43) are included in this issue and the articles are being referred for publication. More information is available at: www.iec2003.uni-muenchen.de.

Previous issues of this bulletin are available online, in English and French at: http://www.spc.org.nc/coastfish.

The last issue of the Bulletin of the Echinoderms Newsletter is available online at: http://www.nmnh.si.edu/iz/echinoderm

Chantal CONAND

Produced with financial assistance from the European Union.

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

PIMRIS
Pacific Islands Marine Resources Information System

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Advances in Sea Cucumber Aquaculture and Management (ASCAM)

The international workshop, "Advances in Sea Cucumber Aquaculture and Management (ASCAM)", organised by the Fishery Department of the Food and Agriculture Organization (FAO) was held from 14 to 18 October in Dalian, Liaoning Province, China. Fifty experts from around the world, including China, attended the workshop.

The ASCAM workshop focused its presentations and discussions on three main topics:

Session I: Status of sea cucumber fisheries
Session II: Sea cucumber resources management
Session III: Aquaculture advances

The abstracts of presentations are included below. All workshop reports and recommendations made during the discussions following each session, will be published by FAO in early 2004 (Lovatelli, A., Conand C., Purcell S., Uthicke S., Hamel J.-F. and Mercier A. (eds). Advances in sea cucumber aquaculture and management.

Participants to ASCAM Workshop (*Photo J.-F. Hamel*)

*1- ABSTRACTS**

SESSION 1 - STATUS OF RESOURCES AND UTILISATION

Present status of world sea cucumber resources and utilisation: An international overview

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In this report the data on traditional and recent worldwide tropical and temperate sea cucumber fisheries for the last fourteen years (1986–2000) are summarised based on FAO statistics, data from various issues of the SPC Beche-de-Mer Bulletin, and other available publications. There has been increasing interest in this benthic resource and an expansion of the fisheries as a whole. Numerous sea cucumber fisheries are witnessing conflicts among the fishermen, processors and the authorities managing the resources. The processed products are generally exported from the producing countries to Hong Kong (China), Singapore and Taiwan, Province of China, all three of which are important Asian markets for sea cucumber as well as ports for re-exporting to other markets such as the one in China. These market trade flow mechanisms, particularly in Singapore and Hong Kong (China), are difficult to quantify and to keep track of as products are re-exported based on regional demand and quality. The different qualitative indices analysed clearly show that overexploitation is becoming apparent on a worldwide basis as the demand for *trepang* increases. In support of a sustainable utilisation of the resource, an efficient management plan of action has become a priority that should take into account all the different levels of the "Holothurian system" described.

This presentation will help provide a general and current picture on the state of affairs within this industry. The need for further action is emphasised, particularly with regards to the development of standardised stock assessment methodologies and the collection of statistical data.

Present status and prospects of sea cucumber industry in China

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In China, there are about 20 species of edible sea cucumbers that have been considered as a traditional medicine and tonic food for many years. Nutrient analysis shows that the body wall and intestine of sea cucumbers has a high nutrient value. Protein content of dried sea cucumber is more than 50 per cent for most edible species, while glucosaminoglycan was detected in sea cucumbers and considered as a functional component for its pharmaceutical value. The clinical function of sea cucumbers is reviewed. In order to meet the increasing demand, while protecting the natural resource, the highest priority of fisheries authorities has been given to seed production of sea cucumber (*Apostichopus japonicus*) and development of farming and ranching techniques. Sea cucumber farming and ranching has become a vital fraction of the aquaculture sector in the northern part of China, including Liaoning and Shandong Provinces. The total landing volume from farming reached over 5800 tonnes (wet weight) in 2000, which were either directly sold to restaurants or processed as dry products and healthy food (functional food). Farming methods and ranching techniques are presented in detail. The confusion of the quality processed products has become a main issue in holding back market development, while overexploitation of sea cucumber farming in earthen ponds may result in a similar disaster to that of shrimp viral diseases occurring in the early 1990s. Suggestions dealing with further development involve seed production, farming and ranching models, as well as quality control.

* *Abstracts have been provided by the authors, and have been reproduced as is*

Historical overview on holothurian exploitation, utilisation and trade in Japan

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Although dried holothurian (*iriko*) was a major export commodity of Japan for at least the last 300 years, it is currently a minor one. On the other hand, nearly all of the Japanese holothurian, namako, from the domestic market are consumed raw in slices soaked in a mixture of vinegar and soya sauce. The ovaries are dried (called *konoko*), and the intestines are salt-fermented (called *konowata*). These byproducts are rare and expensive, and are good income sources for holothurian processors. This presentation has two objectives: 1) to provide a historical overview of the export trends (i.e. when the dried holothurian trade began, how holothurians were fished and produced), and 2) to provide current information on holothurian exploitation in Japan. Based on observations in the Hokkaido and Setouchi regions, the speaker will report on fishing methods, several commodities related to holothurians, and resource management programmes. National catch statistics in Japan are also provided.

Status of sea cucumber fisheries and farming in Indonesia

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Indonesia is the biggest island state in the world (8.3 million km^2), consisting of 17,508 islands and 81,000 km of coastline. Sustainable annual catch from Indonesia's marine resources is about 6.2 million metric tonnes (t). The coastal and sea area of Indonesia provide favourable habitats for many sea cucumber species. Sea cucumbers have been exploited for decades and Indonesia remains a major exporter of sea cucumber in the world.

Fishermen exploit sea cucumber by using small- and medium-size fishing boats (1–10 GT). Fishermen that exploit sea cucumber generally have low capital, and few skills in handling and post-harvest processing. Poor handling and post-harvest processing results in a low quality product and price (about USD 1.92 at fisherman level). An additional problem affecting the Indonesian sea cucumber industry is overexploitation. Available statistical data show an important fluctuation of volume (2500–3000 t per year) and value (USD 1.44–15.06 per kg). Price reduction is likely due to a decrease in the individual capture size or the low economic value of the exploited species.

Four important geographical regions that have developed sea cucumber farming in Indonesia include: Papua (378 t wet weight per year), Central Sulawesi (200 t), Southeast Sulawesi (3 t), and East Kalimantan (1 t). Part of the sea cucumber volume reported as cultured is in fact not really a product of farming activities; some fishermen rear their catch, generally *Holothuria scabra*, in cages or ponds until large enough to sell or process. The long rearing period and low number of available seeds are the two main problems of sea cucumber farming in Indonesia.

Overfishing will certainly have a negative effect on the sustainability of sea cucumber production in Indonesia. Overexploitation will accelerate the destruction and depletion of sea cucumber populations. Based on internal and external factors that influence Indonesian sea cucumber fishing and farming, some alternative development strategies have been resumed: 1) promote sustainable use/fishing; 2) develop re-stocking and mariculture activities; 3) marketable size regulation; and 4) improve handling and post-harvest processing.

Fisheries, trade and utilisation of sea cucumbers in Malaysia

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Sea cucumber fisheries in Malaysia are exploited in substantial quantities in the coastal waters around the coral reef regions in Sabah in Eastern Malaysia. In Peninsular Malaysia, this resource is minimally exploited because more than 90 per cent of the coral reef islands in both the east and west coasts have been gazetted as marine parks where fishing activities are prohibited in the vicinity. In Sabah, in the 1980s, sea cucumber landings recorded an annual catch of about 400–500 tonnes, while landings in the 1990s fell to an annual catch of around 100 tonnes. Species exploited for food include the sandfish

(*Holothuria scabra*), black teatfish (*H. nobilis*), white teatfish (*H. fuscogilva*), elephant's trunkfish (*H. fuscopunctata*), *H. leucospilota*, orange fish (*Bohadschia graeffei*), brown sandfish (*Bohadschia marmorata*) and prickly redfish (*Thelenota ananas*). The sea cucumbers caught in Sabah, apart from being consumed locally, are exported mainly to Peninsular Malaysia, Sarawak, Singapore, Thailand, Hong Kong, Taiwan and China. They are processed by boiling and evisceration, and are then exported dried or frozen. Sea cucumbers are also imported into Sabah by fishermen from neighbouring Indonesia and the Philippines, and may be re-exported after processing; however since the 1990s, the volume of imports have decreased drastically.

In Peninsular Malaysia, sea cucumbers (locally known as gamat) belonging to the Stichopidae family, mainly curryfish (*Stichopus hermanni* formerly known as *S. variegatus*) and warty sea cucumber (*S. horrens*), are exploited for their medicinal properties. In Pulau Langkawi on the west coast of Peninsular Malaysia in the state of Kedah, the processing industry has depleted the resources of *S. hermanni*, which is now an endangered, if not an extinct, species in the vicinity of the Langkawi islands. *S. horrens*, however, are still found in relative abundance on the reef flats of Pulau Pangkor located on the west coast of Peninsular Malaysia in the state of Perak. The raw products are traditionally processed into gamat oil and gamat water, and recently into medicated balm, toothpaste and soap.

This paper describes the sea cucumber fisheries in Malaysia — the type of gear used, the abundance, localities where they are caught and ways for stock enhancement. Presently there are no fishing regulations aimed at preventing overexploitation of sea cucumber stocks (except for regulations prohibiting fishing in marine parks). Suggestions for management measures to address overfished stocks are discussed. Sea cucumber trade, pharmaceutical or nutraceutical properties of the Malaysian species are also described.

The status of sea cucumber fisheries and mariculture in the Philippines

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There are about a hundred known species of sea cucumbers in the Philippines, 25 of which are harvested commercially. Although, the traditional trade of these resources, which is export, has existed for centuries, statistical monitoring only started in the 1970s. Over the last two decades, export level has been maintained at 1000 metric tonnes (t) annually with the decline in the volume of high value species compensated by the low value species. Hong Kong, as the major export partner, likely serves as a transit point for other countries in the region as well as for the Western Hemisphere, such as Canada. Treated primarily as an export commodity, government statistics on domestic trade and consumption are not available. However, processed products can be found in supermarkets in big cities; for example bêche-de-mer is a common ingredient in Chinese dishes but is largely unknown to local clientele. Between the fishers and the export market are a series of middlemen who have complete control over domestic prices, which in turn are largely influenced by the Chinese market. The fisher or middleman who does the primary processing of drying /chilling the product would first hoard a certain volume before selling to the next middleman in the city. Such practice allows a return of investment period of one week to several months.

Available scientific reports focus mainly on taxonomy and distribution; data on the rate of extraction have been limited to stories of localised depletion as narrated by the fishers during interviews. All those interviewed agreed that their catch per of unit effort has been declining significantly through the years that is, for two or three pieces of >500 g individuals, the fishers have to go to deeper waters for a longer time. Research and development (R&D) on the mariculture of the high value *Holothuria scabra*, began in 2000 with a long-term objective of producing seeds for the enhancement of the wild populations. Studies on an experimental scale were conducted to improve the survival rate of fertilised eggs to juveniles. Likewise, initial investigations on the growth of juveniles in cages in the field have begun. At full scale, the reseeding activity is envisioned to be a partnership between the academe and the stakeholders with the latter taking full charge of the management component. Recently, these R&D efforts suffered a major set back when financial support from the government was suspended.

Status of the sea cucumber fishery in the Red Sea: The Egyptian experience

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The beche-de-mer fishery in Egypt began in 1998 in the southern part of the country. Initially this was at a low level and primarily performed by trawling boats. By 2000 the fishery had expanded dramatically, leading to fears of overexploitation. As a consequence, The Red Sea Governorate initiated a ban on sea cucumber fishing in 2001 whilst a baseline survey and stock assessment could be performed. This survey began in 2001 and was undertaken jointly by the Egyptian Environmental Affairs Agency and Universities of Hull and Suez Canal through a UK government-sponsored Darwin Initiative project. The initial ban on fishing resulted in the development of a large illegal fishery along the coast of Egypt. In addition, pressure from the Government Fisheries Agency to re-open the fishery, led to the Red Sea Governorate lifting its ban in 2002. However, preliminary data collected by the Darwin project indicates that populations of commercial sea cucumber have undergone a rapid decline, and this has now led all government agencies and departments to realise that the resource needs immediate protection. Consequently, a new ban was decreed in March 2003 to cover the entire coastline. The government will make a new decision on the fishery in 2004 based on the results from the project stock assessment. This paper will review what is known of the current status of the fishery together with preliminary data collected as part of the stock assessment.

Population density and fishery impacts on the sea cucumber (*Stichopus fuscus*) in the Galápagos Islands

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Over the last decade, the sea cucumber *Stichopus fuscus* has been the target of a continuous fishery in the Galapagos Islands. The increasing growth of this activity and its potential impacts prompted the Park authorities to initiate a participatory management programme to assess the status of the resource. From 1999 until date, density surveys of *S. fuscus* have been conducted before and after each fishing season by teams of fishers, naturalist guides, managers and scientists. Using a 100 m^2 sweep circular transect an average of 900 m^2 have been surveyed in specific sites of Fernandina, Isabela, Española, Floreana, Santa Cruz and San Cristóbal. A drastic decrease of density and size structure of *Stichopus fuscus* has been observed after each fishing season, with population densities partly recovered between fishing periods. In Isabela and Fernandina, a single recruitment event was recorded in April 2000, which reached its peak in March/April 2001 and probably helped the ongoing fishery on those islands. No recruitment has been detected on any other island. Nonetheless, current adult and juvenile densities show that *S. fuscus* populations in the Galápagos Islands are severely depleted and unless another recruitment pulse occurs with a complete ban on fishing activities, these populations are in serious risk.

From the sea to the market place: Issues, problems and opportunities of sea cucumber fisheries and trade

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Using published information and an exploratory questionnaire, this paper presents the difficulties associated with the collation of official statistics on sea cucumber catch, effort and trade. This paper highlights specific problems associated with the identification of catch origins, illegal landings and trade, trans-boundary effects, taxonomic problems, confusing beche-de-mer categorisation, inadequate monitoring and a lack of internal national prioritisations and funding. It concludes with a clear presentation of the issues that need to be addressed and an analysis of the possible means by which to do so.

World markets and trade flows of sea cucumber

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The international trade structure for sea cucumber differs from the general trends in seafood. While its demand is restricted to Oriental Asians of Chinese origin, the market is also dominated by the same race. Sea cucumber species are mostly exported in dried form but a small quantity of fresh and frozen sea cucumber also enters into the international trade. Nearly 90 per cent of this trade takes place in the Asia Far East where Hong Kong (China) and Singapore dominate the business and China PR remains the main consuming area. The niche markets located outside Asia are strongly linked with trading houses in these two markets.

Regular supply of this seafood continues to remain in question and prices have increased over the years. However, it is interesting to observe the changes in consumption pattern of this highly traditional product outside of China.

Sea cucumber fishery and mariculture in Madagascar: A case study of Toliara, southwest of Madagascar

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Sea cucumber fishing is a permanent activity in coastal regions of Madagascar, especially near coral reefs. Production of Malagasy trepang is based on family or artisanal fisheries, and the resource is entirely exported to Asian countries. The first exportation recorded in Madagascar was in 1920 with about 40 t of trepang from three species. Exportation varied annually from 50 to 140 t. Since 1990, sea cucumber harvesting greatly increased and resulted in the overexploitation of the resource. The maximum intensity of the exportation was recorded in 1994 with 540 t of trepang. The fishery then declined.

The number of species collected shifted from 8 in 1990 to 28 in 1996. At the present time, more than 25 species are exploited. The actual harvested species, however, vary according to the market price, the international demand and availability. *Holothuria scabra*, *H. nobilis*, *H. fuscogilva*, *Thelenota ananas* are the main species collected.

Declining export and strong competition between collectors indicates overexploitation of the resources, which affects the local economy and the environment. The situation of some fishermen's villages in the Toliara Province (southwest of Madagascar) is presented. A survey of the production of the main harvested species over one year was made and changes in sea cucumber processing techniques during the seven last years are presented.

Aquaculture is considered to be a solution for solving the problem of sea cucumber overexploitation. A hatchery has been built up in Toliara in 1999/2000 thanks to funds from the Belgian "Coopération Universitaire au Développement". The larval development and metamorphosis of the species *Holothuria scabra* are now under control. An additional project is now considered; it aims to master the growth process of post metamorphic sea cucumbers.

Current status of the sea cucumber fishery in the southeastern region of Cuba

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The analysis of the sea cucumber (*Isostichopus badionotus*) fishery, during August 1999 to June 2003 in the southeastern region of Cuba is synthesised. During the first two years of the fishery (1999–2000) more than three million individuals were captured. In that period, all fishing effort was conducted by one fishing enterprise with 12 boats, in the southeastern region. In 2001, the former enterprise was split into three fishing units, so the effort was then divided into three boats in order to arrange a better

management system. During the first two years, CPUE was around 1153 ± 630 sea cucumbers/boat/day. The capture and CPUE curves decreased throughout the year, until values reached lower than 500,000 individuals for the fishery season and almost 350 sea cucumber/boat/day, respectively. Currently, CPUE values are 1200 ± 200 sea cucumbers/boat/day. This general situation of declining CPUE does not constitute an index of a biomass decrease, as this index fluctuated between 4500 ± 4100 to 7610 ± 3600 ind./ha. The above statements are justified due to the logistical support failures (fuel, etc.) for a prime fishery during 2001–2002.

At present, efforts are being made to re-establish the normal fishery conditions. A total of 1438 t of wet weight have been extracted in the southeastern region, 920 t of this belonging to the two first years of the fishery. A capture of 200 t of wet weight for this region was planned during 2003, which is below the capture quota of 611 t. CPUE has been recommended for each fishery season and locality of no more than 1200–1500 sea cucumbers/boat/day, depending on the locality abundance. At present, around 68.9 t dry weight have been processed and sold in a Hong Kong (China) market and prices have increased from USD 13.5 (1999–2001), to USD 18.0 (2001–2002), and to USD 22.0 (2002–up to date) per kg of dry product, according to the product class and quality.

SESSION 2 - RESOURCES MANAGEMENT

Overfishing of holothurians: Lessons from the Great Barrier Reef

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Holothurian fishing has a long tradition in Australia, and provided the first cultural contact of aboriginal and islander communities with non-Australians. These were Macassan fisherman and traders who visited centuries before European settlement. The trepang fishery continued in a typical "boom and bust" fashion. The last cycle commenced in the mid–1980s, and signs of overfishing are now evident. The main target species was the black teatfish (*Holothuria nobilis*). Initiated by a request by the fishing industry and supported by data obtained through studies presented here, the fishery on this species was subsequently closed in 1998. Surveys conducted in 1998/99 on over 60 reefs along the entire Great Barrier Reef (GBR) indicated that stocks of this species were generally lower in the southern half of the GBR. Probably for that reason, nearly the entire fishing effort was concentrated north of Townsville (ca. 12°S to 19°S). The design of the Great Barrier Reef Marine Park allowed a comparison between reefs fished and reefs protected from fishing (Green Reefs, or No Take Zones). This comparison showed that the fishery reduced the densities on fished reefs by about 75 per cent. GIS-based calculations indicate that an initial ("virgin") biomass of about 5500 t was reduced by 2500 to 3000 t. This figure corresponds well to the total reported catch since opening of the fishery.

These model calculations have three major implications for future management of *H. nobilis*, and potentially other species, on the GBR and elsewhere. 1) No take zones can provide an effective means for stock protection of these species. However, whether the area protected was sufficient as a source of recruits for the whole area is currently unknown. 2) The agreement between reported catch and total reduction of numbers indicates that recruitment is very low and fishing has simply reduced stocks over more than a decade without appreciable replenishment. Repeated surveys of 23 reefs one and two years after the closure of the fishery could not detect any recovery of the stocks, providing further evidence for little recruitment. 3) Annual catches of (on average) less than five per cent of virgin biomass severely reduced stocks of *H. nobilis*. This is in sharp contrast to notions that 20 to 40 per cent of virgin stock size might be taken annually. These data suggest an extremely cautious approach in the management of beche-de-mer fisheries.

When should restocking and stock enhancement be used to manage sea cucumber fisheries?

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Access to technology for producing and releasing juveniles is not a sufficient rationale to proceed with restocking (restoring stocks to the point where they can sustain regular harvests) or stock enhancement (increasing yields by overcoming recruitment limitation) of sea cucumber populations. Rather, careful decisions need to be made about whether these interventions are likely to be cost-effective ways of improving productivity. Although restocking is designed to restore severely depleted stocks, it will be essential to determine whether the release of cultured juveniles will significantly reduce the time needed for replenishment compared to other forms of management, e.g., artificially aggregating and protecting some of the wild adults to promote egg fertilisation rates, or a total moratorium on fishing. This will require an evaluation of population recovery rates under various restocking scenarios, and other interventions, using both theoretical (life table analysis and population modelling) and empirical approaches. The information needed for such comparisons includes: remnant stock size and density, population age/size composition, generation time, fecundity, annual variation in the recruitment rate, natural mortality at different life stages, and behaviour of the species that may affect spawning success or survival at low population density. Investments in hatchery production for restocking should only proceed when the modelling described above demonstrates that releases of cultured animals will "fast-track" replenishment considerably.

Stock enhancement can be considered once sea cucumber fisheries have been rebuilt to the desired level of spawning biomass, although it can only be expected to be of benefit where the supply of juveniles regularly falls well short of the desired levels of recruitment. To assess whether stock enhancement is likely to be effective, managers need sound information on: the carrying capacity of the habitat for sea cucumbers, the abundance and age structure of the stock, the natural supply of juveniles each year, the cost of cultured "seed" and post-release survival rates. Even where the supply of juveniles falls short of the desired level, stock enhancement will not be appropriate if the cost of producing the juveniles exceeds the value of the additional harvests expected to result from the releases.

Another important point is that stock delineation is central to the success of restocking and stock enhancement programmes. The assessments described above need to be made at the level of self-replenishing population units within the stock.

Criteria for release strategies and evaluating the restocking of sea cucumbers

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Careful management should be the key to sustainable sea cucumber fisheries, and the release of hatchery-produced juveniles could speed the recovery of depleted stocks. Advances in methods for culturing sea cucumbers have allowed juveniles to be produced in high numbers for restocking. However, the lack of research on release methods and assessment of stock recovery jeopardises the success of restocking programmes. In order to gain credibility as a wise investment for resource management, programmes should rigorously demonstrate that releases of hatchery-produced juveniles contribute substantially to the replenishment of stocks.

A key criterion before releasing juveniles should be genetic similarity of stocks at release sites and sites of broodstock collection. Research is then needed on release methods, including the optimal mode of transportation, habitat, times of the day and season, and the most cost-effective size for release. Acclimation of juveniles to improve survival may include behavioural conditioning at the hatchery or temporary protection from predators upon release. Field experiments using replicate pen enclosures in New Caledonia have shown high initial survival and growth of hatchery produced *Holothuria scabra* juveniles in certain habitat types. The results also indicate that care is needed for the pen design and the method for extracting juveniles from sediments when conducting experiments. Spatial variability at small scales suggests that high replication is needed for experiments and that multiple release sites are essential for large-scale restocking.

Further to experiments on release methods, cost-benefit analyses at a larger scale will require larger experiments and an accurate evaluation of restocking effects beyond natural recruitment. Until tag-

ging methods for juveniles are developed, such research is likely to utilise experimental designs involving multiple release sites and control sites without released animals. Modelling of the visibility of animals using environmental variables, such as tide, time and temperature, can standardise the data from stock assessments and reduce sampling error. Non-linear mixed effects models offer improved detection of restocking effects, in comparison to ANOVA statistics, when the trends in visibility of animals at sites are temporally repetitive, e.g. seasonal trends. Incorporating these techniques into the analysis of abundance of sea cucumbers is likely to improve the resolution of stock assessments and restocking effects.

Studies on sea cucumbers in Tanzania and the gaps towards resource inventory and management

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The story of overexploitation of sea cucumbers in Tanzania has been repeated in many locations throughout the Indian Ocean. Collection methods include i) hand-picking, ii) collection by free-diving, using both ready-made and home-made goggles and iii) SCUBA diving in a few locations. Neither fishery regulations, sea cucumber mariculture, nor resource inventories have been conducted as steps towards management in Tanzania. Data were compiled from various works carried out on the sea cucumber resource in Tanzania and questionnaires were given to sea cucumber dealers and fishery officials. This approach showed several reasons underlying the lack of management of sea cucumber resources: a) the extent to which the stock size of this resource is known to fishermen of Tanzania, b) the lack of proper management framework and stock assessments on sea cucumbers and c) scientific orientation of funding agencies and research findings contrary to dealers' level of education and lack of technological capacity. The appropriate actions to achieve successful management of sea cucumbers should be taken in phases. That is, to raise fishermen's awareness, implementation of regulations, resource assessments, and establishment of pilot small-scale mariculture of the most known species in Tanzania, *Holothuria scabra*.

The Papua New Guinea national beche-de-mer fishery management plan

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Papua New Guinea exports more than 400 t of dry beche-de-mer annually, mainly to Hong Kong (China) and Singapore. A total of 21 species are harvested each year. The moving average for the last five years shows a gradual decline in catch rates. This has caused the establishment of the National Beche-de-mer Fishery Management Plan (NBFMP), which aims at sustainably managing the fishery in the country. The objectives are to ensure that the economic benefits, and social and environmental impacts of the fishery are recognised. The stakeholder participation is administered through the establishment of the National and Provincial Management Arrangements as one of the most important parts of the management plan. It ensures that stakeholders are regularly advised on the management of the fishery. The representatives bring perspectives from different provinces so that a large range of issues is considered as management recommendations are agreed upon.

A National Management Advisory Committee was formed and includes stakeholders from across the country. The Committee provides advice on most key management measures and reports to the Managing Director as well as decides when the plan needs revision. The Committee is involved in consultations with the beche-de-mer fishing community. The committees at the provincial level advise the National Advisory Committees on provincial management measures, forming a link with all stakeholders.

Management measures include the type of licenses, licence eligibility, licence requirement, export requirements, prohibitions, closures and reporting requirement. Licensees are closely monitored by the National Fisheries Authority (NFA) to ensure they comply with all management measures. In particular, reporting by exporters becomes even more important, being the only trade information NFA collects. A total allowable catch (TAC) is set for each of

two groups of species because the higher value species are more heavily fished than the lower value ones. Once the TAC of a value group has been reached, NFA closes the fishery, because it is too difficult to monitor the harvest of just one value group.

The trade of undersized and broken beche-de-mer is prohibited in order to protect the young and also to stop people from breaking up undersize beche-de-mer and trading and exporting it — making any undersize product difficult to detect.

A single closed season applies for the whole country during the spawning season from 1 October to 15 January. However, the fishery in each province closes when the TAC of a value group is reached or on the date of the season closure, whichever comes first. If the TAC in one province is reached, other provinces may continue to fish until their TAC is reached or the season is closed. Any customary management practices, which is/are consistent with the plan are recognised by the National Fisheries Authority and will be incorporated into the plan as schedule/s.

Management of trepang in the Northern Territory, Australia, and current research to further improve understanding of the fishery

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Australian federal, state and territory fishery agencies, are committed to the concept of ecologically sustainable fisheries and as a result have in place a plan to demonstrate this for all Australian fisheries. As a result, the trepang fishery in the Northern Territory of Australia is being reviewed and a new research programme has been initiated to further quantify the current fishery, and to develop a suitable monitoring programme to underwrite its sustainability.

Archaeological and historical data from the late 19th and early 20th century demonstrate that current fishing grounds have been consistently harvested for over 300 years, indicating that long-term sustainability of trepang fishing is possible.

ArcView® was used to visualise fishing effort by location in the modern fishery after cleaning the initial dataset from fisheries logbooks. The same software was also used to determine relationships between trepang number and weight.

A fishery-independent survey of the existing trepang fishery and of potential new grounds is proposed for the next two years. This work will combine diver surveys and the use of target specific sampling gear towed by a trawler, utilising a stratified sampling approach to gain information on local habitat preferences. As 12 major fishing grounds account for over 90 per cent of the total catch of the fishery, these will be targeted in the survey, with biological, physical and habitat data being collected on a relatively fine scale.

Beche-de-mer – the West Australian perspective: The fishing history and aspects of the reproductive biology and ecology of the black teatfish, *Holothuria nobilis*

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The fishing history and biological aspects of sea cucumbers, namely the abundance, distribution and reproductive activity, are discussed from a Western Australian perspective. There is little information regarding the sea cucumber fishery in Western Australia (WA), and only a limited history of government sanctioned fishing operations. Fisheries in Western Australia currently support six beche-de-mer fishing authorisations. In addition, some fishing is undertaken by a small number of remote aboriginal communities. Management of the WA beche-de-mer fishery will be reviewed post 2007.

The reproductive cycle of the black teatfish, *Holothuria nobilis*, from the Ningaloo Reef, Western Australia, was investigated over the 30-month period, from July 2000 to January 2003. Reproductive activity in *H. nobilis* peaks in late autumn through winter. This pattern follows closely that demonstrated in northeastern Australia and New Caledonia. The timing of spawning and its implications for larval dispersal within WA are discussed.

The abundances of commercial sea cucumber inhabiting Ashmore Reef, Cartier Reef, Ningaloo Reef and Rowley Shoals, NW WA, are described with particular reference to the black teatfish, *H. nobilis*. Observable deleterious fishing pressure has affected both Ashmore and Cartier reefs; abundances of black teatfish are less than 1 individual ha^{-1} in both

cases. Ningaloo Reef and Rowley Shoals, both representing areas closed to beche-de-mer fishing, maintain healthy populations of black teatfish, with abundances ranging between 19 to 27 and 40 to 80 individuals ha^{-1}, respectively. Numbers reported from the latter reefs approximately equal or exceed those reported on reefs that are closed to fishing on the Great Barrier Reef. Hence, it is doubtful Ningaloo Reef or Rowley Shoals have experienced significant fishing pressure in recent times, if at all.

The distribution pattern of adult *H. nobilis*, *H. atra* and *Stichopus chloronotus* was examined on the Ningaloo Reef. Results to date demonstrate distinct distributional patterns between *H. nobilis* and *S. chloronotus*. Relatively, *H. atra* showed little or no pattern of distribution. Studies are underway to determine the relationship between species distribution and physical habitat characteristics.

In contrast to adult sea cucumber, very little to no data exist on habitat preferences of juvenile holothurians. This report highlights the need for in situ research examining the ecology of juveniles and tabulates existing observations of juveniles in their natural habitat. Understanding habitat preferences of juvenile sea cucumbers is crucial to the development of aquaculture-based restocking programs aimed at replenishing areas affected by overfishing.

Management of the Seychelles sea cucumber fishery: Status and prospects

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For a long time, the sea cucumber fishery in the Seychelles has been open-access with no management measures in place. The fishery has remained relatively unimportant since the 1950s but has recently seen a rapid development due to the increase in demand for beche-de-mer on the international market. The lack of information on the fishery makes it difficult to ascertain its development, as well as the stocks of sea cucumbers. Six species *Holothuria nobilis*, *H. scabra*, *H. fuscogilva*, *Thelenota ananas*, *Actinopyga mauritiana* and *A. lecanora* are currently exploited, mainly for the export market. The fishery is located on the Mahé Plateau surrounding the main granitic islands of the Seychelles and further south on the Amirantes Plateau. Around 33,000 kg of beche-de-mer were exported in 2002.

Signs of stock reduction have been evident during the past four years, as fishers have to dive deeper, sometimes using scuba. In order to avoid further depletion of stocks, a precautionary approach was taken by the Seychelles Fishing Authority. Some management measures were introduced in 1999 to regulate access to the fishery. A license for fishing and processing sea cucumbers was introduced but the licensees failed to provide adequate and timely catch data. The main constraints in controlling the fishery are the lack of human and financial resources. Fishery dependent data based on catch reports lack accuracy, and catch is often under-reported. This led to more stringent regulations whereby catch and effort reporting became mandatory, and a limit imposed on the number of fishing licenses. Despite these measures, signs of localised overexploitation were evident, and the Seychelles Fishing Authority was charged to conduct a stock assessment and produce a rational management plan for the sea cucumber fishery.

Due to the lack of in-house expertise, the FAO was approached to fund a stock assessment and management programme. The project, which is expected to start in late 2003 will have two major outputs and associated capacity-building. The first output is expected to produce a comprehensive and sustainable programme to assess sea cucumber resources and monitor the development of the fishery. The second output is the development and implementation of a management plan with a revised and improved licensing, reporting and enforcement mechanism; a framework for improved fishers' and stakeholders' participation in the management of the holothurian resource, and a strong link between the scientific assessment of the resources and the regulation of the fishery. The participation of fishers in drafting the management plan will hopefully give them an enhanced sense of responsibility towards the fishery. As a long-term strategy, the project will also look at the potential of sea cucumber culture for restocking purposes.

Holothuria nobilis **(Photo: Aymeric Desurmont)**

The application of the adaptive principle to the management and conservation of *Stichopus fuscus* in the Galápagos Islands, Ecuador

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Beche-de-mer fishing started in the Galápagos Islands in 1999 after commercial depletion of the populations in mainland Ecuador. The management of this fishing activity has evolved from top-down decisions on the little regulations to an adaptive and participatory management scheme. This scheme involves the direct participation of local stakeholders. All decisions approved by a consensus in the local discussion forum (Junta) are then set into law by the government. This strategy is adaptive as it takes into account previous experiences to better the current management of the species.

This paper presents an historical overview of the management regime since the 1990s. We present a conceptual framework, based on which the regulations have been passed in order to support the management of *Stichopus fuscus* on a sustainable level. Changes in the management have been achieved, due mainly to two key factors: 1) the innovative participatory system implemented by the Ecuadorian Government for the management of the Galápagos Marine Reserve (GMR), which enables the equal participation of stakeholders: science and conservation, tourism, fishing and managers. All decisions regarding the GMR, including the management of *S. fuscus* are taken on a consensus with later approval by the Government; and 2) the availability of demographic, biological and ecological information on this species, which acts as a tool on the decisions taken by the stakeholders. Population density information in over 60 sites in all fished islands, reproductive biology, fishery statistics and ecological information has enabled the production of specific regulations aiming to produce a sustainable fishery.

Finally, the document highlights the obstacles such as changes in representatives to the local forum and the social and economic pressure exerted by the fishers and their families, which prompted government decisions in detriment of the species.

Customary marine tenure in Solomon Islands: A shifting paradigm for management of sea cucumbers in artisanal fisheries

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With limited success of western models to manage fisheries resources, customary marine tenure (CMT) could be a more effective vehicle for forming and imposing sustainable management of sea cucumber resources in Solomon Islands. Analysis of national export data from 1991 to 2001 shows a decreased landing of sea cucumbers from a record level of 622 t (dried) in 1991 to 240 t (dried) in 2001, with > 75 % of the 2001 landings derived from species of medium- and low-commercial value. The resources appear to be overexploited as the falls in landings contrast sharply with the increase in both the exploitation of non-traditional fishing areas and participation of fishers in the fishery in the last 10 years.

The recent years (1998–2000) of civil war and resulting economic hardship in the country have left the sea cucumber resources extremely vulnerable to unsustainable and destructive exploitation. This vulnerability has been complicated by a marked weakness in the government's capacity to formulate and implement the necessary policies to protect these resources. Regulations such as size limits, bag limits, gear restrictions and seasonal closures (which are ad hoc in nature) have failed to achieve the desired aims, due in part to the limited human, financial and technical resources. Given the failure of centralised management of the fishery, the CMT system is likely to be a better tool for managing the sea cucumber resources. Because the CMT system is community-based and the inshore marine resources fall under this jurisdiction, active participation of fishing communities and resource owners in forming and implementing management strategies at the community level is fundamental within this context.

Management of these resources should be transferred to communities and should entail the enforcement of regulations such as bag limits, gear restriction and seasonal closures, species rotation and area restriction. These should be implemented in accordance with the local system of CMT. This shift in the management mode will give a feeling of ownership and control within the communities, providing and empowering them to determine plans, activities and methods of implementation, fitting to local circumstances and needs. In contrast, the national government would undertake a supportive and coordi-

nating role, developing policy and regulatory frameworks. The shift to customary management of sea cucumbers should reduce or halt the current overfishing and reveal an alternative approach for artisanal communities in the Pacific.

Fishing, processing and the resource management of sea cucumber in the archipelagos of Dongsha, Nansha, Xisha, and Zhongsha

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Dongsha Islands, Nansha Islands, Xisha Islands and Zhongsha Islands of the South China Sea are situated in the tropics and subtropics and are rich in sea cucumber resources. Generally there are eighteen species of sea cucumbers in the area: *Actinopyga echnites*, *A. lecanora*, *A. mauritiana*, *A. miliaris*, *Bohadschia argus*, *B. marmorata*, *Holothuria arenicola*, *H. atra*, *H. cinerascens*, *H. edulis*, *H. impatiens*, *H. leucospilota*, *H. nobilis*, *H. pervicax*, *H. scabra*, *Stichopus chloronotus*, *S. variegatus*, *Thelenota ananas*. These inhabit the seabed of coral reefs 70 metres deep and feed on organic matter and micro-organisms in the coral sand. For more than 400 years fishers in the eastern Hainan Island have visited Xisha Islands and Nansha Islands to catch sea cucumbers using a specially designed tool named "fork to sea cucumber". Processing of sea cucumbers includes three steps: cleaning out the viscera, cooking and drying. When sea cucumbers are cooked and dehydrated, care is needed in controlling intensity of the fire and the degree of cooking, according to the boiling duration and changes in colour of sea cucumber. Sea cucumbers are rich in ingredients such as protein and amino acids, and are a Chinese traditional medicine as well as a delicious dish. The extended, excessive fishing has caused the resources of sea cucumbers in these four islands to gradually decline. To promote the reasonable utilisation and sustainable fishing of these resources, a plan to protect some regions from fishing should be outlined in the islands where the resources are rich. At the same time, the fishing season and minimum legal size for capturing sea cucumbers should be restricted to preserve adequate breeding populations. Moreover, studies are needed on the artificial reproduction of economically important species of sea cucumber which are also essential to maintain an ecological stability of this resource.

SESSION 3 - AQUACULTURE ADVANCES

Sea cucumber (*Apostichopus japonicus*) pond polyculture in Dalian, Liaoning Province, China

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The sea cucumber *Apostichopus japonicus* Liao can be found in Korea, Japan, the eastern shores of Russia, and along the coast of China. It is a favourite seafood in these areas, especially in China. Aquaculture research on this species began in the middle of the 1980s. There were great progresses made in the breeding and larval rearing of *A. japonicus*, which promoted the rapid development of the aquaculture industry in Dalian, Yantai, Weihuai, and Qingdao in northern China. In the early 1990s, numerous coastal ponds, traditionally used for prawn culture, were abandoned due to the emergence of diseases. Hence, many ponds were restored and used for sea cucumber mono-culture or in polyculture with shrimp. Both methods proved to be financially profitable.

There are more than 2000 hectares of ponds used for polyculture of sea cucumber and shrimp in the Dalian area. The best results are obtained in leak-proof ponds with muddy-sand bottoms. The typical size of a pond is usually between 2 and 6 hectares. Water depth is maintained at 1.5–2.5 m. The seawater is changed by opening and closing the sluice gates with the change of tide. The salinity is 25–35 ppt and the water must be clean and unpolluted. The survival rate varies according to the size of the juveniles. Individuals larger than 2 cm will have a survival rate of 20–30 per cent. The rate of survival will increase if stocking is carried out with larger specimens. The stocking density of sea cucumbers and shrimp is 10,000–15,000 and 1500–3000 per hectare, respectively.

During the culture, the quality of the seawater, and the growth of sea cucumbers and shrimp, should be monitored daily, and the food supply adjusted accordingly. Undesired algae species and harmful organisms should be regularly removed from the ponds. The depth of the water must be maintained throughout summer and winter. After about 1.0–1.5 year, the sea cucumbers can either be collected by divers or taken out after the ponds have been properly drained.

Advances and prospects of sea cucumber (*Apostichopus japonicus*) aquaculture in China

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This article summarises the latest progress in the artificial breeding and aquaculture of sea cucumbers *Apostichopus japonicus* Liao along the coast of Dalian, China. The development of specialised techniques will be discussed, emerging problems analysed and future prospects outlined. For the artificial breeding, the broodstock sea cucumbers are maintained under low temperatures (15–16ºC) to maximise the quality, quantity and maturity of the gametes. The density of larvae is kept under 1.0 ind. ml^{-1}. The algae *Dunaliella euchlaia*, *Chaetoceros gracilis*, *Chaetoceros muelleri*, *Nizschia closterium* and *Phaeodactylum tricornutum* can be selected as food for the larvae, whereas *Sargassum* sp. is used to feed the juveniles. The quality of the seawater is a basic requirement for larval and juvenile production.

The grow-out of sea cucumbers is mainly carried out in former shrimp ponds and newly-built ponds in the in-shore regions of Dalian. It has become an important industry after more than ten years of development; the area used for farming is now exceeding 70 hectares. A recently developed model of culture in open sea will be presented in this paper.

Breeding and culture of the sea cucumber *Apostichopus japonicus*

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Apostichopus japonicus Liao is the most important and valuable commercial sea cucumber species in China. The life cycle of *A. japonicus* includes the following stages: auricularia, doliolaria, pentactula, juvenile sea cucumber, young sea cucumber and adult. This paper outlines the several spawning induction methods and artificial rearing techniques. The specific means of cultivation during the different stages of development, the control of chemical and physical factors in the seawater and the prevention and cure of diseases and harmful life-forms will be discussed. The work compares different methods of culture and their respective merits and limitations.

At present, artificial breeding and culture of sea cucumbers is still a work in progress, but the scale of the production is increasing and a number of questions related to the culture techniques are being raised, calling for further studies on the commercial aspects of *A. japonicus* aquaculture.

Studies on hatchery techniques of the sea cucumber *Apostichopus japonicus*

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In this paper the authors give an outline of hatchery systems and breeding techniques of the sea cucumber *Apostichopus japonicus* in north China. The selection and maintenance of broodstock, spawning induction method and larval rearing, stimulation of settlement, juvenile growth and management of wintering are presented. The cause of some common diseases observed in the hatchery such as "rotten-stomach" of larva, low success of larva metamorphosis, and mortality of juvenile sea cucumbers are discussed, together with methods used for preventing such problems.

Diseases of cultured sea cucumber (*Apostichopus japonicus*) in China

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Ever since the artificial breeding technique of *Apostichopus japonicus* has been broken through in the 1980s, Chinese researchers have been making efforts to efficiently develop and improve the rearing protocols. In recent years, sea cucumber aquaculture has developed rapidly along the northern coast of China, where more than one billion seeds can be produced and 90,000 t of sea cucumber (fresh weight) can be harvested every year.

The rapid expansion and intensification of sea cucumber farming has led to the occurrence of various diseases, causing serious economic losses and becoming one of the limiting factors in the sustainable development of this industry. Recently, a study was carried out on the diseases of cultured sea cucumber, revealing that several non-reported diseases have been discovered. The epidemiological study showed that the syndromes of rotting edges, ulceration of the stomach in auricularia stages and autolysis of young juveniles were caused by bacterial agents, whereas skin ulceration, erosion of epidermis and body oedema were triggered by various pathogens including bacteria, fungi and parasites during the outdoor cultivation. These pathogens induced high mortality rates, occasionally reaching up to 80 per cent. Upon the isolation of these etiological agents, morphological, physiological, biochemical, molecular and pathological studies have been performed, and a preliminary identification of the isolated agents was conducted in the present study.

Parasites and biotic diseases in field and cultivated sea cucumbers

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Amongst echinoderms, the Holothuroidea represents the class that is the most infested by parasites. Parasites of holothuroids are Bacteria, Protozoa and Metazoa. There are about 150 species of metazoans which parasite holothuroids. Most of them are turbellarians, gastropods, copepods, crabs or fishes. The main body organs suffering from infestation are the digestive system and the coelom. The diseases induced by metazoan parasites are mostly structural: they create galls at the surface of the epidermis, pierce the respiratory tree or dig into the body wall down to the coelom. Most metazoans that live in the digestive system do not induce obvious diseases and their relationship with their hosts is probably close to commensalism. Most Protozoa that parasite holothuroids are sporozoans. They occur mainly in the coelom and/or the haemal system, one species having been reported infesting the gonads. Even in heavily infested hosts, the signs of disease induced by sporozoans are low: at most, host haemal lacuna is occluded by trophozoites or cysts are formed into the coelomic epithelium.

The most frequent pathogen agents reported from cultured sea cucumbers are Bacteria. Cultivated holothuroids may suffer from a bacterial disease affecting their body wall. In particular, juvenile *Holothuria scabra* reared in the Aqua-Lab hatchery of Toliara, Madagascar, suffered from a very contagious disease, which was due to a severe bacterial infection that caused death within three days. The first sign of the infection is a white spot that appears on the integument of individuals, close to the cloacal aperture. The spot extends quickly onto the whole integument leading to the death of individuals. The white spot lesions consist in a zone where the epidermis is totally destroyed and where collagen fibres and ossicles are exposed to the external medium. This zone is surrounded by a borderline where degrading epidermis is mixed with connective tissue. White spot lesions include three bacterial morphotypes: rod-shaped bacteria, rough ovoid bacteria, and smooth ovoid bacteria. Three species of bacteria have also been put in evidence in the white spot lesions thanks to biomolecular analyses (DGGE and sequencing): *Vibrio* sp., *Bacteroides* sp., and an a-Proteobacterium.

Nutrient requirements and growth of the sea cucumber *Apostichopus japonicus*

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The sea cucumber *Apostichopus japonicus* (Echinodermata, Holothuroidea, Aspidochirotida, Stichopodidae) is widely distributed in the waters off China, Japan, Korea and Russia. In China, the species is mainly distributed in the Bohai Sea and the Yellow Sea. Studies on *A. japonicus* started in the 1950s when scientists from China and Japan first tried to develop breeding techniques. During the 1980s, Chinese scientists made a break-through in the larval-rearing of sea cucumbers and made considerable progress in the culture techniques on a commercial scale. Over the last decade, the farming industry of *A. japonicus* has been developing quickly. As of 2003 in the Shandong Province, a total volume of 145,000 m^3 of larval-rearing facilities is being used to produce up to 1.27 billion juveniles. It is estimated that the cultivation areas span on some fifteen thousand hectares and that a harvest of 2250 t can be expected.

Research on sea cucumbers is a relatively recent field of interest. Worldwide, there are only a limited number of reports on the feeding and growth of juveniles. The present paper summarises the latest results on the nutritional requirements of A. japonicus. The feeding experiment was conducted over 70 days by giving artificial feed, mainly composed of fish meal, Sargassum thumbergii and lees, to juvenile sea cucumbers. Using Cr_2O_3 as a marker, we determined that the weight gain rate and digestibility increased with the protein contents of the feed. The optimal protein content was 21.49 per cent. Based on a 40-day growth experiment, during which five different feed formulas were essayed, we found that the increment of weight gain rate was maximal when the food was rich in threonine, valine, leusine, phenylalanine, lysine, histidine and arginine. The highest growth rates were obtained when the ratio between calcium and phosphorus content ranged from 6.78 to 8.80. However, the weight-gain rate decreased when the juveniles were given a fibre-rich feed.

Sandfish breeding and rearing in Vietnam

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The aims of this project were to develop large-scale breeding and rearing methods for sandfish (*Holothuria scabra*) for commercial culture and/or restocking. The work was carried out in Khanh Hoa Province, Vietnam.

Wild-collected sea cucumbers were initially difficult to spawn. After a period in earthen ponds or seabed pens the broodstock could be induced to spawn year round using temperature changes, emersion, treatment of water with UV light, addition of dry phytoplankton etc. Numerous batches of larvae have been reared to settlement and further, using simple hatchery methods.

Juveniles coming out of the indoor hatchery tanks (mostly below 3 mm in length and about 1 µg in weight) have been grown to a few grams or tens of grams in two or three nursery stages. Trials have been carried out to test these nursery stages. This has been done using different kinds of tanks, in a range of earthen ponds, sometimes using hapas (fine-net bags), larger bag nets and pens inside the ponds, and in the sea using various seabed cages, covers and pens. Nursery has been carried out in monoculture and in polyculture with the shrimp *Penaeus monodon* or the Babylon snail *Babylonia areolata*.

Further growout of nursed juveniles has also been tested in ponds, pens and cages. Big pens (up to 2000 m^2) were built in marine protected areas and stocked with hatchery-produced sandfish, to test their potential as alternative income sources for local fishermen. Growout has often been rapid, in the range of 1–3g day^{-1}. At best, pond growth from 30 g to 300 g has been achieved in only 3 months. Hatchery-produced sandfish from ponds were spawned at less than one year of age, and several batches of their progeny have been produced. Pens have proved cheap and effective for holding broodstock and for ongrowing.

Constraints in sandfish culture include low prices paid by dealers, the large area needed for nursery and growout (growth often slows down or stops when stocking densities exceed about 150–300g m^{-3}), high variability in survival rate at many stages, pre-

dation pressures (including predation by shrimp), the need to guard pens against theft and problems of pond management. Positive factors include the relatively high tolerance of this species to temperature and salinity changes, ease of containment, the fact that sandfish do not need addition of feed in ponds or pens and the idea that they may help to clean the pond floor or seabed of organic matter associated with other aquaculture activities.

Coastal population surveys have not yet been carried out, and only a few small releases of hatchery-produced sea cucumbers made. Natural recovery of overfished sea cucumber populations may be delayed by various factors at different stages in the life cycle. This needs to be better understood in order to design and test possible interventions, including restocking with hatchery-produced juveniles. It is hoped that the information obtained on growth rates and stocking densities, age at maturity and year-round egg production will be of value in this process.

Aquaculture of the Galapagos sea cucumber *Isostichopus fuscus*

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This paper presents the results of the first attempt to breed the sea cucumber *Isostichopus fuscus* in land-based installations on the coast of Ecuador. This species has been intensively fished along the mainland and around the Galapagos Islands, where efforts at management have always met strong opposition from local communities. Ecuadorian populations of *I. fuscus* have thus been severely depleted over the past decade. The topics presented here include spawning, fertilisation, larval rearing, disease control and juvenile growth. Data pooled from monthly trials conducted over three years indicate that, under optimal conditions, juveniles can be grown to a size of ca. 8 cm in length in 3.5 months. The survival rate is typically between 30 and 50 per cent. Furthermore, preliminary experiments have shown that the growth of young sea cucumbers in old shrimp ponds is a promising option. Overall, this study demonstrates that *I. fuscus* can be reared in captivity, thus providing an alternative to fisheries, or a way to maintain sustainable harvests and eventually contribute to the restoration of the natural populations.

Synchronous gamete maturation and reliable spawning induction method in holothurians

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Several years of research on the gametic development and spawning of different species of holothurians have produced results that find applications in aquaculture and fisheries management programs. The first set of data shows that sea cucumbers secrete a biologically active chemical, which allows gamete synthesis synchrony among conspecifics. Laboratory experiments have revealed that the gametic development was significantly less synchronous among individuals that were maintained separately under natural environmental conditions than it was among similarly treated individuals kept in group. Furthermore, the presence of mature individuals was found to induce the gametic development of less mature ones. The active substance is present in the mucus secreted by the body wall, enabling it to travel fair distances, although transmission is often favoured by pairing and aggregative behaviours. These findings indicate that the lunar cycle, photoperiod, food supply and temperature cannot individually account for the onset and synchronisation of reproduction, but rather that environmental cues act synergistically and can be transmitted within and between populations through chemical communication. This has repercussions on both fisheries and aquaculture techniques. Preserving untouched populations while fishing intensively on other grounds should be favoured compared to steadily lessening the biomass, whereas broodstock should be maintained in a way that promotes interactions long before the breeding season. The other aspect of the study propped up from the fact that holothurians are among the most commercially valuable echinoderms for which successful spawning induction is still difficult to obtain on a reliable basis. Recent results show that the transfer of perivisceral coelomic fluid (PCF) can be used as a reliable tool to induce spawning in mature individuals. PCF collected from individuals that had been in the typical spawning posture, without shedding gametes, for about 20 min triggered spawning in 71 to 100 per cent of conspecifics. The individuals responded to the injection of a 2–3-ml aliquot by displaying the spawning posture within 30–62 min, followed by massive gamete broadcast 57–83 min later.

The results varied according to the time of PCF collection with respect to the spawning activity of the donor and the amount of PCF injected. The inductive substance was found not to be sex-specific since positive responses were observed in individuals of the same or opposite sex as the donor. Thus, PCF collected from early spawners, usually males, can be used to spread and maximise the spawning success.

Mariculture of sea cucumber in the Red Sea: The Egyptian experience

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Severe overfishing of sea cucumbers has occurred in most countries of the world. Even though they were abundant on the Red Sea coast of Egypt in the mid 1990s, sea cucumber populations are now significantly reduced and some species have almost disappeared. As a consequence, and as part of a Darwin Initiative project, the release of cultured juveniles is being examined at the Marine Science Department in Suez Canal University, Egypt, as a means of restoring and, eventually, enhancing sea cucumber stocks. One of the most important sea cucumber species occurring along the Red Sea coasts is *Actinopyga mauritiana*. Worldwide, this species is highly valued, in great demand, and harvested in large numbers. This paper summarises the morphological characteristics, anatomy and biology of this species as an introduction, before over-viewing the spawning methods attempted in the Red Sea. The results indicate that outside the spawning season, asexual propagation methods appear the most practical option for increasing the stock of cultured individuals. However, this will only be practicable if the mortality rate of *A. mauritiana* can be reduced during the process. If successful, there is some potential to use this technique in hatcheries with minimum costs.

Captive breeding of the sea cucumber *Holothuria scabra* from India

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The present report deals with the hatchery and culture techniques of the sea cucumber *Holothuria scabra* from India. Larvae and juveniles were produced for the first time in 1988 at the Research Centre of Central Marine Fisheries Research Institute of Tuticorin on the south eastern coast of India. Large, healthy and uninjured specimens were selected as broodstock. They were stocked in one-tonne tanks in the hatchery. Mud from the natural habitat was collected and put at the bottom of the tanks for the sea cucumbers to bury. The seawater in the tank was changed daily and the bottom mud was changed every fortnight. At Tuticorin, this species was subjected to thermal stimulation during March–May, the major breeding peak and also during November–December, the minor breeding peak. First the males released the sperms within three hours after stimulation, followed by the females, about an hour later. The eggs were washed in fresh seawater and stocked at a density of 0.3 million eggs per 750 litres of seawater. Early the next day, auricularia larvae were developed. These larvae were fed on a microalgal culture of *Isochrysis galbana*. On the tenth day some of the auriculariae transformed into doliolariae. They were smaller than the auriculariae in size, highly motile and non-feeding. After three days some of them transformed into pentactula larvae. They were fed on a mixed culture of *Chaetoceros calcitrans* and *Tetraselmis chuii*. The water in the tanks was changed daily but the bottom was not cleaned to allow the algae to settle. After two months the juveniles reached a length of 20 mm.

These juveniles produced in the hatchery were grown in one-tonne tanks, rectangular cages, velon screen pens and netlon screen pens, concrete rings at Karapad Bay, Valinokkam Bay and inside the harbour area for security. Best growth was noticed when the juveniles were grown in a prawn farm near Tuticorin. It is well known that much of the feed given to the prawns goes to waste, settling at the bottom of the farm pond enriching the farm soil, at the same time polluting the environment. The sea cucumbers are detritus feeders subsisting on the organic matter present in the substrate. The presence of the sea cucumbers at the bottom of the farm pond in no way affects the activities of prawn farming. In fact, the prawns grow faster since the excess of food on the bottom is removed and the environment is kept cleaner by the presence of sea cucumbers. It is an ecofriendly practice that is beneficial both to prawns and sea cucumbers. In recent years the prawn farming industry in India is rocked by disease and legal problems. The culture of sea cucumbers in prawn farms comes as a boon for the prawn farmers.

2- VISIT OF HOLOTHURIAN FARMS AND HATCHERIES
(16 October 2004)

A visit of two large holothurian farms, probably the largest in Asia (or the World) was organised. Visitors were very impressed by the size of the facilities and the quality of the infrastructure. The firms manufacture themselves all the elements necessary to the hatchery and farm (feed, etc. . .). They produce also other marine resource such as abalone, urchins but their principal activity is based on the production of sea cucumbers. A farm can produce several millions of sea cucumbers per year. You will find below some information on and several pictures of the two companies visited by the Workshop participants.

Company Name: Dalian Bang Chuidao Sea Cucumber Development Co. Ltd.
Contact Person: Mr LIU Chun Sheng
Address: Chengzi, Dalian Developing District, Dalian, Liaoning Province, 116045 China
Tel: +86 411 7227888

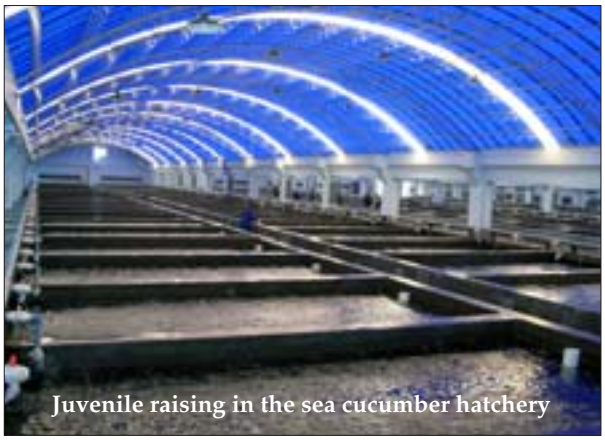
Brief company description:

Dalian Bang Chuidao Sea Cucumber Development Co. Ltd. is located in the Natural Conservation Zone of Chengshantou, Dalian City. The company is a leading Chinese integrated company engaged in mariculture (hatcheries and on-growing facilities), processing and trade of sea products. As a result of its performance over the years, particularly with regards to the production of quality products, the company has been rewarded by the Municipal Government and certified by the National Bureau of Trademarks.

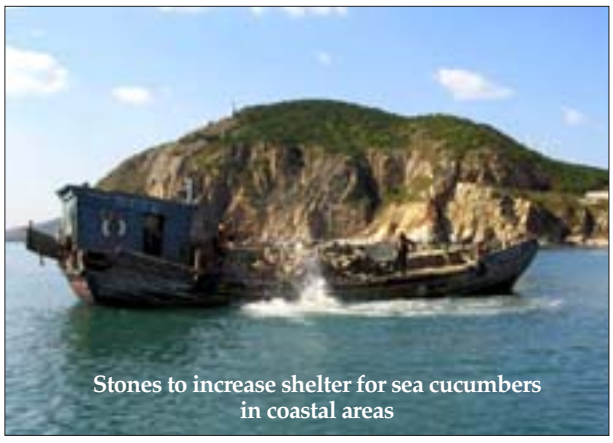
In 2002 the company received approval from by Ministry of Agriculture (MOA) to establish and administer a national sea cucumber project focused on the conservation of endemic species and breeding of commercially important species. In the same year the company established a land-based facility and produced 30 million and 5 million of sea cucumber and sea urchin seed, respectively. All juveniles of both species were stocked in the conservation coastal zone for resource enhancement.

With the completion of the project the company will be in a position to produce annually 60 million sea cucumber seeds. The company plans to produce 3 million sea cucumber annually that will be valued at RM 200 million yuan (@ USD 24 millions with 1 USD = 8.27 RMB ; 1.7.03). In the future the company has plans to invest RMB 38 million yuan (@ USD 4.6 million) in sea cucumber aquaculture. The company's ambition is to become a world leader in sea cucumber aquaculture using its popular "Bang Chuidao" trademark.


Site of the hatchery and sea ranching


Juvenile raising in the sea cucumber hatchery


Juveniles raised on net in the hatchery


Stones to increase shelter for sea cucumbers in coastal areas

(*Photos: C. Conand*)

Company Name: Dalian Youde Marine Biological Garden
Contact Person: Mr JIANG Chun Jia
Address: Chengguan, Pulandian District, Dalian, Liaoning Province, 116222 China
Tel: +86 389 8651188

Brief company description:

The Dalian Youde Marine Biological Garden company is part of a newly established group of companies operating in Dalian. The estimated capital of the group is RMB 130 million (@ USD 15.7 million). The company operates its land-based facilities on a 15 hectares plot and has a sea concession of 4260 hectares.

The company has a large-scale production capacity of a variety of marine species juveniles including sea cucumber, Yeso scallop, geoduck, sea urchin, giant cockle and several finfish species. The company runs its own hatcheries, grow-out facilities (land-based and sea), enhancement programmes and processing facilities. This year the company expects to produce approximately 150 million sea cucumber seeds and 5 billion of scallop seed for their aquaculture programme.

Facilities of the Dalian Youde Marine Biological Garden company (*Photo: C. Conand*)

3- SEA CUCUMBERS IN MARKETS, CHINA

Dalian supermarkets sell different qualities of *Apostichopus japonicus*, Dried, fresh, frozen. In Beijing Hongqiao Market, different tropical species (as well as temperate) sea cucumbers fresh and processed are sold.

Fresh *Apostichopus japonicus* (*Photo: C. Conand*)

Processed *Apostichopus japonicus* (*Photo: C. Conand*)

Periodic movement and sheltering behaviour of *Actinopyga mauritiana* (Holothuroidea: Aspidochirotidae) in Solomon Islands

Jane C.H. Graham[a] and Stephen C. Battaglene[b]

Abstract

Spatial patterns, movement, and sheltering behaviour of the holothurian Actinopyga mauritiana *were examined on an intertidal reef in Solomon Islands over several days between March and October 1998, and in May 1999. Adult animals were associated most commonly with solid reef rock and scattered tables of the coral* Acropora *sp. The holothurians were found in patches with densities ranging from 2.8 to 6.6 animals 100 m^{-2}. Individuals were identified from the white markings on the tegument. Rates of movement ranged from a minimum of 0.04 m h^{-1} (± 0.01 SE) during high tide at night to a maximum of 0.21 m h^{-1} (± 0.02 SE) during low tide in the daytime. Analysis of movement patterns and sheltering behaviour over 24-hour periods from four tidal cycles revealed that* A. mauritiana *has activity rhythms related to the diel cycle and/or tides. The method used in the study offers a repeatable, accurate, and quantitative way of studying movement of holothurians inhabiting shallow water, provided individual animals can be identified.*

Introduction

Although much research has been devoted to reproduction and feeding of tropical holothurians, relatively little is known about other aspects of their behaviour and its effect on distribution. However, one of the main behaviour patterns to emerge across a range of species is a diel activity rhythm with nocturnal feeding (Crump 1965; Reese 1966; Hammond 1982; Conand 1991; Preston 1993; Wiedemeyer 1992, 1994; Mercier et al. 1999, but see Yamanouchi 1939 for conflicting evidence).

One of the species for which little information on diel activity exists is the surf redfish, *A. mauritiana*. This species is widespread in the Indo-Pacific and typically inhabits hard substrates on reef flats. These habitats are approximately 1–3 m deep and are subject to strong waves and currents (Baker 1929; Yamanouchi 1939; Bakus 1968, 1973; Conand and Chardy 1985; Zoutendyk 1989; Conand 1991, 1993; Hopper et al. 1998). These holothurians graze on epifaunal algal films that consist mainly of plant debris and on the brown and blue-green algae common on the hard substrates they inhabit (Conand 1990; Ramofafia et al. 1997).

The shallow, intertidal and sub-littoral habitat of *A. mauritiana*, and its relatively high commercial value, has led to overexploitation in many countries. Accordingly, the potential for using aquaculture to increase the productivity of *A. mauritiana* has been investigated by the International Center for Living Aquatic Resources Management (ICLARM) (Ramofafia et al. 1997). Our goal was to study the periodic behaviour of *A. mauritiana*, particularly time spent moving and sheltering, to complement work being done to assess the potential for farming this species. Other aspects of behaviour that were investigated included foraging range and homing.

Methods

Study location

Our study was carried out at ICLARM's Coastal Aquaculture Centre (CAC) at Aruligo (159°47'E, 9°18'S), 25 km west of Honiara, Guadalcanal Island, Solomon Islands (Fig. 1). A 400-m section of the foreshore at the CAC was declared as a marine reserve in 1986 and was among the few locations in Solomon Islands where individuals of *Actinopyga mauritiana* were not being harvested at the time of this study.

The foreshore reserve at the CAC consisted of a fringing coral reef, 20–40 m wide. At a depth of 5–10 m, the reef gave way to a rapidly shelving sandy substrate. The reef was exposed to moderate to high wave action, varying both on a daily and a seasonal basis.

The tidal regime in the vicinity of the CAC is mixed and during the study, high and low tide occurred at a similar time each day for many months, with a maximum tidal range of 1.1 m. From late March until late November 1998, high tide occurred at night and low tide during daylight hours (Solomon Islands Hydrographic Unit 1998). The tidal pattern changed only for the months of December 1998 through March 1999, when the cycle reversed and high tide occurred during the day and low tide occurred at night. A fixed reference point on the reef was used to measure water height at the start of each sampling. The average water depth over the reef at low tide was ~20 cm.

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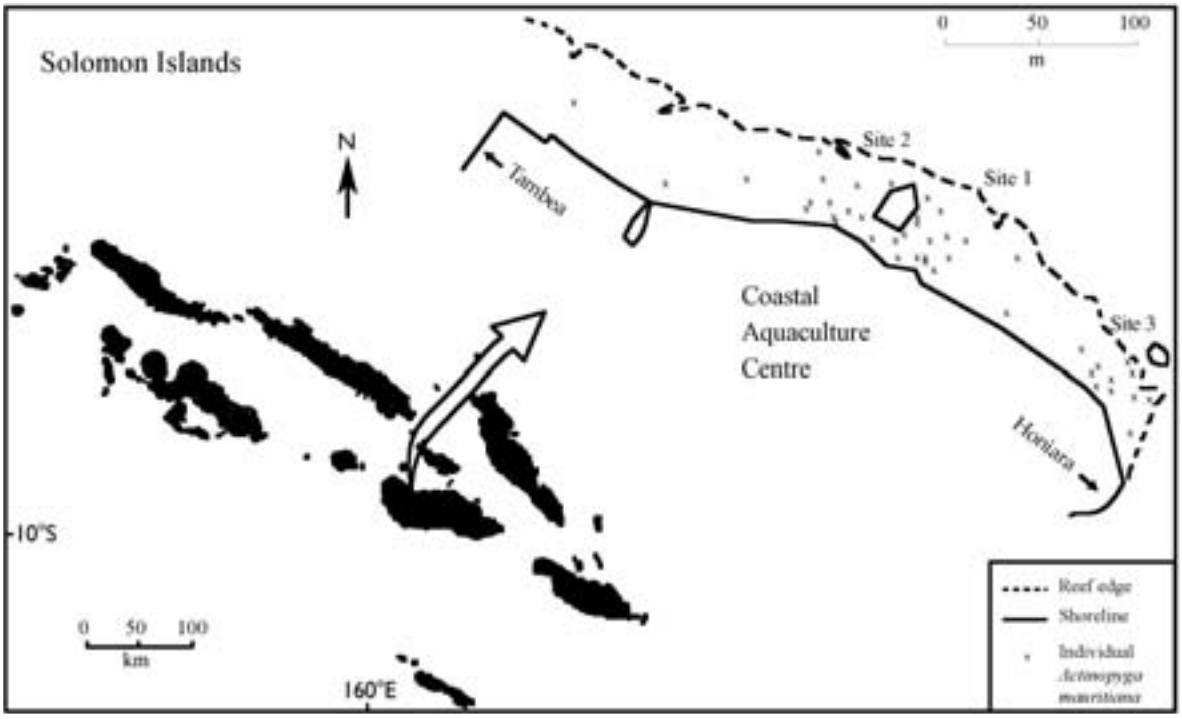

Figure 1. **Location of study sites in Solomon Islands. Inset shows the size of the sites at Aruligo and the distribution of individuals at each site in March 1998.**

Three sites were identified within the reserve, each selected to contain at least 10 specimens of A. mauritiana (Fig. 1). All sites were located on the reef flat close to the wave impact zone and consisted of solid reef rock with scattered boulders of dead coral. At each site, individual holothurians could be distinguished from one another by the size and pattern of white spots on their tegument (Fig. 2).

Measuring movement and sheltering behaviour

Movement and sheltering behaviour of *A. mauritiana* were studied at Site 1 on 18 and 19 March 1998. Observations were restricted to individuals >300 cm^3. Movement was assessed by measuring the position of each individual every 3 h, for a period of 24 h.

Figure 2. **Individuals of *Actinopyga mauritiana* showing unique patterns of markings on the tegument.**

To calculate distances, 2 steel posts were driven into the reef flat at the landward edge of an area ~240 m^2 containing 16 animals (Fig. 1). The distance from each post to the centre of the upper surface of each animal was measured to the nearest 0.01 m. By triangulation, we calculated the extent and direction of movement from one observation period to the next using the method of Underwood (1977). This technique calculates linear displacement over a sampling interval, not the total distance moved. The accuracy of measurements was calculated as ± 0.05 m and was determined by moving 20 animals to known distances of 0.1 m to 2.0 m and comparing the known distance with the calculated displacement. For all analyses, any movement <0.05 m was treated as zero.

An individual was considered to be "sheltered" if more than half its body was obscured from view. Sheltering animals were not seen to feed and so sheltering behaviour was used to estimate the proportion of non-feeding individuals. When an animal could not be found, its most recent position was located using the previous coordinates and the surrounding area was searched (without disturbing rocks and boulders) to a radius of 3 m. Animals that were not found within five minutes were considered sheltered. All animals that were not sheltering were considered to be "exposed."

Patterns of movement and sheltering behaviour over a 24-hour period

To determine if *A. mauritiana* had a pattern of movement and sheltering behaviour, the positions and behaviours of all individuals found within the three sites were recorded at 3 h intervals for 24 h, beginning at 1700 hours. The study was conducted on three non-consecutive days between 29 March and 5 April 1998 at Site 1 and on another three non-consecutive days between 8 and 27 April 1998 at Sites 2 and 3. Site 2 (240 m^2) contained 12 animals and Site 3 (390 m^2) contained 11 animals. Movements of individuals were plotted over 24 hours to determine if they returned to the same position when sheltering (homing), and to examine the extent of overlap in the foraging ranges. In addition, data from the first and last sampling intervals were used to calculate the net displacement and direction of movement over a 24-hour period.

Patterns of movement and sheltering behaviour at different tidal height

We tested the null hypothesis that there was no difference between the distances moved by these holothurians, or the proportion of individuals sheltering, during high and low tide. The positions and visibility of 35 individuals within the reserve were recorded at 1.5 h before and after high and low tide for two consecutive tidal cycles. To ensure independent estimates of movement and sheltering behaviour among sampling intervals, eight animals were chosen at random for each sampling interval. These animals were not used again in statistical analysis. The study was conducted from 15 to 17 June 1998 (low tide: 15 June 1448 hours, high tide: 16 June 0542 hours, low: 16 June 1521 hours, high: 17 June 0356 hours) and repeated from 17 to 19 March 1999 (low: 17 March 1328 hours, high: 18 March 0430 hours, low: 18 March 1405 hours, high: 19 March 0456 hours).

Data analysis

A 3-factor analysis of variance (ANOVA) was used to test for the effect of tidal height on the movement and sheltering behaviour of individuals. Years and tides were fixed factors and day was nested in tides (n = 8). Student-Neuman-Keuls (SNK) tests were used to separate those means that differed significantly at a = 0.05. Homogeneity of variance was evaluated using Cochran's test and data transformed using ArcSin when necessary. Pooling of factors to increase the power of tests was carried out only if p > 0.25 (Winer 1971; Underwood 1981).

Results

Density and distribution

The density of *Actinopyga mauritiana* was 6.6, 5.0, and 2.8 animals 100 m^{-2} at Sites 1, 2, and 3, respectively. However, the distribution of animals was patchy. They were encountered most frequently on solid reef rock where scattered tables of *Acropora* sp. provided shelter. *Actinopyga mauritiana* were absent from areas of the reef dominated by foliaceous corals. No specimens were found on sandy substrate.

Patterns of movement and sheltering behaviour over a 24-hour period

The average total distance moved by individuals over 24 hours at all three sites in 1998 was 3.02 m (SE ± 0.16, n = 72). The animals showed marked diel differences in activity and sheltering behaviour (Fig. 3). The pattern was one of increasing movement during the day, peaking in the evening, then declining through the night to a period of relative immobility between 0300 hours and 0630 hours (0.04 m h^{-1} ± 0.01 SE, n = 72). The most movement occurred during the 3 h period 2000–2300 hours (0.21 m h^{-1} ± 0.02 SE, n = 72). The periods of greatest and least movement corresponded to low and high tide, respectively (Fig. 3). Sheltering behaviour was closely related to movement, with the greatest proportion of animals exposed during the periods of most movement (Fig. 3).

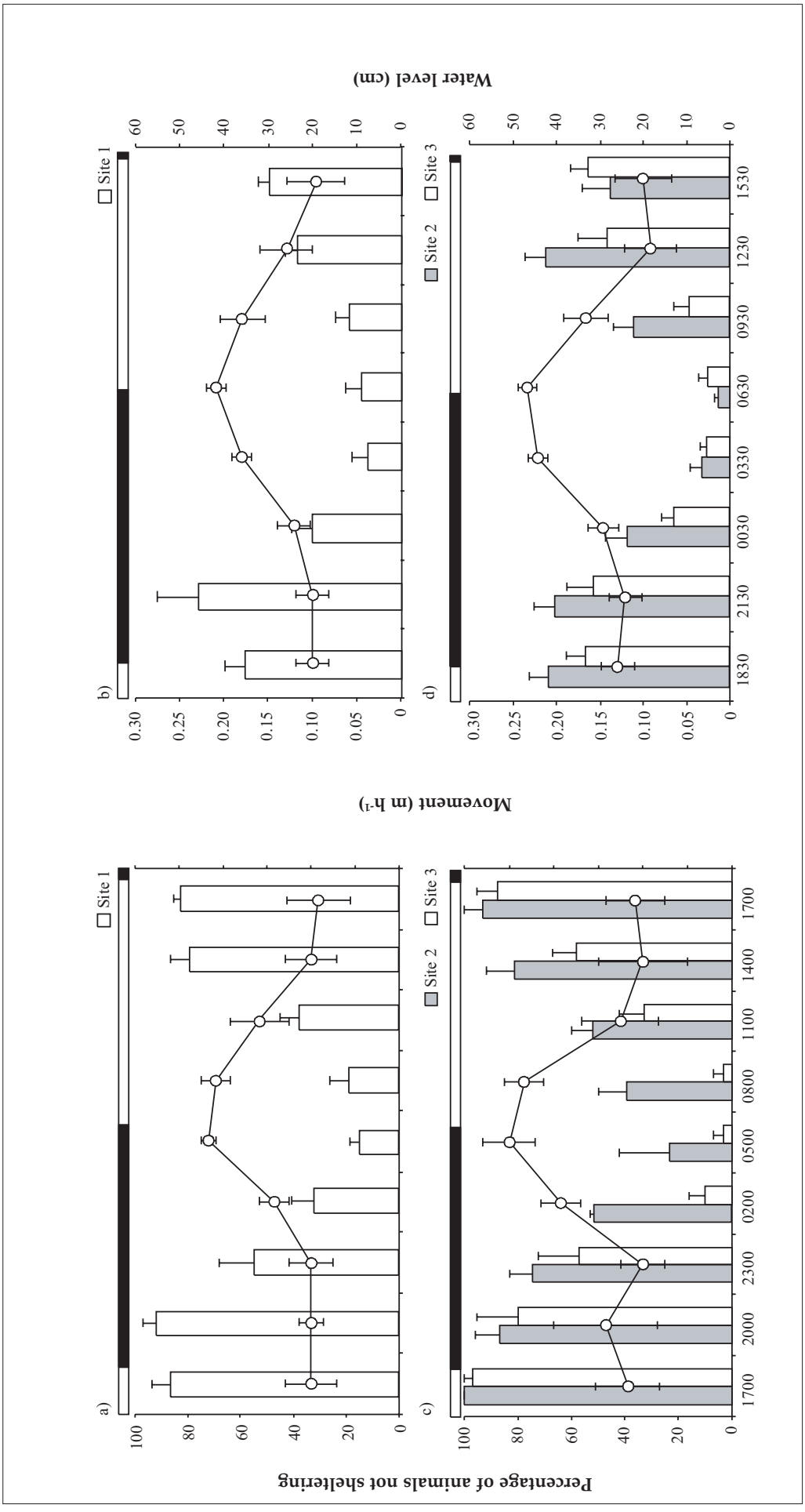

Figure 3. Mean (± SE) rates of movement (m h^{-1}), and percentage of animals exposed, at three sites at Aruligo. Data were averaged over 3 sampling days, n = 9–17 for each sampling period. Open circles represent water level above the reef measured from a fixed reference point (cm ± SE). Horizontal bars give times of daylight (open bar) and darkness (closed bar). a) and c) percentage of animals not sheltering at each observation period at Site 1 and Sites 2 and 3, respectively; b) and d) rate of movement during each 3 h sampling interval at Site 1 and Sites 2 & 3, respectively. Site 1 and Sites 2 and 3 are separated due to different sampling dates.

Homing behaviour, net displacement, and direction

We detected no evidence of homing behaviour or exclusive foraging ranges (Fig. 4). Although the movement of animals showed no strict directional pattern when averaged over all sites and times, there was a tendency for animals to move seaward within the NE to SE quadrant (Fig. 5). The average net displacement and direction of movement of individuals was calculated using coordinates at 0500 hours on Day 1 and 0500 hours on Day 2. The net displacement of individuals over a 24-hour period, pooled across all sites and sampling times, averaged 1.11 m (± 0.06 SE, n = 97); only 15% of individuals were found within 0.50 m of their original position.

Patterns of movement and sheltering behaviour at different tidal heights

Both movement and sheltering were associated with water height. During both years, the movement of animals at high vs low tide differed significantly, with animals moving more during low tide than high tide (Fig. 6, Table 1). The average rate of movement was 0.25 m h^{-1} (± 0.03 SE, n = 32) at low tide and 0.09 m h^{-1} (± 0.03 SE, n = 32) at high tide. Sheltering behaviour was again associated with periods of less movement, with a significantly greater percentage of animals sheltering during high tide than low tide (Table 1). Movement of individuals was significantly greater in 1999 than in 1998 (Table 1). However, there was no difference between the two consecutive days in 1998 or 1999 (Table 1).

Discussion

The method used in this study provides a repeatable and accurate way of analysing the movement patterns of at least some holothurians. The method was particularly suitable for *Actinopyga mauritiana* because individuals could be identified from one sampling interval to the next by patterns on the tegument. Raj (1998a, b) found that photography of individuals of *Stichopus mollis* prevented disturbance of animals but the angle of the photograph and the extent of body markings affected success in identifications. Both the physical examination of animals and photo-identification clearly have advantages over invasive tags, which can alter behaviour and require experimental controls (Chapman 1986; Conand 1989; Chapman and Underwood 1992), but they depend on the presence of distinctive markings.

The low and patchy density of *A. mauritiana* at the Aruligo reserve (2.8–6.6 individuals 100 m^{-2}) is comparable to the reports of 2.0 animals 100 m^{-2} in Vanuatu (Baker 1929) and 3.0 animals 100 m^{-2} in Papua New Guinea (Lokani 1991). All these densities are low among those recorded for tropical aspidochirotes, which range from 0.11 animals 100 m^{-2} for *Holothuria fuscogilva* to 20,000 individuals 100 m^{-2} for *H. difficilis* Semper (Bakus 1973; Preston 1993). However, density estimates for different species must be compared with caution because of the different

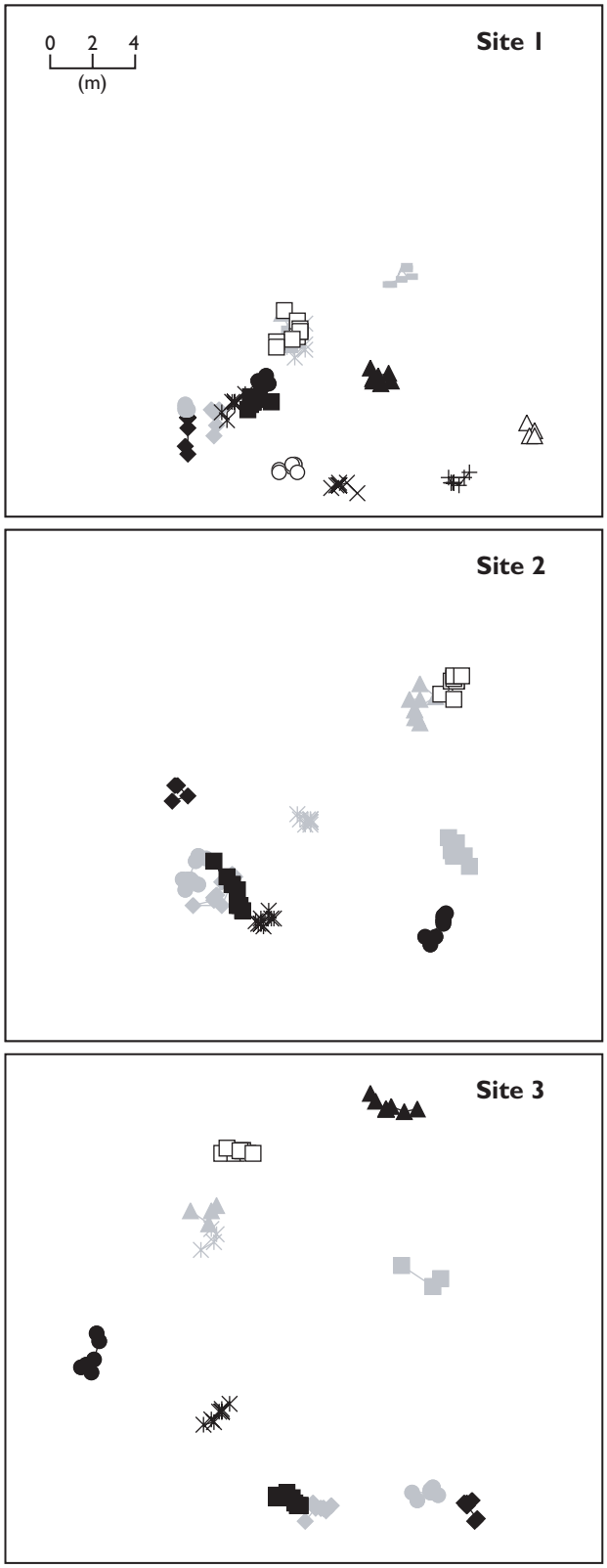

Figure 4. Plots of the movement of individual *Actinopyga mauritiana* at the 3 sites at Aruligo over a period of 24 hours.

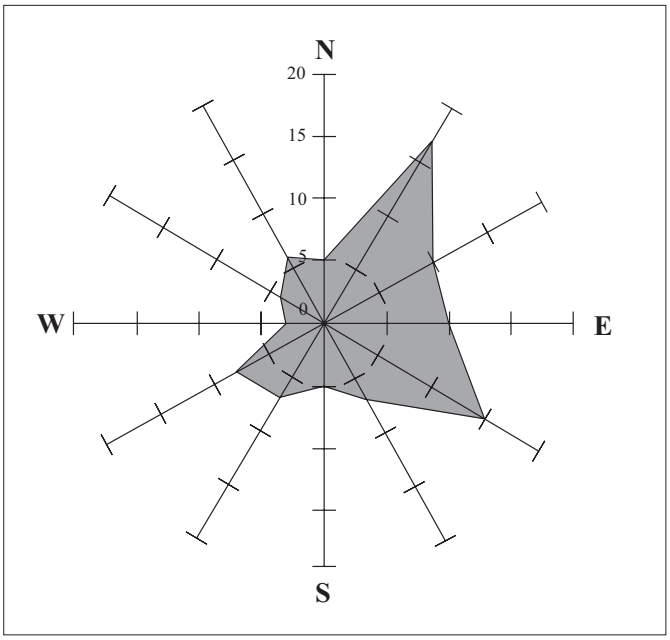

Figure 5. **Graph of the net direction of movement of all individuals at the three sites at Aruligo on three days.**

sizes of animals and variety of sampling techniques. Variation in levels of harvesting across species can also be expected to confound estimated densities. Moreover, this study shows that the cryptic behaviour of *A. mauritiana* may lead to underestimation if surveys are not carried out during periods of activity.

Yamanouchi (1956), Hammond (1982), DaSilva et al. (1986), and Wiedemeyer (1994) have investigated rates of movement of holothurians, although not of *A. mauritiana*. The rates of locomotion recorded in this study (0.04 to 0.21 m h^{-1}) were comparable to those found by Hammond (1982) for two other aspidochirotes, *H. mexicana* (Ludwig) (0.08 to 0.40 m h^{-1}) and *Isostichopus badionotus* (Selenka) (0.04 to 0.4 m h^{-1}), but far less than those found by Wiedemeyer (1994) for adult *A. echinites* (9 m h^{-1}). Yamanouchi (1956) found that *H. atra* and *H. scabra* moved between 0 and 52 m d^{-1} although, as noted by Wiedemeyer (1994), this study involved moving individuals to artificial habitat and is therefore not comparable. Mercier et al. (in press) found that movements of released, cultured juveniles of *H. scabra* ranged between 0.017 m h^{-1} and 0.033 m h^{-1} depending on the substrate type.

The difference between the cumulative displacement over 24 h (3.02 m d^{-1}) and net displacement (1.11 m d^{-1}), together with the plots of individual movements (Fig. 4), show that movements of *A. mauritiana* over 24 h were not

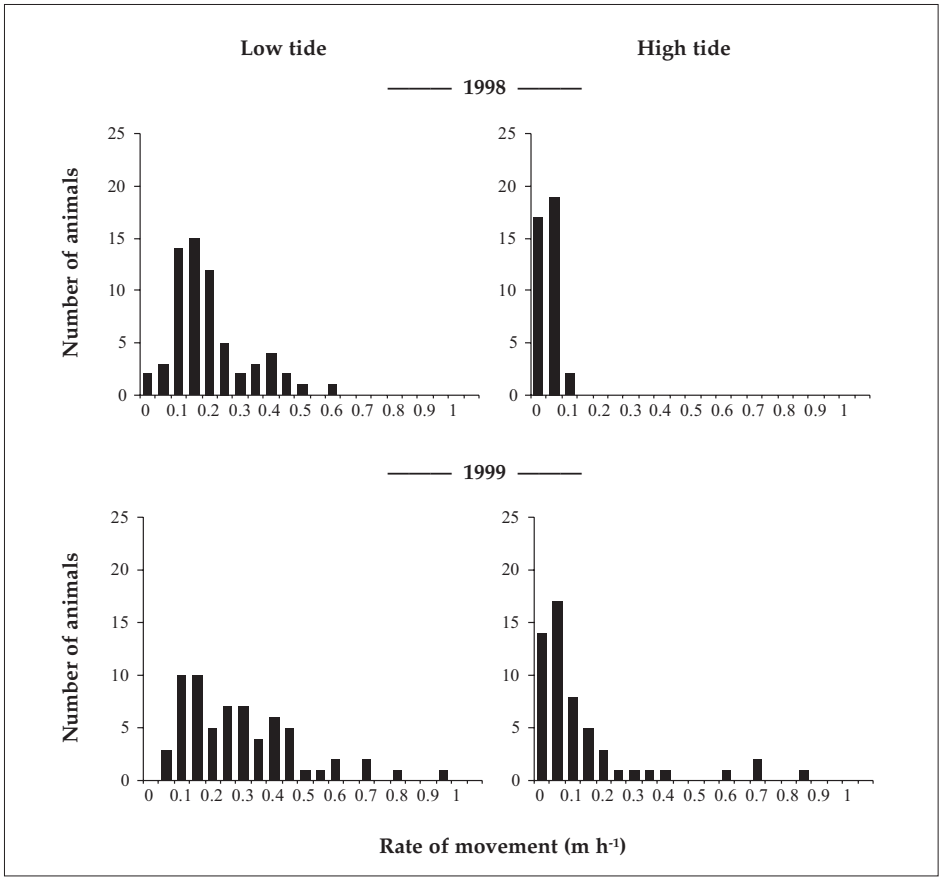

Figure 6. **Frequency histograms for rates of movement by *Actinopyga mauritiana* during low and high tide for two days in 1998 and 1999.**

Table 1. **ANOVA results for the effect of water level (high and low) on movement and exposure of *A. mauritiana* on two consecutive days in the field at Sites 1, 2 and 3 in 1998 and 1999 (n = 8). Year and tides were fixed factors and days were random and nested in tides. Movement data were transformed to ArcSin(%) to stabilise variances (C = Cochrans test). SNK test for differences in movement and sheltering between high and low tides. Numbers in brackets are standard errors. ns=p>0.05; *= p<0.05: **=p<0.01.**

	Movement (m)				Sheltering (%)			
	C = 0.3096, n.s.				C = 0.50, n.s.			
Source of variation	MS	df	*F*	*p*	MS	Df	*F*	*p*
Years	27.00	1	90.39	*	1.00	1	8	ns
Tides	47.39	1	89.85	*	16.00	1	128	**
Days (Tides)	0.53	2	0.91	ns	0.13	2	0.25	ns
Year* Tides	0.25	1	0.84	ns	0.25	1	2	ns
Year* Day (Tides)	0.29	2	0.51	ns	0.13	2	0.25	ns
Residual	0.58	56			0.50	8		
SNK	*1998 0.07 (0.02)<1999 0.27 (0.04)							
	*High 0.09 (0.03)<Low 0.25 (0.03)				*Low 3.87 (0.13) > High 1.88 (0.30)			

in a consistent direction. Reflected in the lack of directional movement is the finding that individuals did not return to the same shelter sites (Fig. 4). Rather, our data indicate that animals sheltered in the closest available cover after feeding, even though this often resulted in partial exposure. This finding is in contrast to that of Hammond (1982), who found that 68% of *H. tomasi* Pawson and Caycedo, and 72% of *A. agassizi* (Selenka), returned to the same hole to shelter, and who suggested that this was due to the limited number of crevices available for shelter. The abundance of suitable shelter on the reef at Aruligo, and the ability to attach firmly to the substrate for long periods without displacement, appears to explain why the animals in our study did not return to the same shelter sites.

In a study in New Caledonia, Conand (1991) found that *A. mauritiana* displayed some "preferential" (directional) movement towards the reef crest or surf zone to compensate for passive displacement towards the shore by the rising tide. We found a similar net direction of movement of individuals seaward towards the reef crest (Fig. 5), although we found no evidence for passive movement by tides. In contrast, we found that the scope for passive displacement of the animals was minimised by their small movements at high tide. Further investigation into the small-scale patterns of directional movements of *A. mauritiana* is required to determine whether long-term patterns of movements are due to short-term random feeding, or a series of directed movements in response to patchy distributions of food or shelter. However, the fact that the same individuals of *A. mauritiana* remained within a small area of reef for > 12 months, suggests that they did not need to migrate to find these resources.

Due to the mixed nature of the tides in Solomon Islands, we were unable to separate the relative influences of the diel and tidal cycles on the movement and sheltering behaviour of *A. mauritiana*: high tide occurred at night, and low tide in the day, during our study. Thus, the distinct pattern of activity peaking at dusk, and sheltering beginning at dawn, can be described equally well as activity at low tide and sheltering at high tide. Other studies of aspidochirote activity have proposed that nocturnal activity is the dominant behaviour and that periods of increased activity are associated with feeding (e.g. Hammond 1982). This is in line with anecdotal evidence from local harvesting patterns of *A. mauritiana* in Solomon Islands, which suggests that the highest catch per unit of effort occurs during dusk and early evening. Wiedemeyer (1992), however, found that *H. scabra* and *H. atra* deviated from the accepted pattern of nocturnal activity in that their feeding behaviour was not restricted to the period of darkness, and differed among seasons and habitats.

Separating the effects of photoperiod and tidal height on the behaviour of *A. mauritiana* will depend on repeating the research described here when the tidal pattern reverses so that high tide occurs during the day and low tide at night. We were unable to do this because of ethnic tension on the island of Guadalcanal in 1999, which prevented further research at Aruligo. We trust that others will have the opportunity to do this work at another location.

Acknowledgements

We thank M. Byrne, R. Harcourt, J. Bell, and R. Graham for their comments on the draft manuscript, and for their advice and support. We also thank the staff at

ICLARM, Aruligo for their assistance in the field and with equipment. G. Chapman kindly assisted with experimental design and provided the computer program for calculating distances. ICLARM Contribution No. 1574.

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Resource evaluation of current populations of two commercially harvested sea cucumber species (*Actinopyga mauritiana* and *Stichopus chloronotus*), and recommendations for management for Kosrae State, Federated States of Micronesia

Stephen Lindsay[1] and Simpson Abraham[2]

Background

The Kosrae state government, municipalities and individuals have expressed concerns over the past several years regarding the sustainability of commercial sea cucumber harvesting. The Development Review Commission and the State Marine Resources Division were therefore asked to undertake appropriate scientific studies to determine if the current commercial harvesting of sea cucumbers in Kosrae is sustainable and to recommend any activities that should be undertaken to allow this fishery to remain sustainable in the future.

In November 2000, these departments recommended that a moratorium be decreed on all commercial harvesting of sea cucumbers until such time that recommendations, based on scientific information, can be compiled and provide information on the sustainability of these operations. The government of Kosrae accepted and cancelled all permits, which effectively stopped legal commercial harvesting.

These agencies, through grant assistance money from Marine Resources Pacific Consortium (MAREPAC), contracted a marine biologist to provide baseline biological information. The consultant was hired to:

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2. Kosrae Island Resource Management Program. Email: kirmp@mail.fm

- undertake a marine evaluation stock assessment of the current populations of commercially harvested sea cucumbers in Kosrae;
- provide information pertaining to these species' habitats and population locations on the reefs;
- undertake a training and information exchange programme for the government of Kosrae on all relevant marine evaluation techniques and potential management options;
- provide information and advice to assist the government of Kosrae in developing a sustainable management plan that can be maintained over an extended period of time, including a monitoring programme if required;
- generate any other biophysical data that are important to the formulation of a management plan; and
- provide a written report on all findings at the completion of the contract.

The target audience for this report is the Kosrae state government agencies, interested individuals and the general community.

Executive summary

Visual resource survey methods were used to evaluate current standing stock populations of two commercially harvested sea cucumbers, the surf redfish *Actinopyga mauritiana* and greenfish, *Stichopus chloronotus* in Kosrae, Federated States of Micronesia. Fifty-six tows, covering 10.1 ha were conducted during the evaluation. Fifty-two tows were made on the reef flats of Kosrae and four tows were made on the reef edge and slope. Data collected for each tow included: water depth, tow width, tow length, total number of sea cucumbers and percentage of coral cover.

Inclement weather conditions precluded the survey team from evaluating the reef crest and reef edge on the eastern side of the island, the preferred habitat of the surf redfish. Therefore, only limited data were collected for this species. Data collected were insufficient for scientifically estimating stock abundance of this species. An additional survey will be required to provide data on this species stock abundance. This information is a prerequisite for the development of a management plan to determine acceptable levels of commercial exploitation for this species.

Sixteen species (Table 1) of sea cucumbers were located during the evaluation, and data were recorded only on those species of potential commercial value. Stock populations of all potential commercial sea cucumber species inhabiting the reef flats of Kosrae were low to very low, including the two harvested species.

A total of 571 individual greenfish, *Stichopus chloronotus*, were found in 11 transects (20 per cent of transects) that covered a combined reef flat area of 4026 m^2. All transects, but one (transect 52) (where greenfish was found), were located on the reef flats between the seaward side of the airport in Tafunsak to the western end of Walung. Transect 52 was located on the reef flat to the north of the island of Lelu.

The density per square metre of these individuals varied between site locations, however all sites recorded very low stock densities when compared to the previous study undertaken in 1997 (Edward 1997). The mean greenfish density per square metre for all sites, where this species was recorded, was 0.015 as compared with 1.21 in the 1997 survey (Edward 1997). These low numbers are a direct result of commercial harvesting. The current level of exploitation of this species is not sustainable and a management plan, based on scientific data, must be developed and implemented.

Recommendations

A total ban on the commercial exploitation of all species of marine sea cucumbers should be imposed in Kosrae until the recommendations listed below have been addressed. The commercial exploitation of sea cucumbers in Kosrae must be done on a sustainable basis. Data collected indicate large declines in stock populations of greenfish. This decline is directly attributed to commercial harvesting. Information on the surf redfish is incomplete due to unfavourable weather conditions preventing the col-

Table 1. List of commercially valuable sea cumbers recorded during the investigation.

Actinopyga mauritiana
A. echinites
A. miliaris
Bohadschia argus
B. marmorata
Euapta godeffroyi
Holothuria atra
H. coluber
H. difficilis
H. hilla
H. leucospilota
H. nobilis (both colour varieties)
H. scabra
Stichopus chloronotus
S. horrens
Synaptula recta

lection of data. Stock population survey data are required for this species. The recommendations below will provide baseline scientific data to enable a sound environmental management plan to be developed and implemented for these sea cucumber species.

The recommendations presented below have wider implications for other marine species located in Kosrae and should be used in this context. This is not a definitive list and additional priority areas should be developed.

- Undertake a resource evaluation of the current stocks of surf redfish on the reef edge and reef crest on the eastern side of the island when weather conditions are more favourable. Line transects and timed swims should be used.

- Collect basic life history data on both species of commercially targeted sea cucumbers (the surf redfish and greenfish). These (biological and morphological) must be collected on a monthly basis over an annual period for each sea cucumber species. Information obtained on each individual species is imperative to the development of a suitable marine management plan. These must include date of sample, location of sample, sex, body length, wet and dry weight, reproductive condition, and gonad index.

- Undertake an intensive public awareness programme to provide information on sea cucumber management and why it is required. This could include, but is not limited to, public media announcements, community-based workshops and relevant public discussions groups. This programme could be expanded to include additional reef species.

- Develop a marine resource management plan for the commercial harvesting of sea cucumbers for Kosrae state. This will need to be done once the scientific information has been gathered.

- Include within the management plan marine reserves, minimal harvest size limits and bans on collection during spawning seasons for both species of sea cucumber.

- Further develop appropriate government regulations to allow control, through permits of all commercial sea cucumber harvesting operations. This should include permit requirements that include basic data reporting duties. Fines should be incorporated with all violations.

- Conduct yearly marine resource stock surveys (as undertaken in this evaluation) to provide information on the population structure and abundance of sea cucumbers over time.

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Marine resource survey and assessment of Jaluit Atoll, Republic of the Marshall Islands

John Bungitak[1] and Stephen Lindsay[2]

Background

The Jaluit Atoll Marine Conservation Area (JAMCA) was established in 1999. JAMCA was developed by the combined efforts of the Jaluit Atoll Development Association, the Jaluit Atoll Local Government Council, the Jaluit Community, and the National Environment Protection Authority. Assistance has been received from the South Pacific Regional Environment Programme through their South Pacific Biodiversity Conservation Programme and a Conservation Area Supporting Officer has been recently appointed to manage and develop the programme.

The goals of JAMCA are to develop and implement:

- a sustainable marine resource management plan,
- a sustainable terrestrial management plan,
- community-based management structures,
- alternative income-generating activities,
- public awareness, training and education programmes, and

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2. Micronesian Aquaculture and Marine Consultant Services. Email: slindsay@mail.fm

- strengthen the capacity of the community to effectively manage a conservation area.

The starting point for the JAMCA programme was the development of an adaptive marine resource management programme that has access to reliable baseline biological information on the condition of the marine ecosystem and species-specific population data. This information will provide the basis for the formulation of a robust monitoring programme and a resource management plan.

The information summarised below provides the data collected on the commercially targeted holothurians within Jaluit Atoll during the marine resource assessment.

Summary on holothurians populations

Eleven species of sea cucumber were found on the reefs of Jaluit Atoll (*Holothuria atra*, *H. nobilis*, *H. horrens*, *H. edulis*, *H. fuscopunctata*, *Actinopyga mauritiana*, *Bohadschia argus*, *B. marmorata*, *Stichopus hermanni*, *Thelenota ananas*, *T. anax*). Population abundances are high for all species except for the commercial species currently harvested. Stocks of these commercial sea cucumbers (*H. nobilis*, *H. fuscopunctata*, *B. marmorata*, *S. hermanni*, *T. ananas*) are low to very low within the lagoon, resulting from current commercial harvesting. Stock populations of these animals below a water depth of 20 meters are unknown.

Management protocols need to be developed and implemented to preserve the existing stocks of commercial sea cucumbers to allow recruitment and sustainable commercial harvesting. Suggested protocols to consider are bans on the collection of certain species, bans on collection locations, size limits, season limits and closures.

Sea cucumber survey results and discussion

All commercially important species (*H. nobilis*, *H. fuscopunctata*, *B. marmorata*, *S. hermanni*, *T. ananas*) were found in low densities in all tows. The low occurrence of these commercially important species is a direct result of the current commercial harvesting that specifically targets the collection of these species on Jaluit Atoll.

Only eight specimens of *H. nobilis* (black teatfish), the most commercially valuable species on Jaluit Atoll, were found in one tow during the survey, although large areas within the lagoon are suitable habitat for this sea cucumber. Similarly, only 15 specimens of *T. ananas* (prickly redfish), the second most valuable species was found in 7 tows during the survey.

The two largest non-commercially targeted species of *Thelenota anax* (amberfish) and *Bohadschia argus* (leopardfish) dominated the survey counts. 503 individuals of *T. anax* were located in 19 per cent (44 tows) of all tows undertaken. Other commercially valuable species included 126 individual *B. argus* in 16 per cent (37 tows). *H. atra* (lollyfish) dominated the population numbers of the small non-commercial species; 2050 individuals were located in 17 per cent of all tows. The population of these cucumbers was high in certain areas of the reef.

The results obtained during the survey reflect only those stocks of sea cucumbers that live in less than 18 meters of water. The survey did not evaluate stocks of sea cucumbers deeper than this due to the limitation of free diving. Scuba and hookah systems have not been used on Jaluit Atoll to harvest sea cucumbers and therefore the maximum depth of collection is reflected in the survey results. The majority of large commercial sea cucumbers can live in both shallow and deep water (up to 60 m) and, therefore, stocks may be present at these depths. The size of these stocks is unknown as is the role they play in recruitment.

Stock populations of all commercially important species of beche-de-mer were low to very low within Jaluit lagoon. These low stock numbers are a direct result of commercial harvesting. Therefore, the current level of exploitation is not sustainable and a management plan must be developed and implemented. There are currently no regulations on the harvesting of sea cucumbers within Jaluit Atoll or the Marshall Islands.

The stocks of commercially valuable beche-de-mer on Jaluit Atoll have already been overharvested and stock numbers are low. Therefore, there is an urgent need for some form of community management to preserve remaining stocks within the lagoon in order to allow recruitment and future sustainable commercial harvesting to continue.

It is therefore recommended that the following management practices be considered:

- Sea cucumbers should only be collected by hand while free diving. A total ban on the use of any underwater breathing apparatus (scuba or hookah) should be introduced and enforced. In addition, the use of beche-de-mer "bombs" and other home-made equipment, which allow the collection of deeper water stocks, should also be prevented. A beche-de-mer bomb is made out of concrete or lead with a steel barb protruding from the bottom and the top, and is connected to a rope. The diver positions the bomb above the intended sea cucumber and drops the bomb onto the animal. The steel barb pierces the skin of the

sea cucumber and the animal can be hauled to the surface. In clear water this method has been successfully used in depths up to 30–35 meters. This collection method has not been used in Jaluit. A ban on the use of bombs will prevent deeper water sea cucumber stocks from being harvested.

- The suggested marine reserve areas have been designed to prevent harvesting of organisms within the area, therefore preventing the harvesting of sea cucumbers. These reserve areas will allow reproductive stocks of the commercial species to survive and reproduce in shallow water.

Sea cucumbers are only harvested on Jaluit Atoll for commercial activities; they are not used for subsistence.

Monitoring programme

A monitoring and licensing system should be developed with the community council to collect reliable data on all commercial sea cucumber activities. Information should be collected on species, location, number, water depth, date and whether processed or not. In addition, each company (local and off island) and diver should be registered with the island council and made to provide the above information. The council may wish to place a small license fee on these commercial activities. This industry is suitable for Jaluit Atoll and should be developed along with a management plan. The Conservation Area Supporting Officer should also discuss the general biology and reasons behind the sea cucumber management plan, and assist collectors in producing a top quality product that increases profits.

In addition, biannual marine assessment surveys should be undertaken to provide baseline population numbers of sea cucumbers in the reserves and on the harvested sections of the Jaluit reef.

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Sea cucumber fisheries in the Mayotte reef system, Indian Ocean

Adeline Pouget[1]

Introduction

On Mayotte, a small French island in the Comoros Islands, sea cucumbers (*papacajo* in Mahorais) have not yet been studied. The development of this fishery and the steep rise in the number of tickets issued for illegal underwater harvesting of sea cucumbers, justified setting up a study to examine the fishery and the status of the resource. This article provides an overview of the fishery gained through information from fishers and animal health services.

Beginning of fishery operations

In contrast to the Malagasy islands, sea cucumber fishing in Mayotte has only recently begun in a very limited way. It may be linked to a transfer of activity due to stock depletion in Madagascar.

It is difficult to state exactly when sea cucumber fishing began. In fact, no fisheries information exists for Mayotte. This is due, in part, to the fact that those people involved perform a wide range of other work activities, and there is a high percentage of fishers who are fishing illegally.

As with most sea cucumber producing countries, production is not meant for local consumption but rather for export to Asian countries (Conand 1990). The first seafood product health and quality export certificate was issued by the Mayotte Animal Health Office (DSV) on 11 April 2002. Therefore, it is estimated that sea cucumber fishing for export first began in early 2002.

Management measures and fishing techniques

At present, sea cucumber fishing is not subject to any specific measures designed to ensure sustainable resource management. However, this activity is subject to Prefectural Order no. 3/95/CAB/AM, which provides regulations for underwater fishing in the French coastal and territorial waters adjacent to the Department of Mayotte. Articles 1 and 2 of this order respectively stipulate that:

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- Underwater fishing refers to actively capturing animals while swimming or diving, and collecting marine plants by any method whatsoever (by hand, harpoon, net or using special underwater fishing gear).

- Fishing in coastal waters (lagoon) or inside the base lines set out by the Decree of 12 September 1977 is prohibited."

Sea cucumbers must therefore be collected along the fringing or barrier reef at low tide.

Exploitation zones

Due to constraints linked to regulations, it is difficult to determine where the exact fishing zones are located. In fact, a difference must be made between the legally exploitable zone and the zone that is actually exploited. Fishers go to sea every day, weather permitting, for about nine hours (personal interviews with fishers), beyond low tide periods. From information from tickets issued by the DAF/SPEM, exploited zones appear to comprise very circumscribed sectors of the lagoon, (Fig. 1):

- the inner reef off the bay of Kani Keli;

- the reef flat on the outer barrier reef opposite Kani Keli;

- the white sand islet;

- the reef flat on the outer barrier reef north of Petite Terre;

- the area around Sada islet;

- M'tsahara and N'Gouja fringing reefs (personal interviews with fishers);

- areas outside the barrier reef (from north of Petite Terre all the way to the pass opposite Koungou).

Estimated catches

Because little information on sea cucumber exports exist in Mayotte, most of our data come from seafood product health and quality export certificates issued by the Mayotte Office of Animal Health (DSV).

Exports are not made directly to Asia but rather pass by "middleman countries" such as Mauritius, Madagascar or Tanzania. Since April 1992, 1582 kg of processed sea cucumbers have been exported. This quantity seems to be decreasing because in November 2002, exports totalled 1410 kg but in July 1993 they were only 122 kg (Table 1).

This decrease may be due to the following factors:

- dissuasive surveillance by the Lagoon Brigade (DAF/SPEM);

- the vagrancies of fishing (e.g. buyers, weather);

- trepang exports conducted in a clandestine manner (i.e. without going though DSV checks, on vessels that transport the sea cucumbers, processed or unprocessed, directly to middleman countries).

During this same time period, the number of tickets issued by the Lagoon Brigade (DAF/SPEM) increased. No steps were taken in 2002, whereas since January 2003, 425 kg of sea cucumbers have been seized.

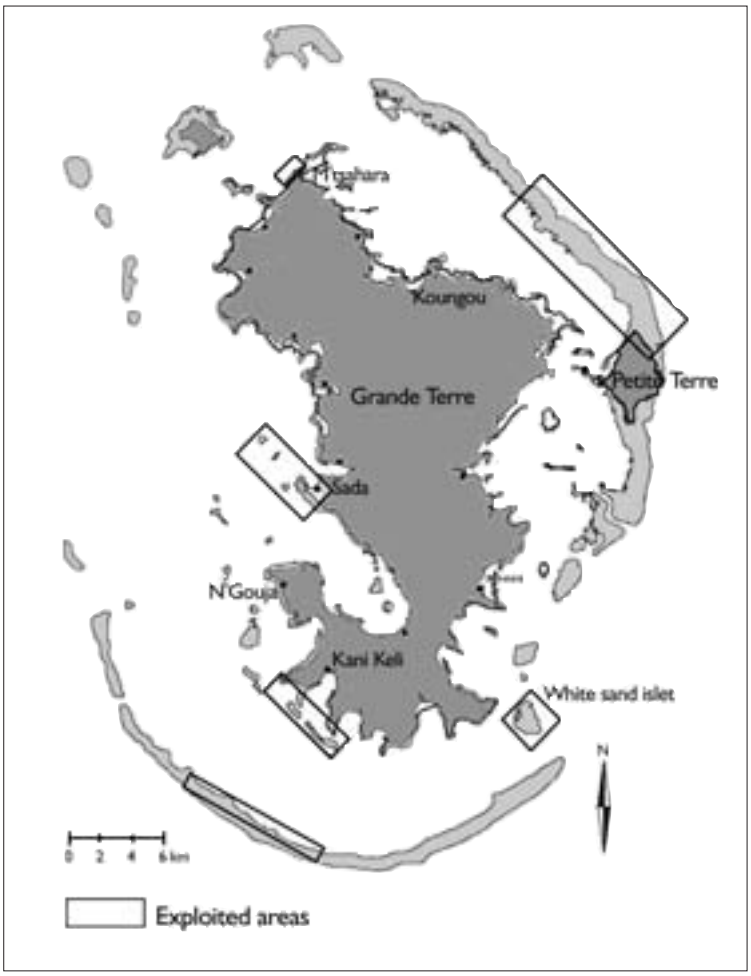

Figure 1. **Mayotte and the areas where sea cucumbers are collected**

Species captured and product processing

A meeting with fishers to photo-identify using identification records and personal examination of the products after processing, made it possible to determine that about seven species are harvested in Mayotte.

Most of these species, however, are harvested on an experimental basis. In fact, this fishery, which is new to Mayotte, requires fishers to acquire very precise techniques for processing the products (process described by Conand 1990, 1999) in order to meet certain criteria imposed by the Asian market.

Two processing techniques are used (personal interviews with fishers) as shown in Table 2. These techniques differ somewhat from those used in Madagascar but fishers are currently in a testing phase that is designed to observe how various species respond to processing (in particular, their size after cooking and drying).

The species harvested are shown in Table 3. The species caught most often is *Holothuria nobilis*.

Table 1: Trepang exports from Mayotte (information taken from seafood product health and quality export certificates issued by the Mayotte DSV)

Certificate's date of issue	Destination	Species	Weight (kg)
11/04/02	Tanzania	*Holothuria* sp.	1000
21/10/02	Hong Kong via Mauritius	*Holothuria nobilis*	275
19/11/02	Hong Kong via Mauritius	*Holothuria nobilis*	1410
29/11/02	Hong Kong via Mauritius	*Holothuria nobilis*	480
13/12/02	Hong Kong via Mauritius	*Holothuria nobilis*	900
23/12/02	Hong Kong via Mauritius	*Holothuria* sp.	1295
21/02/03	Madagascar	*Holothuria* sp.	300
11/07/03	Tanzania	*Holothuria* sp.	122

Table 2 Processing techniques

Processing phases	Length of time
Technique #1	
Gutting on boat	
Covered with salt water in shop	24 hours
Cooked in boiling water	35–40 min
Dried at constant temperature	A few days
Technique #2	
Gutting on boat	
Cooked in boiling water	12 min
Covered with salt water in shop	24 hours
Dried at constant temperature	A few days

Conclusions and prospects

Sea cucumber fishing in Mayotte is just beginning. Based on the Madagascar model, some fishers began this activity in early 2002. But two major problems limit sustainable exploitation of these species: 1) no resource management regulations exist, and 2) information on these creatures and the techniques for processing them is still very limited. Additional studies, particularly on exploitable sea cucumber stocks, are needed in order to enact appropriate legislation for managing them. An awareness and information campaign for fishers could also avoid poor exploitation of available stocks.

Acknowledgments

I would first like to thank O. Abellard, Director of the Mayotte Fisheries and Marine Environment Department (SPEM) for making it possible for me to take part in this three-month training session at that office. I would also like to acknowledge J. Wickel, who agreed to be my training session supervisor, and the SPEM team, particularly D. Fray, for logistical assistance and sharing knowledge about the island.

Table 3: Sea cucumber species harvested in Mayotte, according to a market classification (Conand 1999)

	Species	English name
FIRST CATEGORY: Species of high market value	*Holothuria nobilis*	black teatfish
	Holothuria scabra	sandfish
SECOND CATEGORY: Species of average market value	*Actinopyga echinites*	deepwater redfish
	Thelenota ananas	prickly redfish
THIRD CATEGORY: Species of low market value	*Holothuria fuscopunctata*	elephant trunkfish
	Bohadschia vitiensis	brown sandfish
	Stichopus chloronotus	greenfish

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Conand, C. 1990. The fishery resources of Pacific Island countries. Part 2. Holothurians. FAO Fisheries Technical Papers FAO, Rome, Italy. 143 p.

Conand, C. 1999. Manuel de qualité des holothuries commerciales du sud-ouest de l'Océan Indien. Programme Régional Environnement de la Commission de l'Océan Indien – Union Européenne publ.: 40 p.

Black teatfish (*Holothuria nobilis*) dipped in seawater

The room used for the drying process

Different species at different stages of processing (L to R: *H. nobilis, B. vitiensis* and A. *echinites*)

"Trepang", the processed product

Length–weight relationship for sandfish, *Holothuria scabra*

Rayner Pitt[1,2] and Nguyen Dinh Quang Duy[2]

Lengths and weights were measured for sandfish (*Holothuria scabra*) at the Research Institute for Aquaculture no 3, Nha Trang, Vietnam. The sandfish were taken from five separate groups and ranged size from 1.16 g (2.7 cm) to 574 g (24 cm). In total, 133 animals were measured.

After being removed from the water, the sandfish were left to dry in the shade for a period that depended broadly on the group size (see Table 1). The sandfish were weighed, generally to three significant figures, with a digital balance, then gently straightened and their lengths measured to 1 mm with a ruler. Linear and log plots, trendlines and equations were determined using MS Excel software.

It is hoped that these data will be useful in helping bridge the gap between reports that discuss sandfish in terms of length, and those using mainly weight measurements. Both length and weight measurements, of course, are highly variable for sea cucumbers.

Individuals can stretch or contract and can vary in the amount of substrate and water held inside their bodies. It is not obvious which parameter changes less for a particular individual over a short period of time, and, therefore, which measurement gives the most accurate average size. It would, however, be fairly easy to follow changes in a group of individuals over a few days, measuring both length and weight at fixed or random intervals.

It should be noted that the relationship is a power curve; weight = constant x lengthn (where n = 2.8). Therefore, in calculus notation, dw/w = n dl/l. In

Table 1: Details of sandfish groups used for measurements

Group	Origin	no.	Taken from	Range (cm)	Range (g)	Drying time (min)
1	hatchery	15	pond 24 hours in bare tank	12.1–21.3	145–400	5
2	hatchery	20	nursery tank on sand	2.0–7.9	1.16–10.93	0.5
3	wild	34	pens (>1 year) 20 hours in bare tank	14.5–26.0	157–574	10-20
4	hatchery	8	nursery tank on sand	5.6–8.8	17.4–46.2	3
5	hatchery	32	pond 5 hours in bare tank	10.5–21.0	101–379	5

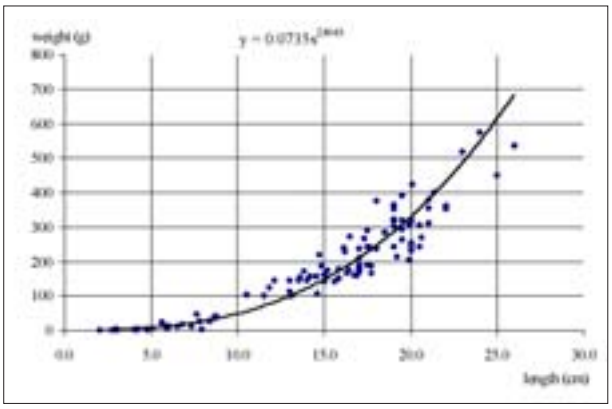


Figure 1. Length (cm) against weight (g)

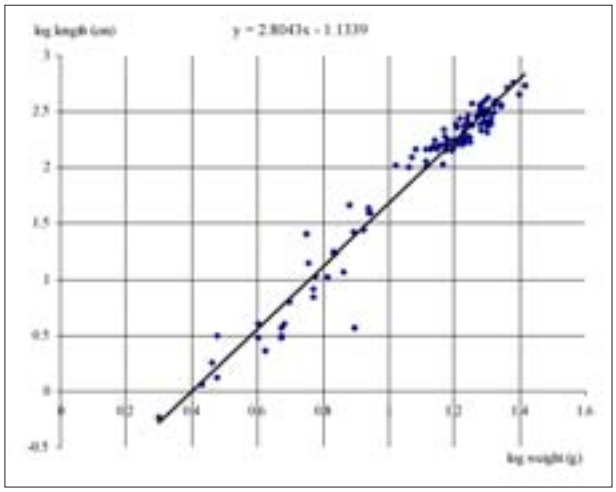


Figure 2. Log length (cm) against log weight (g)

1 WorldFish Center, Email: raynerpitt@yahoo.co.uk
2 Research Institute for Aquaculture number 3, 33 Dang Tat, Nha Trang, Vietnam

other words, any percentage error in determining length will lead to a percentage error in estimating weight that is almost three times as high. Additionally (except when working underwater), weight measurements are generally quicker, less subjective and more accurately made than lengths, as long as suitable balances are available.

Holothuria scabra from Southeast Asia appears generally to be smaller than the same species from the South Pacific. One can speculate whether this is due to current heavy fishing, many generations of fishing having exerted a selective pressure for quick maturation and breeding at a small size, or some more fundamental difference. It would also be interesting to know whether sandfish from other areas, and those recently collected from the wild, fit into the same length–weight relation.

Natural spawning observation of *Holothuria tubulosa*

Adrian Valls[1]

Species: *Holothuria tubulosa*, Gmelin 1788

Location: Cala Montgo, near L'Escala on the north east coast of Spain, known as Costa Brava, Mediterranean Sea.

Date and time: Unfortunately, the date was not precisely recorded. Photo was taken between 27 June and 3 July 2003 at 15:00.

Depth: 1.5–2 m, close to shore.

Moon phase: New moon was on 29 June 2003, so the spawning event might have taken place from two days before to four days after new moon.

Note: Several other sea cucumbers were spawning in the area at the same time.

Holothuria tubulosa
Photo: Adrian Valls

Email: avalls@grn.es. More underwater photos taken by Adrian Valls are available at: www.art-centre.com/sea

Questionnaire on the field observations of juvenile sea cucumbers

Glenn Shiell[1]

Note from the editor:

Following the questionnaires on 1) spawning observations and 2) fission still occurring, this new questionnaire on juvenile occurrence seems very appropriate for expanding the knowledge on the life cycle of most holothurian species.

Introduction

My research investigates various aspects of the ecology and biology of black teatfish, *Holothuria nobilis*, on Ningaloo Reef, Western Australia. Although my initial research objectives flagged juvenile ecology as a possible avenue of study, I have experienced great difficulty locating juvenile holothurians generally, and *H. nobilis* specifically. In fact, I have yet to locate a single juvenile *H. nobilis* specimen in any of the habitats I have studied on Ningaloo Reef, and in addition, have found little information regarding the ecology of juvenile holothurians in the literature.

This has caused me some concern, as recent advances in tropical sea cucumber mariculture have created scope for the rehabilitation of habitats affected by overfishing, via a process of "re-seeding" using hatchery-raised juveniles. At this stage, however, I believe this process could be impeded by the considerable lack of information regarding the habitat and ecological requirements of juvenile sea cucumber as the requirements of juvenile and adult holothurians may be quite different.

Clearly, more in situ research is required in this area, and for this reason, both Professor Conand and I are interested in compiling a list of observations of all juvenile sea cucumbers in their natural habitats. This will begin the process of consolidating the existing information relevant to habitat preferences of juvenile sea cucumbers to assist researchers in the preparation of field-based experiments. This observations list will be published with due acknowledgements in the next edition of the Beche-de-Mer Information Bulletin.

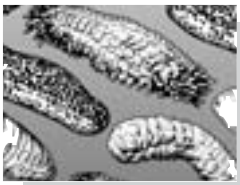
I hope that you can be of some assistance by providing details of any observations you make of juveniles in the field. I have provided a table below to help you record relevant details. Please send your observations to the address below with a copy to Professor Chantal Conand (or see complete mailing address on the cover page of this bulletin). If you can be of assistance in this matter, I would be most appreciative.

Juvenile holothurian questionnaire (one sheet per observation please)

Please send to Glenn Shiell (cucumber@cyllene.uwa.edu.au) with a copy to Professor Chantal (Conand.Conand@ univ-reunion.fr)

A Species observed:	
B Number of individuals observed:	
C Approximate size *(length and width):*	
D Location: *e.g. Ashmore Reef, Western Australia*	
E Habitat: *e.g. sea grass, coral rubble, mud, sand, limestone sand, limestone platform, etc.*	
F Time of day:	
G Approximate date:	
H Were adults present within the same habitat or nearby?	
I Name and affiliation of observer:	

1. School of Animal Biology MO92, University of Western Australia, 35 Stirling Hwy, Nedlands 6009, Australia. Telephone (+61) 8 9380 7043. Email: cucumber@cyllene.uwa.edu.au



Correspondence
beche-de-mer

Letters to the editor

From: K.P. Manikandan
24 April 2003

I take the privilege of introducing myself as Manikandan from India. After my post graduation in Marine Biology and Oceanography, I worked under the able guidance of Dr D.B. James on the hatchery and culture aspects of the sea cucumber, *Holothuria scabra*. I pursued this work in the Maldives where we produced around one million juveniles over a period of four years.

To do my PhD, I came back to India and I am at the point of submitting my thesis on the biology and toxicological properties of *Acaudina molpadioides*.

I have expertise in the identification of sea cucumbers, shrimps, stomatopods, lobsters and mostly reef fish. I am also a certified Java programmer and well versed in modern statistical tools such as Fisat, Vonbit, SPSS and STATISTICA.

At present I am in search of a suitable position anywhere in the world.

Manikandan K.P., Research Scholar, CAS in Marine Biology, Annamalai University, Parangipettai, Tamil Nadu, India-608502

Email: kpmanikandaan@rediffmail.com
or manikandaan@hotmail.com

From: Robin D. Gill

Dear Professor Chantal Conand,

My book, Rise, ye sea slugs, with 1000 holothurian haiku in Japanese and 2000+ translations in English has been published by . . . me. I became a publisher to do it cheaply. It costs only USD 25 for 480 pages, including all Japanese original in the main text. It looks very good.

For more information on "Rise, ye sea slugs", please go to the new website: http://www.paraverse.org

From: Abdoulkader Ahmed Aouled, Assistant to the National PAS Coordinator, Madagascar
13 February 2003

The Republic of Djibouti, located where the Red Sea and the Gulf of Aden meet, is characterised by two alternating seasons (cool and hot) lasting about six months each, with low annual precipitation levels. As part of the Strategic Action Programme implementation for the Red Sea and the Gulf of Aden (PERSGA), which targets the conservation and protection of marine ecosystems, the Ministry of the Environment is introducing an experimental sea cucumber aquaculture project. For that reason, we would like to get some information on inputs into sea cucumber farming in coastal areas, as well as the relative costs for the equipment needed (farming in floating cages?). In addition, we have opted for farming in cages with free seawater flow, using a marketable indigenous species, *Pearsonoturia graeffei*, after taking in account the ecological criteria.

Response from Chantal Conand: *You'll find a great deal of information in the SPC Beche-de-Mer Information Bulletin, available at: http://www.spc.int/coastfish/News/BDMVF/Labdm.htm. I am surprised that you are targeting* Pearsonothuria graeffei, *which is of low market value as far as I know.*

abstracts, publications, workshops & meetings

beche-de-mer

Note from Editor: Abstracts have been provided by the authors, and have been reproduced as is.

Towards an understanding of the shallow-water holothuroid (Echinodermata: Holothuroidea) fauna of the western Indian Ocean

Yves Samyn
Assisting Academic Staff Free University Brussels (VUB), Unit for Ecology & Systematics (ECOL) Pleinlaan 2 - 1050 Brussel - Belgium

Source: Summary of PhD

The study of the Holothuroidea, commonly known as sea cucumbers, started some 23 centuries ago when Aristotle defined them as "a kind of motionless marine organisms". Only in the mid sixteenth century were holothuroids recognised as animals *per se*. Nowadays, Holothuroidea is firmly recognised as one of the five extant classes of echinoderms. Currently some 1600 species are described; these occur from the intertidal to the deep ocean trenches and from the polar to the tropical regions.

The ultimate aim of this dissertation is to understand the shallow-water holothuroid biodiversity of the western Indian Ocean, the area stretching from Suez to Cape Town and from the East African coast (Red Sea and Persian Gulf included) to 65 degrees East. To attain this goal, several expeditions to two contrasting regions of the western Indian Ocean (the tropical coast of Kenya together with Pemba Island in northern Tanzania and the subtropical coast of KwaZulu-Natal in the northeast of the Republic of South Africa) were undertaken. The purpose of these was to assemble a representative collection of species.

An extensive part of this dissertation is concerned with the construction of a reliable and up-to date faunistical list of the holothuroid fauna of these two case areas. The faunistics of the rest of the western Indian Ocean was filled in with the aid of important collections from the Seychelles and Inhaca (which were deposited as largely unidentified material in the collection of the Royal Africa Museum, Tervuren, Belgium), with detailed study of virtually all the available literature as well as with numerous loans of specimens from museums worldwide. In the course of the construction of this species inventory, my colleagues and I discovered several species and one genus new to science. We, however, did not blindly follow the standing biological classifications when describing our findings. *Au contraire*, while constructing the species lists we took great care to critically question the employed classifications. This attitude resulted in the taxonomic revision of the *Holothuria* subgenus *Mertensiothuria* and of the holothuriid genus *Labidodemas*. Interestingly, the type species of the latter genus revealed itself as a cryptic species. We were rewarded with the discovery of two additional new species.

Throughout this process, the historical opinions towards holothuroid taxonomy and systematics were never denied. This approach enabled us to revive methodically ignored characters such as the ossicles from the musculature. These characters proved not only diagnostic in the recognition of taxa, but also were informative in terms of recovery of phylogenies. By using our rejuvenated insights into such (and other) characters we were able to construct a large, morphology-based dataset, which allowed the recovery of the phylogeny of the Holothuriidae, the family best represented in this work. This cladistic analysis not only revealed that *Labidodemas* was indeed monophyletic (as suggested by our earlier systematic revision), but also allowed us to state that it has arisen from within the (now paraphyletic) genus *Holothuria*. As such, *Labidodemas* is evolutionary much younger than generally assumed. Our phylogenetic studies further suggest a close relationship between the genera *Actinopyga*, *Bohadschia*

and *Pearsonothuria*, but unfortunately the recovered support proved low. Future studies (see also annex on CD Rom) will have to decide whether a new classification of the Holothuriidae is desired.

Taking all these caveats into account, we finally succeeded to construct the wanted faunistical list of the Holothuroidea from the western Indian Ocean. This list was then further used to analyse the patterns of biodiversity by means of cluster analysis on several b-diversity coefficients and parsimony analyses of endemicity. These analyses showed that the investigated holothuroid fauna of the western Indian Ocean is non-homogeneous and best split into several biogeographic units. These can be explained with (i) species' dispersion ability, (ii) the prevalent current patterns and (iii) the recent geological history.

Phylogeny of the Holothuriidae (Echinodermata: Holothuroidea) inferred from morphology

W. Appeltans

Source: MSc thesis, Vrije Universiteit Brussel. 94 p. 2002

Despite the efforts of numerous notable taxonomists, the taxonomy and systematics of the grand family Holothuriidae (Holothuroidea: Aspidochirotida) remain vague for some groups. As such, a cladistically substantiated phylogeny based upon clearly defined morphological characters can bring insights into the evolution of the holothuriids. Thus, here I present a phylogeny of the group based on morphological characters. Cladistic analysis was performed by an heuristic search under the maximum-parsimony optimality criterion. 27 ingroup taxa, representing all currently recognised genera and subgenera and 6 outgroup taxa, belonging to the closely related Stichopodidae and deep-sea Synallactidae, were scored for a total of 68 characters concerning gross external and internal morphology and ossicle assemblage in the body wall, the tentacles and the tube feet. Moreover, often ignored body parts such as longitudinal muscles, cloacal muscles and anal papillae were examined for the presence of ossicles. Preliminary analysis revealed that for the synallactid genus *Mesothuria*, the species used as outgroup (e.g. *M. sufflava*) clustered in the ingroup. As it is here argued that this is the result of erroneous identification, *Mesothuria* was omitted as outgroup taxon. On the other hand, two genera of the Stichopodidae successfully lent themselves as outgroup. For the Holothuriidae, the monophyly of the genera *Actinopyga*, *Bohadschia* and *Labidodemas* was confirmed. *Labidodemas*, however, clustered in the paraphyletic lineage *Holothuria*. The enigmatic genus *Pearsonothuria* turned out to be the sister group of *Actinopyga*. From the resulting phylogeny, inferences on character evolution are made.

Contribution to the study of the relations between fish of the family of Carapidae and their holothurian hosts

Eric Parmentier
Email: E.Parmentier@ulg.ac.be

Source: PhD Thesis, Université de Liège, Laboratoire de Morphologie Fonctionnelle et Évolutive, 4000 Liège Belgium

A remarkable example of association between animals is this one of Carapidae fish (Ophidiiformes) and different invertebrates. These fish are known as pearlfish. The origin of this name would be the discovery of dead carapid fish, paralysed and completely covered in mother of pearl in the inner face of the valves of the shell of certain oysters (Ballard 1991). The fish belonging to the genus *Onuxodon*, *Carapus* and *Encheliophis* are capable of penetrating and residing inside different invertebrates such as sea cucumbers, sea stars, bivalve molluscs and ascideans.

In this thesis, a multidisciplinary approach was realised to understand the biology of the Carapini (*Carapus* and *Encheliophis*) fish living inside holothurians and to highlight the various factors which make these associations possible.

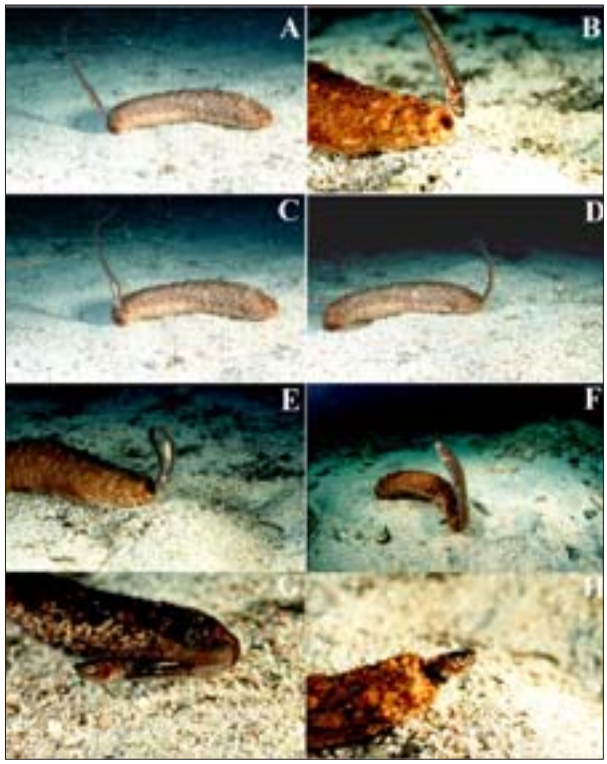
The morphofunctional study of the bucco-pharyngeal apparatus, the stable isotopes of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$), the stomach content determinations and the study of otolith increments allow to define clearly the commensal behaviour of *Carapus* and the parasitic behaviour of *Encheliophis*, the latter eating the gonads and the respiratory trees.

At the tenuis stage, the *Carapus* larvae leave the pelagic area and may enter an holothurian host for the first time. Once inside the sea cucumber, the fish undergo a drastic metamorphosis with a spectacular 50-60 per cent reduction of the body length. The study of the larval development (axial skeleton and otoliths) reveals that the association between the fish and the host is obligatory as the fish needs its host to initiate its metamorphosis. However, the

host is used as a black box and not as a source of food.

Three Carapini fish (*C. boraborensis*, *C. homei* and *E. gracilis*) have also show the ability to emit sounds and the structures (skeletal, muscular and of the swim bladder) responsible were identified and described. In the framework of the present study, sounds are not likely to be used by the fish to identify the presence of an eventual congener in the holothurian before penetration but are produced in the presence of the congener, inside the holothurian. Indeed, no sound has been recorded while the fish were approaching the potential host or while penetrating the unoccupied holothurian.

The sea cucumber cloaca is located close to the current of water exhaled, coming from the respiratory trees. Two strategies have then been observed. (1) The fish can penetrate into the host head first, propelling itself by violent strokes of the tail; (2) it places its head at the entry to the host anus and brings its thin caudal extremity forwards, alongside the fish body, at the level of the lateral line. This position allows the fish to use its body as a guide to rapidly bring the tail towards the cloaca and have it penetrate when the exhalant current is emitted by the host. Once the caudal extremity of the fish is inside the sea-cucumber, the Carapidae redresses itself and enters the host with backwards movements. The penetration head first is realised when the cloaca is wide-opened and the penetration tail first is used when the cloaca is closed. Because the host needs to breathe, it can not avoid the fish entrance.



A pearl fish* (Carapus acus*) penetrates a sea cucumber
Photo: Daniel Bay (Capri, Mediterranean Sea, 1997)

The sticking principle of the Cuverian tubules does not have an effect on pearlfish and the latter shows a better resistance to the sea cucumber toxins than other reef fish. The system of defence, however, is still unknown.

Gene flow and population history in high dispersal marine invertebrates: mitochondrial DNA analysis of *Holothuria nobilis* (Echinodermata: Holothuroidea) populations from the Indo-Pacific

S. Uthicke and J.A.H. Benzie

Source: *Molecular Ecology* 12(10):2635–2648

The sea cucumber, *Holothuria nobilis*, has a long-lived planktotrophic larvae, and previous allozyme surveys have suggested that high dispersal is realised. In contrast, recent ecological studies indicate that dispersal is low. To reconcile these data, and to investigate the evolution of this Indo-Pacific species, we screened geographical variation in 559 bp of a mitochondrial gene (*COI*) in 360 samples from the Australasian region and La Réunion. Sequences from La Réunion differed by > 7% from others and may constitute another species. Haplotype diversity in other samples was high (0.942, SD = 0.007), but haplotypes were closely related (mean nucleotide diversity: 0.0075, SD = 0.0041). Anova, pairwise FST values and exact tests did not detect significant population structure. Nested clade analysis showed that one of two main clades was over-represented in west Australia, whereas the other was more common in the northern Great Barrier Reef. Isolation-by-distance was identified as the main determinant of population structure at several clade levels. Contiguous range expansion was inferred for evolutionary older clade levels and this may correspond to a late Pleistocene (88,000–193,000 years ago) population expansion inferred from haplotype mismatch distributions. Thus, the population genetic structures detected are likely to be formed prior to the last ice age, with some indications for high dispersal on shorter time scales.

Evaluation of the resource following the sea cucumber fishery of Saipan, Northern Mariana Islands

M. S. Trianni

Source: Proceedings 9th International Coral Reef Symposium, Bali, Indonesia 23–27 October 2000, Vol.2; 829–835.

A sea cucumber fishery targeting the surf redfish, *Actinopyga mauritiana* and the black teatfish, *Holothuria whitmaei*, occurred on the island of Saipan in the Commonwealth of the Northern Mariana Islands (CNMI) during 1996 and 1997. A pre-harvest stock assessment was not conducted and the fishery was managed based on catch-effort statistics. The fishery was temporarily halted in early 1997 due to declining CPUE. A subsequent analysis of catch-effort statistics was conducted using three depletion models; the Leslie, DeLury, and an unbiased likelihood estimator derived from the Leslie, termed the Akamine model. These models indicated that the remaining population numbers in the fishery management units were considerably harvested, with 78 to 90 per cent of the initial population sizes taken. The fishery was subsequently shut down and a post-harvest survey conducted by the CNMI Division of Fish and Wildlife supported the depletion model analysis results. Results from the depletion models varied, with the Leslie and DeLury failing to produce valid results for all management units. The Akamine model was preferred for any future depletion estimation analyses, although a pre-harvest stock assessment along with the collection of harvest statistics was concluded essential for coherent management.

The genus *Stichopus* (Echinodermata: Holothuroidea) from the Johore Marine Park (Malaysia) with the description of two new species

C. Massin, Y. Zulfigar, A. Tan Shau Hwai and S.Z. Rizal Boss

Source: Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, Biologie, 72: 73–99, 2002

The study of the holothurian genus *Stichopus* from the Johore Marine Park (Malaysia) revealed at least six different species, two being new to science: *Stichopus ocellatus* n. sp. and *Stichopus rubermaculosus* n. sp. Each species is fully described and illustrated. For the known species a list of records and the geographic distribution are given. A seventh species, *Stichopus monotuberculatus*, not yet recorded from the Johore Marine Park, but likely to be found there, is included in an identification key based on ossicle characters, colour patterns and behaviour.

ABSTRACTS FROM THE 6th INTERNATIONAL ECHINODERM CONFERENCE

The following abstracts of oral communications and posters related to holothurians have kindly been provided by Pr Thomas Heinzeller: heinzeller@anat.med.uni-muenchen.de [Ed.: Abstracts have been reproduced as is]

Behavioural-ecological, morphological, and mtDNA evidence to resurrect *Bohadschia bivittata* (Mitsukuri) from the *B. marmorata* (Jaeger) species complex

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Behaviour, habitat selection, body size, colour, spicule complexity and mtDNA were used to examine taxonomic relationships among specimens from the *Bohadschia marmorata* species complex. Spicules were more highly branched, perforated, and spiked in bivittata specimens than those of the classic marmorata type. Moreover, spicule complexity did not correlate with body size. Phylogenetic analyses of partial nucleotide sequences of 16s and 12s ribosomal genes were done with the hypothesis that cladistic groupings would reflect morphological similarity instead of geographic proximity. This hypothesis was supported by the clustering of bivittata-looking specimens despite being from different Micronesian islands. The resulting tree (*Pearsonothuria graeffei* (*B. marmorata*) (*Bohadschia argus* (*B. bivittata*)) indicated that *marmorata* and *bivittata* are not even sister species, with *bivittata* more closely related to argus. These results were corroborated by colour and spicule examinations made of specimens from this complex in the NMNH (Washington, DC, USA) collection and by behavioural observations made in the field.

A study of the biology for fishery in two populations of *Cucumaria frondosa*: in the Gulf of Maine (USA) and in the Barents Sea (Russia)

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Cucumaria frondosa has been involved in the commercial fishery in some localities: the East coast of Canada, the Gulf of Maine (USA), the Barents Sea (Russia). Despite some series of the investigations in the biology and ecology of *C. frondosa*, we still know very little that to evaluate the extent to which the population can withstand sustained fishery pressure. Impacts of the fishery to the sea cucumber resources and effectiveness of the current regulation remain unknown.

To prevent overfishing, a rational management is essential for long-term harvesting of *C. frondosa* populations. The rational management of valuable resources means not just sustainable fishery approach but it must be coupled with complete utilisation, and both of them are based on thorough research. In fact, a sustainable fishery is based on three foundation: biology, ecology and fishery management. Hence, certain information on the biology and ecology of the sea cucumber is needed for developing sound stock assessment models.

Results of the recent research in the taxonomy, biology, ecology, fishery and utilisation of *C. frondosa* in the Barents Sea (Russia) and the State of Maine (USA) will be presented and discussed.

Evolutionary diversification of Holothuroid ecologies on coral reefs

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An organism's potential to adapt to a novel environment depends in part upon its history of evolving features needed in previous environs. Aspidochirote and apodan holothuroids are diverse and ubitquitous groups of echinoderms inhabiting a derived habitat, scleractinian coral reefs. These two groups provide replicate radiations into an identical ecosystem, allowing one to test the question: How has the evolutionary history of organisms prior to their expansion in the tropics constrained or facilitated their diversification onto coral reefs? Ancestral character reconstructions using ecological data and a new phylogeny based on morphology and several molecular markers suggest that aspidochirote coral-reef sea cucumbers evolved from deepwater epibenthic ancestors, while reef apodans arose from littoral infaunal forms. Much ecological novelty evolved in situ as species expanded into the numerous new microhabitats afforded by coral reefs. Associations between habitat choice and diel patterns of activity have evolved multiple times. Finally, despite high local species diversity in the tropics, expansion onto coral reefs does not appear to have been an adaptive radiation facilitated by the evolution of a "key innovation," as diversification was not accompanied by an increase in net speciation rates.

Phylogeny of Holothuroidea based on 18S and histone 3 DNA sequences

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We present a phylogeny of 30 species of Holothuroidea based on PCR-amplified complete 18S-like ribosomal and partial histone-3 gene sequences. Estimated maximum parsimony and maximum likelihood topologies using POY direct optimisation strategies are largely congruent with a previous phylogeny based on morphological characters. For example, as first hypothesised by Carl Semper in 1868, Apodida (as currently defined) is sister to all other holothuroids. Molpadida is sister to Dendrochirotida. The new estimates also differed in several important ways. Synallactidae, a morphologically diverse group, appears to be paraphyletic. Also, surprisingly, the deepwater order Elasipodida appears polyphyletic with the deimatids grouping within synallactids at the base of the aspidochirote clade. Points of contention are defined by short internal branches co-eval with a rapid radiation of holothuroids and other marine organisms in the early Mesozoic.

Development of an apodous holothuroid, *Oestergrenia variabilis* (Theel, 1886)

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Holothuroids consist of about 1250 species; 215 belong to the order Apodida. Larval development has been reported in less than 10 apodous holothurians. Both indirect and direct development occur, the former with an auricularia larva and the latter with a doliolaria. Among apodids with the doliolaria, brooding is known.

Spawning of an apodous holothuroid in the laboratory occurred on the morning after collection from about 25 m depth in Tsukumo Bay, Ishikawa on 11 December 1991. This holothuroid which has been identified by D. Pawson as *Oestergrenia variabilis* (Family Synaptidae) is hermaphroditic and natural self-fertilisation takes place. Ova are orange in color and 200 µm in average diameter. Four and a half hours after spawning the 8-cell stage is reached at 15°C. Cleavage is radial and equal and the resulting blastula is holoblastic. Gastrulation begins by invagination approximately 10 hr after spawning. Embryos develop into doliolaria larvae with 4 transverse ciliary bands 2 days after spawning. The larvae are ca. 400 µm in length and 250 µm in width. One day later, formation of the calcareous ring is apparent. Five primary tentacles are visible, confirming the onset of the pentactula stage. At this stage

ciliary bands begin to degenerate. At about 15 days, pentactulae stop swimming and sink to the bottom, signalling the completion of metamorphosis. Metamorphosed juveniles move on the substratum by using the tentacles. They are about 400 µm in length and 180 µm in diameter. Present study shows that development of this species is direct and non-brooding.

The pattern of Vietnamese holothurians symbionts interactions

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Shallow-water stichopodids and holothurids very often are inhabited by a lot of animals from different taxa. That implies the appearance of various kind of intra- and interspecific interactions among symbionts. To reveal the pattern of these interactions the diets, injuries, distributions on hosts and locations on the holothurians body were studied in crabs *Lissocarcinus orbicularis*, polychaetes *Gastrolepidia clavigera*, fishes *Carapus homei* and *C. mourlani* and shrimp *Periclimenes imperator*. The regular distribution of symbionts and the traumas suggests the territoriality in these species. The crabs feed on the free-living bottom organisms and were considered as commensals. The polychaetes feed on the host tissues and associated crustaceans, so their relationships with holothurians are parasitic ones. The main food items of fishes were free-living crustaceans and carapids juveniles indicating on commensal interactions with hosts. Symbionts occupy the different parts of holothurians bodies. Crabs were found mainly in cloaca or among oral arms, polychaetes and shrimps were located on the surface of holothurians and fishes inside the hosts. Thus, symbionts diverge to the different trophic niches and locations. The frequency of co-occurrence of symbionts from different taxa didn't differ significantly from the random. It means that the competition for food and space between different symbionts species is minimal. The interactions among symbionts could be characterized as neutralism.

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

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In order to investigate the quality and the quantity of sediment fed by deposit-feeders holothurians, experiments were conducted on the common species *Holothuria atra* and *Holothuria leucospilota* at two stations of Reunion fringing reefs. A relationship has been established between enrichment level of the area and holothurians densities: holothurians are abundant (densities up to 3 ind m^{-2}) in dystrophic areas whereas low densities characterise oligotrophic areas. During field observations, *H. atra* and *H. leucospilota* consumed an average quantity of sediment of 79.7 g dw ind^{-1} d^{-1} and 88.8 g dw ind^{-1} d^{-1} respectively in both stations. We showed that a mixed population of both species in a dystrophic area can rework 82 kg dw m^{-2} y^{-1}, whereas in the oligotrophic area 3 kg m^{-2} are reworked. There was no significant difference in sediment organic matter between stations. Nevertheless, high densities found in dystrophic area indicate biomass storage of benthic production. Gut content analysis showed that the organic matter ingested from the sediment was used with 10 per cent efficiency for both species. C/N ratio decreased along the gut, showing organic matter degradation. It may show the ability of these holothurians to transform organic matter, and make it easily available for other organisms from the sediment. In both species, organic carbon and cholorophyll-a content in the oesophagus were significantly higher than the concentrations in the sediment sampled directly in front of the individuals, suggesting selectivity by both species. The bioturbation activity of these species displays two aspects: on one hand, the nutrition activity will have an impact on bacterial and diatoms populations; on the other hand, perpetual reworking of the sediment will forbid endofaune settlement.

Gut formation during development and regeneration in the holothurian *Eupentacta fraudatrix* (Holothuroidea, Dendrochirota)

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It seems to be of great importance to compare morphogenetic processes involved in embryonic development and regeneration in the same animal species. Regeneration often results in the formation of the body part, which is very similar or identical to that formed during embryonic development. If the result is the same, one could ask whether the morphogenetic mechanisms underlying both these processes are also the same. In order to throw some light on this problem, we investigated the formation of the gut during embryonic development and regeneration in juveniles and adults of the holothurian *Eupentacta fraudatrix*. Our results may be summarised as follows. l) The digestive epithelium (even the cuticular lining of the anterior gut parts) is endodermal in its origin. 2) In regenerating gut of the transversely bisected juveniles, the digestive epithelium and mesothelium are restored at the expense of their respective cells. The most important morphogenetic events are proliferation of the differentiated cells in the digestive epithelium, and dedifferentiation followed by mitotic division, migration and redifferentiation in the mesothelium. 3) In the eviscerated adult specimens of *E. fraudatrix*, the digestive epithelium regenerates from the mesothelium, which covers the thickening at the torn edge of the mesentery. Thus, there are clear differences between the development and regeneration of the gut in *E. fraudatrix*.

Temporal change in density and biomass of five aspidochirotid holothurians species (Holothuroidea: Echinodermata) inhabiting the *Posidonia oceanica* meadow of the Sidi Fredj peninsula (Algeria)

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The "deposit feeders" aspidochirotid holothurians species represent the major component of the *Posidonia oceanica* ecosystem in the Mediterranean sea. Few studies have been undertaken on their life cycle and the factors influencing their density and biomass.

The purpose of this work was to evaluate and follow monthly (from March 1995 to February 1996) the variations of the densities and biomasses of five holothurians species namely, *Holothuria (Holothuria) tubulosa*; *Holothuria (Lessonothuria) polii*; *Holothuria (Holothuria) stellati*; *Holothuria (Panningothuria) forskali* and *Holothuria (Platyperona) sanctori* occurring in one shallow water area characterised by an homogenous *Posidonia oceanica* meadow. The studied area is about 500 m^2 and present a depth of 3–9 m. This evaluation is justified by the part played by these species in recycling of the organic matter by ingestion of the sediment layer and/or the bottom wreck.

The sampling was done by mean of scuba diving and consisted of counting and measuring individuals of each species using the Quadrat method. The parallel analysis of the size structures and the densities/ biomasses cycles showed that the densities and the biomasses evolve in the same way for all the studied species. The two parameters present a spring peak, generally represented by visible individuals of big size, which arrives close to the surface for the reproduction. A reduction of the mean values of density and biomass in summer period would seem to correspond to the migration in depth and by the escapement of young individuals from the studied area. The minimal values observed in fall and winter corresponds to the species migration in depth (where the hydrodynamism is weak) and to a notable mortality caused by the high intensity of hydrodynamism in the area.

Effect of delayed metamorphosis and settlement on the survival and size structure of cultured juvenile *Holothuria scabra* (Holothuroidea: Aspidochirotida)

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The settlement to early juvenile stage of the cultured sea cucumber *Holothuria scabra* is an interesting phase of its life cycle. As in many marine invertebrates with complex life cycle, this is a critical phase when along with developmental changes, shifts in lifestyle and habitat take place. Considerable mortality usually happens at this transition from planktonic to early benthic stage with consequence on the abundance, growth rate and size-structure of the benthic population. In the context of the culture of this species, events in these stages of its life cycle could have implications in the quantity and quality of the yield.

We looked closely at the effect of the timing of addition of the metamorphic and settlement cue on the survival, recruitment to visible size and size structure of juvenile yield from a batch of cultured *H. scabra*. The timing of addition of the cue was critical to post larval survival and recruitment rate. A "9-day delay" in cue addition (at Day 20) gave low juvenile yield (6% + 10) and low recruitment rate. Interestingly, more visible recruits were seen in this treatment early in the monitoring period of recruitment but this was followed by mass mortality. Recruitment to visible size was sustained in both "no-delay" (addition at Day 11) and "4-day delay" (addition at Day 15) treatments. The recruitment rate was higher when cue addition was not delayed while juvenile yield were nearly equally high in both "no-delay" (21% + 6) and "4-day delay" (23% + 20) treatments. However, the size structure in the "no-delay" treatment was more skewed towards the larger sized juveniles compared to the "4-day delay "treatment indicating post-larval performance differences other than mortality.

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

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Understanding patterns of biodiversity always involves gross abstractions because these patterns are subject to a correlate of causal parameters that operate at different scales. At the local-scale, ecologists advocate that the assembly of faunas is shaped by biological mechanisms such as migration, recruitment, predation, competition, extinction and speciation, while at the macro- or geographical-scale biogeographers call mostly upon climate or historical explanations to explain biodiversity patterns. The present study provides the first attempt to describe and understand the biodiversity of the shallow-water holothuroids (as defined by the 50-m isobaths), at the geographical-scale of the western Indian Ocean (here defined as the area ranging from Suez to Cape Town and from the coastline of East Africa up to 65° East). Cluster analysis on several b-diversity coefficients and parsimony analyses of endemicity revealed that the western Indian Ocean is best split in (at least) three biogeographic realms: the Red Sea and associated Arab Basin, an asymmetrical circumtropical region stretching from the horn of Africa to southern Mozambique and the temperate Cape province. The subtropical Natal Basin acts as the bleeding zone between the tropical and temperate provinces. The zoogeography of western Indian Ocean holothuroids is here explained with (i) species' dispersion ability, (ii) the prevalent current patterns and associated up-and downwellings, and (iii) recent geological history. As the ghost of over-harvesting has in recent years also reached the East African Coast, the here proposed zoogeographic scenario will aid in the recognition of local regions that are important to the generation and maintainance of biodiversity.

Revision of the genus *Synallactes* (Holothuroidea: Synallactidae)

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The holothurian family Synallactidae Ludwig, 1894 holds mostly deep-sea forms and it is the least-studied large taxa among the deep-sea cucumbers. The synallactids are one of the most characteristic animals of the deep ocean. They appear repeatedly in photographic collections of abyssal megafauna. Many of these photographs show their characteristic tracks and faecal remains providing evidence of their important role in modifying the sediment landscape and in structuring the communities that live within it. The Synallactidae, as presently recognised, comprises approximately one hundred and thirty one species currently named.

The genus *Synallactes* Ludwig, 1894, embraces approximately twenty-two species. As far as we know, five of these species occur in the Atlantic Ocean, the rest inhabit the Pacific (11 species), Indian Ocean (4 species) and Antarctic Ocean (2 species).

The systematic status of certain species within the genus remains somewhat confused. The purpose of this work is to describe a new species of *Synallactes* from the Southeast Atlantic and clarify some taxonomic problems within the genus.

Comparative analysis of the spicular shape of the six species of the cucumariids (Echinodermata: Holothurioidea)

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We worked out calculus of approximations for quantitative estimation of the spicular shape of cucumariids (Stepanov, Gaidaev and Levin 2001). To calculate quantitative characteristics, a computer programme was created that digitize the ossicle graphic image, create digital data file and estimate necessary parameters before stocking them into the database. We carried out computer analysis of the spicular shape of the six species cucumariids: *Cucumaria frondosa*, *C. japonica*, *C. savelijevae*, *C. djakonovi*, *C. conicospermium* and *C. levini*. Two of them *C. conicospermium* and *C. levini* were described in 2002 (Levin and Stepanov 2002; Stepanov and Pil'ganchuk 2002). We calculated quantitative characteristics of spicular shape using different fatures as: oblongness (factor Rilay sphericity Ksr, parameter of the shape Ksh, parameter of elliptic Ke), ridginess of edge (index of circularity Kc, factor of ridgness Kr), and relative area of holes Qrel (Shvanov 1969; Victorov 1986; Gudimova 1991, 1999; Stepanov, Gaidaev and Levin 2001). For each quantitative characteristics of spicular shape, the minimum, maximum, mean, standard error of mean, mode and standard deviation were estimated. All quantitative characteristics were tested on normalcy of distribution using the Kolmogorov-Smirnov one-sample test. After this, the difference between the quantitative characteristics of all species was estimated by Kolmogorov-Smirnov two-sample test and t-test for independent samples. The analysis displayed differences among the examining species on characteristics of the spicular shape as oblongness, ridginess of edge and relative area of holes.

Shallow-water Holothuroid biodiversity and biogeography of the subtropical east coast of South Africa

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Because of market demands for beche-de-mer, holothurian stocks of the south-western Indian Ocean, notably Madagascar, the Mascarene Islands, Mozambique and the subtropical east coast of South Africa, have all become vulnerable. Of the approximately 150 shallow-water species of holothuroids recorded from these four regions, about 50 species occur on the east coast of South Africa, as far as Port St. Johns (ca. 31.5°S). An attempt is made here to compare the holothuroid faunas of the latter region with that of Mozambique and West Madagascar on the one hand and Mascarene Islands and East Madagascar on the other, in order to determine the degree of shared similarities, using several analyses. It is concluded that the holothuroid fauna of the South African east coast, at least as far south as Port

St Johns, has a mixed origin, being derived from migrating tropical Indo-West Pacific species from east Madagascar and the Mascarene Islands, under the influence of the East Madagascar current and from Mozambique and West Madagascar, under the influence of the Mozambique Current; some warm temperate species from the south, due to the influence of the northward-bound counter-current; and a fairly high level of local endemics (ca. 15%). If southern Mozambique (south of 20°S) is rightly included in the southern African subtropical region, the level of local endemicity increases to ca. 20%, making the southern African east coast region a definite zoogeographical province. Despite a high percentage of Indo-West Pacific species (ca. 70%), the shallow inshore aspidochirotid fauna of the east coast of South Africa is poorly established, a situation, in combination with the establishment of marine reserves and strict ordinances, makes harvesting not only uneconomical but well nigh impossible.

DNA fingerprinting and repeated surveys suggest very slow growth and recovery in overfished holothurians (*Holothuria nobilis*) on the Great Barrier Reef

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To investigate the potential for recovery of over fished beche-de-mer stocks on the Great Barrier Reef (GBR), field surveys were conducted on reefs before and after fishery closure. Total virgin biomass was modelled and compared to the total amount fished. In addition, individual growth rates where estimated using a novel technique involving individual recognition by DNA fingerprinting. Initial surveys on over 60 reefs of the GBR indicated that densities of *H. nobilis* were reduced in the sectors fished for beche-de-mer. This trend was not apparent in other species observed on the reef flats. Two years after fishery-closure for *H. nobilis*, no recovery of stocks on reefs previously open to fishing was observed. Densities on reefs protected from fishing since the onset of the fishery in the mid 1980s remained on a level several times higher then on fished reefs It was calculated that the virgin biomass (in the main fished area between 12° and 19° S) was about 5500 t, which is now reduced to about 2500 t. The reduction is in the same order than the total amount fished between 1987 and 1999 (2000 to 2500 t). DNA analysis of repeated samples on three locations indicated high recapture rates of fingerprinted and released individuals of *H. nobilis*. Fitting growth curves with Francis's growth function indicated that medium sized individuals (1 kg) grew at 35–533 g yr^{-1}, whereas large animals (2.5 kg) consistently shrank and no recruitment was observed. In combination, these data indicate that production of *H. nobilis* stocks is very low, presumably with low mortality, low recruitment and slow individual growth rates. Consistent with anecdotal evidence, recovery of GBR *H. nobilis* stocks may take several decades and a highly conservative management is suggested.

ABSTRACTS OF POSTERS FROM THE 6th INTERNATIONAL ECHINODERM CONFERENCE

The white spot disease in cultivated juveniles of *Holothuria scabra* (Echinodermata)

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It is frequently reported that cultivated holothuroids can suffer from a disease affecting their integument. We report here on a disease of juvenile *Holothuria scabra*, the most marketed edible sea cucumber, reared in the Aqua-Lab hatchery of Toliara, Madagascar. This disease, which has been called the white spot disease, is very contagious and is due to a severe bacterial infection that causes death within three days. The first sign of the infection is a white spot that appears on the integument of individuals, close to the cloacal aperture. The spot extends quickly onto the whole integument leading to the death of individuals. Microscopic (histology and S.E.M.) and biomolecular (D.G.G.E. and sequencing) techniques have been used to describe the lesions and to investigate the infecting microbial communities. The white spot lesions consist in a zone where the epidermis is totally destroyed and where collagen fibres and ossicles are exposed to the external medium. This zone is surrounded by a border line where degrading epidermis is mixed with the connective tissue. White spot lesions include three bac-

terial morphotypes: rod-shaped bacteria, rough ovoid bacteria, and smooth ovoid bacteria. The last morphotype is the only one found on the ossicles and is assumed to be responsible of their degradation. Three species of bacteria have been put in evidence in the white spot lesions thanks to biomolecular analyses: *Vibrio* sp., *Bacteroides* sp., and an a-Proteobacterium. Infection assays of healthy holothuroids have been performed from white spot lesions and from bacterial cultures but the etiologic agent (i.e., the initiator of the disease) has not been identified.

On two rare abyssal Myriotrochidae (Echinodermata: Holothuroidea: Apodida) new to the South Atlantic: *Siniotrochus myriodontus* Gage and Billett, 1986 and *Lepidotrochus* cf. *parvidiscus* Belyaev and Mironov, 1980

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In the course of the DIVA I expediton (RV *Meteor*, cruise M48/1) to the Angola Basin (South Atlantic) two rare Myriotrochidae were brought up from abyssal depths — *Siniotrochus myriodontus* Gage and Billett, 1986 and *Lepidotrochus* cf. *parvidiscus* Belyaev and Mironov, 1980. Until now only few specimens of *S. myriodontus* are known from the northeast Atlantic. The only specimen of *L. parvidiscus* is a posterior fragment from the southern Indian Ocean. These new records for the South Atlantic Ocean indicate a wide geographical distribution of both taxa. The species are described and detailed parameters for the wheel deposits are given.

Remarks on some Holothuroidea described by Heller from the eastern Adriatic Sea

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In 1868 Camil Heller described five new Holothuroidea from the eastern Adriatic Sea. Two of these species – *Thyonidium ehlersi* Heller, 1868 and *Synapta hispida* Heller, 1868 –are still only known from the original description. Recently, some of Heller's specimens were rediscovered in the collection of the Institute of Zoology and Limnology in Innsbruck. From these specimens *Thyonidium ehlersi* Heller, *Thyone inermis* Heller, *Stereoderma kirchsbergii* (Heller) and *Synapta hispida* Heller are redescribed and their current taxonomic status is discussed. Furthermore, a lectotype is designated for *S. kirchsbergii* and a neotype for *T. inermis*.

Population biology of Raine Island and Moulter Cay echinoderms

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Raine Island and Moulter Cay support a diversity of echinoderms with the most abundant being the ophiuroids and holothuroids. These cays support a high density of the commercially important sea cucumber (beche-de-mer), the black teatfish *Holothuria nobilis* (= *H. whitmaei*). Surveys of the sea cucumber populations were done through an extensive series of manta tows. Belt transects were also undertaken in the seagrass habitat. The standing stock of *H. nobilis* on Raine Island and Moulter Cay is higher than that recorded from many Green Zones elsewhere on the Great Barrier Reef. Manta tows of Raine Island and Moulter Cay indicated that the mean densities of this species were 36.74 ha-1 (SE = 9.08) and 19.25 ha-1 (SE = 7.61). The seagrass habitat showed an extremely high density of *H. nobilis*, average 120.8 ha-1 (SE = 29.5). Weight measurement revealed that *H. nobilis* in the seagrass habitat were smaller than those in the lagoon, supporting the suggestion that this habitat is an important settlement area for holothuroids. In comparison to fished and unfished reefs elsewhere on the GBR, the data from Raine Island represents the highest densities recorded for *H. nobilis*. A detailed survey of the ophiuroid population from rubble zone on the reef flat of Raine Island was also undertaken.

An efficient way to evaluate volume and biomass of sea cucumbers through diving surveys

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Biomass can be estimated from organisms wet or dry weight per unit area or their volume per unit area. Estimating sea cucumbers biomass through wet weight represents a problem as animals retain a fair amount of water even after dump drying. Sea cucumbers need to be brought to the surface in order to be weighed or to have their volume estimated. Often, researchers are limited by the number of animals they can bring to the surface, and biomass can be underestimated only by using the weight of a few animals collected at any time. Through a pilot study in Ilha Grande Bay, Rio de Janeiro State, seven reference areas were identified as good sites for working on *Isostichopus badionotus*. A total area of 2200 m^2 was surveyed using SCUBA. The total density of *I. badionotus* was estimated as 0.15 ind. m^{-2} (n = 319), but this varied from 0.03 to 0.47 ind. m^{-2} (n = 18 to 93 respectively) in the different reference areas. As sea cucumbers are touched, their first reaction is to contract for a few seconds, enough time for any diver to take length and circumference at the largest ambit measurements. Supposing the shape of a sea cucumber resembles that of a cylinder with two semi-spheres at both ends, the following formula was applied using the length and ambit taken under water: $V = \pi r^2 h - 2/3 \pi r^3$, where V = body volume, r = circumference radius, and h = body length. A correlation between wet weight (g) of animals brought to the surface and volume (cm^3) was then used to validate the above-mentioned volume measurement ($y = 0.3946x + 140.57$; $r^2 = 0.6926$; n = 131). The total biomass for the study area was then estimated as 68.11 cm^3 m^{-2}. This method could be applied to other sea cucumber species, causes less stress to animals, and it is a much more efficient way of measuring their volume and biomass.

Ultrastructural organisation of the radial nerve cord in the holothurian *Eupentacta fraudatrix* (Holothuroidea, Dendrochirota)

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Most of the available data on the holothurian nervous system comes from the studies of visceral organs. There has been very few information concerning the fine structure of the radial nerve cord and peripharyngeal nerve ring in these animals. The aim of our study was to the ultrastructure of the radial nerve cord in the holothurian *Eupentacta fraudatrix*.

The radial nerve cord is composed of an outer ectoneural part and a smaller inner hyponeural part. The outer and inner surfaces of the cord are surrounded by the epineural and hyponeural sinuses, respectively. The ectoneural and hyponeural parts are separated from the connective tissue by the common basal lamina, which forms deep narrow folds on both sides of the cord separating the two parts. The separation is incomplete, allowing bundles of nerve processes run from one part to another. The ectoneural and hyponeural parts are similar in their structure: both are neuroepithelia composed of supporting cells and nerve cells. Supporting cells are genuine epithelial cells. Their characteristic feature is the presence of thick bundles of tonofilaments in the basal cell processes. The nerve cells are ciliated. Those neurons, whose cell bodies face the lumen of the hypo- or ectoneural sinuses, are probably receptor cells. Nerve processes are mostly longitudinal, but there are also processes running in other directions. Synapse-like structures were occasionally observed.

Dexamethasone-induced apoptosis of holothurian *Eupentacta fraudatrix* phagocytes: Role of catalase

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Phagocytes of holothurian *Eupentacta fraudatrix* were isolated by using ficoll-verographine discontinuous gradient. These cells had high levels of activities of such antioxidant enzymes as superoxide dismutase (SOD) and catalase compared to those in mammals' monocytes. The results of analysing DNA fragmentation by agarose gel electrophoresis have shown apoptosis to be low in the intact phago-

cytes. Dexamethasone at concentrations of 10^{-7}–10^{-4} M, but not of 10^{-8} M, induced apoptosis in 18 hr of incubation. In 72 hr, apoptosis was increased at all concentrations of dexamethasone studied. In 18 hr, dexamethasone (10^{-8}–10^{-4} M) also activated SOD of phagocytes and inhibited catalase activity in a concentration-dependent manner (maximum 467% and 50% of control, correspondingly, at a dexamethasone concentration of 10^{-4} M). The data about decreased level of catalase activity in 18 hr of incubation of the cells with dexamethasone indicate the possible participation of catalase in the mechanisms of hormone-induced apoptosis in holothurian phagocytes. This idea was supported by the fact that apoptosis was reduced in phagocytes treated with hormone (10^{-4} M) and commercially available catalase (0.7 mkg ml^{-1}) in 18 hr.

Functional morphology of the tentacles in the apodid holothuroid *Synapta maculata*

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Synapta maculata is a long snake-like holothuroid inhabiting seagrass beds of the Indo-West Pacific. It has 15–16 pinnate tentacles, each comprising a central stem bearing 30–40 pairs of pinnules which are located in a plane tangential to the mouth. The tentacle inner tissues are organised in such a way that the stem and each pinnules can move independently from the others. This makes the tentacles exceedingly prehensile, being able to wrap around seagrass leaves or press against a flat surface. The internal surface of the tentacles (i.e., facing the mouth) is smooth while the external surface is covered with bulges. It is this surface that is applied on the substratum during feeding. The external epidermis is mainly made up of a typical echinoderm duogland adhesive system involved in the catching of food particles. An additional cell type may also be observed in the tentacular epidermis: the vesicular cells. These cells, packed with large vesicles each containing one spherule, are conspicuous in the tentacle epidermis, being present on both the inner and outer surfaces, but preferentially located on the tentacle margin. It is proposed that vesicular cells could be defensive cells containing a toxic material. The tentacles of *S. maculata* appear therefore to be well adapted for efficient deposit feeding: their large adhesive outer surface and great mobility allow a maximal capture of food particles while the presence in their epidermis of defensive cells would deter tentacle predators and thus allow the animal to optimise its feeding time.

Estimation of the evolution of the Cuvierian tubules, defense organs in the family Holothuriidae, by the character mapping method and by ultrastructural analyses

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Cuvierian tubules are specialised defense organs occurring exclusively in some holothuroid species from the family Holothuriidae. Within the family, these organs differ greatly in terms of their morphology and their mode of functioning. The goal of this work was to determine the evolutionary path of Cuvierian tubules by the character mapping method and by ultrastructural analyses. A fragment of the mitochondrial genome corresponding to two genes was first sequenced for 20 species of Holothuriidae (3 *Actinopyga*, 3 *Bohadschia*, 12 *Holothuria*, *Labidodemas semperianum* and *Pearsonothuria graeffei*) and the relationships between these species were estimated from the molecular data obtained. The methods used to reconstruct those relationships were the neighbour joining, the maximum parsimony and the maximum likelihood. The consensus phylogenetic tree indicates that: (1) the genus *Actinopyga* is monophyletic and was the first to diverge from the rest of the family, (2) the second diverging group was a clade comprising the 3 *Bohadschia*, *P. graeffei* and 4 *Holothuria*, (3) within this clade the genus *Bohadschia* is monophyletic, (4) the remaining clade comprises the other species of *Holothuria* and *L. semperianum*, (5) the genus *Holothuria* is paraphyletic. The analysis of the different characteristics of Cuvierian tubules from the viewpoint of this phylogenetic tree strongly suggests that the common ancestor of the Holothuriidae had Cuvierian tubules and that those tubules were ramified, non-adhesive, non-expellable and non-stretchable; that those tubules have evolved to give the non-ramified, adhesive, expellable and stretchable tubules; and that the loss of Cuvieran tubules has occurred several times independently during evolution.

Reproductive biology displayed by two symbiotic copepods of holothuroids

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Nearly half of the species of copepods are symbionts. These copepods have developed a wide range of morphofunctional and ecological adaptations. More particularly, the life cycle and the reproductive strategies are indicial of the degree of specificity of the symbiosis. This work investigates on a comparative basis two species of symbiotic copepods whose biology is contrasted, namely, (1) *Synaptiphilus luteus*, an ectocommensal living on the tegument of the burrowing synaptid *Leptosynapta inhaerens* and (2) *Allantogynus delamarei*, an endoparasite of the coelomic cavity of the epifaunal aspidochirote *Holothuria tubulosa*. Analysis of the life-cycle of *S. luteus* enabled the identification of two nauplii and four copepodite stages, it also revealed, by the seasonality of sex-ratio and fecundity, that a complex mating behaviour could have evolved in that species. In *A. delamarei*, whose cycle remains largely undescribed, the discovery of a potential male specimen, unknown so far, and the observation of a peculiar sensory apparatus on the first copepodite, bring new hypothesis regarding the life-cycle of this highly modified species. Moreover, the morphological comparison of mature females leads to reinterpret the structural organisation of the ovigerous sac in the two species.

Parasitic turbellaria in *Holothuria tubulosa*, *Holothuria forskali* and *Cucumaria planci* in the northern Adriatic Sea

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The infestation by parasitic turbellaria of the coelom and the intestine of *Holothuria forskali*, *Holothuria tubulosa* and *Cucumaria planci* was investigated. Animals were collected by dredging in the bay of Rovinj (northern Adriatic Sea, Croatia). *H. tubulosa*, the only resident species in shallow water in Val Saline 4 km north of Rovinj was collected by snorkelling.

Umagilla forskalensis and *Monticellina longituba* live in the intestine of *H. tubulosa*. The body cavity of *H. tubulosa* and *H. forskali* is infested by *Anoplodium* sp., *Anoplodiera voluta* and *U. forskalensis*. *Umagilla forskalensis* was the only species found in the intestine of *H. forskali*. In *H. tubulosa* from Val Saline only *M. longituba* was found in the intestine and *Anoplodium* sp. in the coelom.

In the bay of Rovinj all specimen of *H. tubulosa* are infested with turbellarians (7.3 flatworms per sea cucumber). 80 per cent of *H. forskali* are infested (3.7 turbellaria per sea cucumber). 87 per cent of *H. tubulosa* from Val Saline were inhabited by parasites but the degree of infestation with 2.4 parasites per sea cucumber was lower.

H. tubulosa and *H. forskali* are deposit feeders. The different particle size of the sediment ingested might be one reason for the different degree of infestation of the two species collected from the same site. The way of infestation is supposed to be via egg capsules in the sediment. The suspension feeding *C. planci* was never infested by parasitic flatworms in our study material.

Allee effects and species of g. *Cucumaria*

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Echinoderm species with planktonic larvae may exhibit Allee effects (AE) in reproduction or recruitment. Holothurian as most of echinoderm populations consist of isolated subpopulations of relatively sessile adults.

We may assume that species of g. *Cucumaria* as well as other benthic species broadcasting gametes are subjected to AE due to depressed fertilisation success at low population densities. So, increasing harvesting pressure on the populations of the sea cucumbers may result in the densities below to insure

the adequate recruitment. However there was only one experimental evolution of the AE and survival as function of density for g. *Cucumaria*.

On the other hand, AE can play an important role in the adaptation and evolution of the free-spawning species, and the sea cucumbers, in particular. Fertilisation success is high within a small distance from a sperm source and spatial relationship between spawning organisms influence fertilisation. Since metapopulations of marine invertebrates, e.g. *Cucumaria frondosa/japonica* re relatively isolated from each other and connected by low levels of dispersal, they can be subjected to morphological changes as adaptation to the local environment. As a result of this process the appearance of new species of g. *Cucumaria* might be expected. Precipitous changes are particularly likely if the populations display AE. An example of metapopulation model can be the population of *C. japonica* on the Far East (in the Sea of Japan, Okhotsk Sea) with recently described species *C. conicospermium*, *C. levini*, *C. okhotensis*. Some taxonomic changes appear to have evolved in the history of these species and others as the subsequent diversification of larval and adult morphology caused by AE.

Parental investment in *Synaptula hydriformis* (Holothuroidea: Apoda)

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Synaptula hydriformis (Lesueur, 1824) is a matrotrophic holothuroid that supplies its young with nutrients other than yolk during their development. This work aimed to establish the relationship between this parental investment and the survival rate of the released young in laboratory and the size they attained on their first stages of development. Adult specimens were reared in isolation in laboratory, and were measured once a week. The size corresponds to the distance between the oral ring and the posterior end of the body. The young of the first generation released in the laboratory measured between 0.15 and 3.51 mm and were distributed in 12 size classes. The highest mortality rate was observed on the first eight weeks after the young were released, falling sharply after that. This period was considered as a "critic period" for young survival on laboratory conditions. Therefore, data refers to survival to this critical period. It was observed that more than 50% of the dead individuals belonged to the three first size classes. Less than 20% of the survivors belonged to these same classes, and the remaining 80% measured between 1.21 and 3.6 mm. Survival of the young reached 100% among the largest animals, with sizes between 3.0 and 3.6 mm. It was also observed that the size of the young when liberated is related to the size attained at the eighth week of life outside the parental body. These results show that the young released with sizes larger than 1.2 mm have a survival expectancy three times higher than the smaller ones. The size of the young when liberated from the parental body is related to the size they will achieve at the end of the critical period of eight weeks.

Changes in dermal ossicles of *Chiridota rotifera* and *Synaptula hydriformis* (Echinodermata: Holothuroidea)

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Echinoderms usually have a rigid body wall with an elaborate magnesium-rich calcite endoskeleton. The integumental skeleton of the Holothuroidea contains many microscopic ossicles formed within multinucleated sclerocystes' syncytia situated in the dermal layer of the body wall. The sequence of ossicle formation of two apodid holothurians, *Chiridota rotifera* (Pourtalès 1851) and *Synaptula hydriformis* (Lesueur 1824), was observed using light microscopy, scanning and confocal electron microscopy. The first species has clusters of calcareous structures shaped like wheels, gathered inside convex white papillae in the body wall. Those ossicles begin to form as little stars with six or more rays, which develop to form wheels with six rays also, measuring from 40 to 150 µm long. Ossicles aggregate in the papillae by addition of new ones at the star stage in its outer layer. The oldest ossicles, in the wheel stage, concentrate in the middle of the papillae. In the second species, the ossicles have two parts, a plate and an anchor, distributed all over the skin. Each anchor measures about 120 µm long and is attached to a plate. The anchor begins to form as a small baton. The plate is formed later and measures 95–130 µm. In both species ossicle formation occurs during all the life span of the animals.

Lower Jurassic 'worm holothurians': First Liassic body fossils and/or intestinally transformed individuals

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Holothurian spicule morphotypes of Calclamna, Binoculites, and Achistrum are very common in European Lower Jurassic marine clays. Besides some aggregates of associations of such types as possible relicts of original body wall deposits, no complete fossils were known before. Meanwhile, during rebent years dozens of worm-like holothurians consisting of those morphotype associations have been extracted from an almost 2-m thick and several metres laterally extended portion within a monotonous 50-m succession of Lower Liassic silty clays (at Göttingen, Germany). A few 'worm holothurians' contained up to ten ossicles of the calcareous ring showing different 2 dorsal / 3 ventral radials as typical in certain synaptids.

However, some observations may cast doubt on the supposed nature as body fossils, e.g.: (1) apparently non-anatomical positions of ring elements; (2) thin "worms" of densely crowded spicules obviously without a hypothetic space left for an original body cavity; (3) extremely narrow and irregular three-dimensional meanders of thin specimens seemingly too acrobatic (even in rigor mortis if compared with recent synaptids). Hence, similarities with the typical Solnhofen fossil *Lumbricaria* may not be excluded which would suggest a coprolitic (fecal) origin of the 'worm holothurians'. In this case, however, biostratinomic observations would suggest that the supposed holothurian eater can only have fed on one individual until defecation thus transforming it by intestinal passage.

Distribution and abundance of starfish, sea urchins, and sea cucumbers in Galapagos

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Although the starfish, sea urchins, and sea cucumbers that occur in Galapagos are well known, reports of the distribution and abundance are few. This information is essential for understanding their ecology and biology. We documented the occurrence of species at seven sites with distinct habitats in Galapagos. Eight species of sea urchins, four species of sea cucumbers, and five species of starfish were found. Only one or two individuals of some species and low densities <0.5 ind. m^{-2} of most species were found. Only a few species, all sea urchins, had densities >0.5 ind. m^{-2}. Only *Eucidaris galapagensis* was found with densities > 0.5 ind. m^{-2} at Caamaòo (15.6 ± 6.1) and at Punta Estrada (10.1 ± 4.8 ind. m^{-2}). *Eucidaris galapagensis* and *Lytechinus semituberculatus* exceeded this threshold at Academy Bay (1.5 ± 1.2 and 4.6 ± 8.9, respectively) and at Muelle, Santa Cruz (0.7 ± 0.8 and 2.0 ± 3.4, respectively. The most diverse assemblage was at Itabaca Channel with *E. galapagensis* (0.7 ± 0.8), *L. semituberculatus* (2.6 ± 2.2), *Tripneustes depressus* (2.0 ± 1.9), and *Diadema mexicana* (0.5 ± 1.3). Of these dominant sea urchins, *E. galapagensis* was most ubiquitous, followed by *L. semituberculatus*. Variation in the distribution and abundance of the echinoderms in these different habitats has implications for both the characteristics of the habitats and the specificity of habitat requirements of the echinoderms.

Fossil Holothuroidea (Echinodermata): an overview

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The taxonomy and biostratigraphy of fossil holothurians have been reviewed including new records from the Ordovician and Silurian of the Baltic realm as well as Mesozoic of Europe and Africa. These new data suggest that the earliest unequivocal sea cucumber, according to ossicles and calcareous ring elements, is from Lower Ordovician (Arenigian; 470 Myr old) sediments. Currently nearly 800 paraspecies and species of the fossil Holothuroidea have been reported. 778 paraspecies /16 species (body fossils and sclerite associations) versus 282 paraspecies/4 species ("Treatise on invertebrate paleontology" 1966) are known today. The predominant part (>460) of the fossil paraspecies/species comes from the Triassic and Jurassic period; only slightly more than 100 taxa are from Cretaceous respectively Paleogene sediments. Specimens from Neogene sediments are insufficiently known (<50). Compared to their post-Palaeozoic counterparts, the fossil record of

Palaeozoic sea cucumbers are very poor, reported as follows: Ordovician (<5), Silurian (1), Devonian (<50), Carboniferous (<70), and Permian (<20). Localities yielding well-preserved complete fossil holothurians are very rare in the world. Previously, less than 10 such localities (Fossillagerstätten) have been reported in the literature. Non-European and Non-North-American records of fossil holothurians are hitherto rare (e.g. Africa, Australia, South-America), or undescribed up to now. A better knowledge of fossil Holothuroidea is strongly necessary for understanding the early evolution of the Eleutherozoa as well as evolution of Holothuroidea.

Late Cretaceous holothurians (Echinodermata): An overview

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The Late Cretaceous holothurians have been barely studied for over a century, and it is normally assumed that holothurian fossils are so rare and non-diverse as to be of little importance. This poster introduces Late Cretaceous holothurian faunas from several Late Cretaceous successions of Europe (>50 000 holothurian ossicles and pieces from nearly 500 samples), that contradict this view. The taxonomy, palaeoecology, biostratigraphy, and palaeogeography of Late Cretaceous holothurians have been reviewed including new records from the Turonian, Campanian and Maastrichtian of Germany, Denmark, Netherlands, Poland, France, Austria, and the U.K. Currently slightly more than 70 paraspecies and species of Holothuroidea from Late Cretaceous sediments (99 – 65 Myr) are known. All paraspecies have been assigned orthotaxonomical to Recent holothurian orders and families — all modern holothurian orders (Dendrochirotida, Dactylochirotida, Aspidochirotida, Elasipoda, Molpadiida, and Apodida) are present. Compared to the other Upper Cretaceous stages, the knowledge of sea cucumbers from the Coniacian, Santonian, and Campanian periods are very poor, reported as follows: Cenomanian (13 paraspecies), Turonian (12), Coniacian (1), Santonian (1), Campanian (6), and Maastrichtian (45). Localities yielding body fossil of holothurians are very rare in the world. Previously, only one such Late Cretaceous Fossillagerstätte have been reported — the Late Cenomanian lithographic limestone of Lebanon.

Holothurians from the Late Cretaceous "Fish Shale" of Lebanon

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Localities yielding nearly complete fossil holothurians are very rare in the world. Previously, less than ten such localities (Fossillagerstätten) have been reported in the literature; only two are Cretaceous (144–65 Myr old). The lithographic limestones of the Lebanon comprise Fossil Lagerstätten of different Late Cretaceous ages and faunal composition. They have been renowned for a rich fish fauna as well as soft tissue preservation (Coleoidea, Annelida etc). A Late Cenomanian (94 Myr old) age is assigned to the Haqel and Hjoula localities as well as to the Nammoura locality, whereas the beds at Sahel Alma are dated as Late Santonian. The Hjoula sites, from which my material comes, are located about 10 km inland from Jbail (Byblos). Hjoula have yielded nearly 50 specimens of complete fossil holothurians. All specimens consist of more ore less good preserved calcareous ring (diameter 0.5–4.0 cm), and sometimes body outline. Systematically nearly all specimens can be assigned to the Aspidochirotida (Holothuriidae and Stichopodidae). In addition, the results of micropalaeontological investigations are meagre: some poor preserved ossicles indicate also apodid sea cucumbers (Chiridotidae).

Aspidochirote holothurians from the Middle Triassic of southern Germany

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Localities yielding well-preserved fossil holothurians are very rare in the world. Previously, less than ten such localities (Fossillagerstätten) have been reported in the literature – only three are Triassic (e. g. Cherbonnier 1978, Smith and Gallemí 1991). Exceptionally preserved holothurians of Middle Triassic age were found in the Upper Muschelkalk (spinosus zone; 234 Myr old) of Baden-Wuerttemberg, southern Germany (Hagdorn 1993). All new investigated specimens from Nitzenhausen

consist of good preserved calcareous rings (diameter 0.5–1.0 cm), and poor preserved remains of the whole body. Systematically nearly all specimens can be assigned to the aspidochirotes (family Holothuriidae). One new genus and species (*Palaeoholothuria hagdorni*) is represented. The calcareous rings are very similar to the Recent subgenera *Holothuria (Panningothuria)*, *H. (Platyperona)*, *H. (Stauropora)* as well as *H. (Mertensiothuria)*. Additionally, some micropalaeontological investigations (Ockert 1993, Hagdorn unpublished) have yielded comparable disarticulated radialia and interradialia – such a wider distribution in the Muschelkalk of the Germanic Basin is assumed.

A study of *Holothuria scabra* (Jaeger) on different types of sediment at Bolinao, Pangasinan (Philippines)

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The most obvious environmental impact of aquaculture is eutrophication, caused by excessive feeding and decrease in water circulation. If the sea cucumber can efficiently consume the sediment from aquaculture, the deterioration of the water might be lessened and the growth of the sea cucumber might be enhanced by the aquaculture. For this study, juvenile *Holothuria scabra* was placed in cages at three different locations, two with coral sand in a sea grass bed, and one with silty sand near an area of intensive fish farming. Two different batches of laboratory bred animals where used (11 and 4 months after fertilisation).

The organic content in the sediment was not as expected, showing higher values for coral sand than for fish pen silty sand. This was unexpected, and difficult to explain. The animals grew faster (measured as biomass) at the fish pen site than on coral sand. Mortality was higher at the fish pen site, but the total biomass at the end of the experiment was still higher there, than at the other sites. This indicates that a grow-out culture of *H. scabra* juveniles would benefit from being located near fish pen areas.

Variations in the form of the spicules from different parts of the introvert of dendrochirotid holothuroids

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It is well known that the form of the spicules of the body wall and other organs play an important part in the identification and classification of not only species but also genera among holothuroid echinoderms. It is also well known that tentacle spicules often vary in form both in the tentacle shaft and the branches but variations have this far been overlooked in the introvert of dendrochirotid holothuroids, although many writers have shown that introvert deposits play an important part in the identification of species, especially within the very large "supergenus" *Thyone*. An examination of several species within this genus and *Stolus*, among phyllophorid dendrochirotids, has shown that introvert spicules may also vary along the length of the introvert of a single specimen. For example a new, still undescribed species of *Stolus*, possesses only small-noduled buttons and smooth, perforated plates in the anterior part of the retracted introvert and elongated, perforated rods and rosettes in the more posterior part, while all four types of deposits occur in the mid-introvert. Hence, it is advised that in dendrochirotid holothuroids, especially those belonging to the family Phyllophoridae, spicules be studied from all regions of the introvert to prevent erroneous identifications and eliminate, as far as is possible, the duplication of species.

An enzymatic method for examining calcareous ossicles from holothurians

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The different shapes of ossicles are characters of paramount importance in holothurian taxonomy. The method that has been used to isolate these ossicles is to dissolve a small piece of tissue with a small quantity of hypochlorite solution. However, this bleach solution can corrode the calcareous pieces and modify the original shape and dimensions of the ossicles. A new method using a proteolytic enzyme (Pancreatin NF), instead of hypochlorite solution, to dissolve holothurian tissues is proposed. This method was developed by using fragments of body tissues from three species from three different orders: *Holothuria grisea* Selenka, 1867 (Aspidochirotida), *Duasmodactyla seguroensis* (Deichman, 1930) (Dendrochirotida) and *Synaptula secreta* Lopez, 1957 (Apoda). Observations with light and scanning electronic microscopy (SEM) of material prepared using the traditional and the proposed methods was made in order to compare the results. The SEM images show the striking differences in the surface of the ossicles obtained by each method.

Tubulin expression and the regeneration of the enteric nervous system in the sea cucumber *Holothuria glaberrima*

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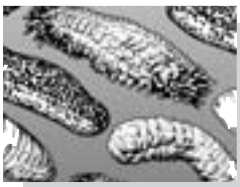
The sea cucumber *Holothuria glaberrima* has the capacity to regenerate its internal organs, including the digestive tract with its enteric nervous systems (ENS). Tubulin, the main constituent of microtubules, has been used extensively as a marker to study regeneration in many organisms. We have identified a 2.1 kb á-tubulin clone (Hgtub) from a regenerating intestine library of *H. glaberrima*. Northern blots of intestinal tissue done with a probe from the conserved coding region identified five bands, suggesting the presence of different á-tubulin isoforms. Moreover, when an Hgtub 3`UTR probe was used, a single band was obtained. This band up-regulates during late regenerative stages, concomitant with ENS regeneration. In fact, immunohistochemical studies using á- and â-tubulin antibodies and other ENS markers demonstrated: (1) an increase in nerve fiber density throughout the intestinal serosa and muscle layers as regeneration advances and (2) the existence of at least two populations of fibers, an extrinsic population that enters the regenerating intestine from the mesentery and that probably originates within the mesentery or body wall and an intrinsic population that appears to originate from neurons within the serosa that distributes homogeneously along the regenerating tissue. These results should provide a clear understanding on the regeneration of the digestive tract and in particular of its associated ENS.

Sea cucumber diversity and resources in shallow waters of Brunei, Borneo Island

D.J.W. Lane

Fisheries for tropical Indo-Pacific sea cucumbers are typically unregulated, overexploited and have historically operated on boom and bust cycles. Concerns range from loss of biodiversity and fishery productivity, to the possible deleterious ecological effects of sea cucumber biomass-depletion on reefs and associated marine sediments. In some localities many highly prized (and priced) species are very rare — so much so that they have been suggested as possible candidates for CITES listing. In contrast to most Indo-Pacific reef habitats, shallow shelf waters off the Brunei sector of the NW Borneo coastline are, in terms of sea cucumbers, unexplored and are relatively unexploited, at least in recent years. There are no licenses issued for beche-de-mer harvesting in Brunei but the relatively undisturbed status of holothurian resources may also be a consequence of offshore oil and gas facilities placing many large reef areas and shallow sediments off limits for fishing. Although there is some evidence of illegal harvesting, both amateur and professional, survey transects, carried out in 2003/2004, indicate a rich holothurian diversity and a wide range of commercial species in significant numbers. Given the limited domain of reef sites in Brunei territorial waters, stocks of commercial species are probably not sufficient to support a viable national fishery but the resource of high-value commercial species is of potential importance as a source of broodstock for mariculture.



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