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Advances in sea cucumber aquaculture and management

Cover photo:
Sea cucumbers juveniles (*Apostichopus japonicus)*. FAO/A. Lovatelli

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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PREPARATION OF THIS DOCUMENT

In 1990, the Food and Agriculture Organization of the United Nations (FAO) published a review on the holothurian resources of the Pacific which described the main sea cucumber species exploited in the South Pacific and reviewed the biology, resource assessment methods, harvesting and processing techniques and principal markets for beche-de-mer (Conand, C. The fishery resources of Pacific Island countries. Part 2: Holothurians. FAO Fisheries Technical Paper No. 272.2. Rome, FAO. 1990. 143p.).

Since the publication of the paper, many countries worldwide – some not traditionally involved in this fishery – began exploiting their sea cucumber resources, encouraged by the strong and growing market demand particularly from the Far East. In the last decades, different management plans for both the conservation and exploitation of sea cucumber have been tested and applied. Considerable advances have also been made on farming techniques and artificial reproduction for some commercially important species through applied research activities.

This document collects all the papers presented at the international Workshop on Advances in Sea Cucumber Aquaculture and Management (ASCAM) held from 14 to 18 October 2003 in Dalian, People's Republic of China, and organized by the Inland Water Resources and Aquaculture Service of the FAO Fishery Resources Division. The papers presented provide up-to-date information on the status of resources and utilization, resource management and advances in aquaculture.

The target audience for this publication includes fishers, farmers, researchers, managers and policy-makers. It is hoped that this document will assist international and regional development organizations and national governments to prioritize their activities concerning sea cucumber conservation and exploitation.

These papers have been reproduced as submitted by the participants at the ASCAM Workshop. The views expressed in this publication are those of the authors and do not necessarily reflect the views of the Food and Agriculture Organization of the United Nations.

Distribution:
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FAO Fisheries Department
FAO Regional and Subregional Offices
Workshop participants

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Numerous individuals contributed to the successful organization and implementation of the sea cucumber workshop in Dalian. All of them are acknowledged for their enthusiastic efforts and contributions during the preparatory phases and at the workshop itself.

Special thanks are due to the Ministry of Agriculture, People's Republic of China, for hosting the workshop and for providing excellent logistical support, notably through the endless efforts of Ms Wang Jin, Deputy Division Chief, Division of Cooperation and Exchange of the National Fishery Technical Extension Centre, and her colleagues.

The preparation of the workshop programme, identification of the various experts and scientific and editorial support throughout this activity was possible thanks to the immense work of all members of the Programme Committee established almost one year before the workshop took place. The dedication and enthusiasm of Prof. Chantal Conand, Laboratoire ECOMAR (La Réunion, France), Dr Steven Purcell, WorldFish Center, Pacific Office (Noumea, New Caledonia), Dr Sven Uthicke, Great Barrier Reef Marine Park Authority (Townsville, Australia), Dr Jean-François Hamel and Dr Annie Mercier, Society for the Exploration & Valuing of the Environment (Katevale, Canada), will hopefully become apparent after reading this document.

Participation of the experts at the workshop was possible through the assistance of the Food and Agriculture Organization of the United Nations (FAO) as well as of a number of other regional and national bodies and institutions. The Secretariat of the Pacific Community (SPC), the WorldFish Center, the University of Hull (United Kingdom) and the Network of Aquaculture Centres in Asia-Pacific (NACA) are acknowledged for their contributions. Thanks are also given to all the institutions that have permitted their experts to prepare for and attend the workshop. Special thanks should go to the Fisheries Research Institute of Hainan Province, the Yantai Fisheries Research Institute, the Liaoning Marine Fisheries Research Institute, the Yellow Sea Fisheries Research Institute and the Dalian Fisheries University for supporting the participation of their experts.

The workshop organizers also wish to thank the representatives of the Dalian Bang Chuidao Marine Products and the Dalian Youde Marine Biological Garden for allowing the workshop participants to tour their commercial sea cucumber hatchery and on-growing facilities. The hospitality was appreciated and provided a tangible opportunity to observe the progress made in China PR in sea cucumber aquaculture and the extent of the industry.

Last, but not least, much appreciation goes to Prof. Chen Jiaxin, former director of the Yellow Sea Fisheries Research Institute in Qingdao for his pivotal role played from the very start of this activity. Finally, the opportunity is taken to thank all the FAO staff members in Rome and Beijing who have contributed in one way or another in the organization of the workshop and, particularly, Ms Mairi Page for her valuable and constant assistance.

Additional editorial assistance was also provided by Dr John Ryder. Layout creation by Mr José Luis Castilla.

ABSTRACT

This document is a collection of all the technical papers presented at the international Workshop on Advances in Sea Cucumber Aquaculture and Management (ASCAM) held from 14 to 18 October 2003 in Dalian (Liaoning Province), People's Republic of China, and organized by the FAO Fisheries Department.

The publication is divided into four sections. The first part includes the introduction and recommendations made by the participants on issues concerning sea cucumber resource management and aquaculture. The next sections contain the technical papers presented and discussed at the workshop sessions, namely (i) on the status of resources and utilization (Session I), (ii) on resource management (Session II), and (iii) on aquaculture advances (Session III).

The first section introduces up-to-date information on the present status of world sea cucumber resources and utilization with special focus on those countries such as China, Ecuador, Indonesia, Japan, Malaysia and the Philippines which have been heavily involved in the industry for decades. Information from other countries such as Cuba, Egypt, Madagascar and Tanzania, relative newcomers to the sector, is also provided indicating to some extent the growing interest with regards to the exploitation of holothurians for the increasing Asian markets.

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

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

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

Key words: Holothurians, sea cucumber, beche-de-mer, resource management, conservation, fisheries, aquaculture, polyculture, hatchery operations, reproduction, spawning, larval rearing, parasites, processing, markets

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ABBREVIATIONS AND ACRONYMS

AFMA	Agriculture and Fisheries Modernization Act
AFMA	Australian Fisheries Management Authority
ASCAM	Advances in Sea Cucumber Aquaculture and Management
ASEAN	Association of South East Asian Nations
BACI	Before After Control Impact
BAS	Bureau of Agricultural Statistics
BFAC	Broad-area Fishery Adjustment Commission
BFAR	Bureau of Fisheries and Aquatic Resources
BML	Bolinao Marine Laboratory
BUS	Bacterial Ulceration Syndrome
CBD	Convention on Biological Diversity
CCFR	Code of Conduct for Responsible Fisheries
CDF	Charles Darwin Foundation
CDRS	Charles Darwin Research Station
CEDENMA	Ecuadorian Committee for the Defence of the Environment
CGIAR	Consultative Group on International Agricultural Research
CIDA	Canadian International Development Agency
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMI	College of the Marshall Islands
CoP	Conference of Parties
CPUE	Catch per unit of effort
CRMO	Association of Coastal Resources Management Office
CUD	Belgian Coopération Universitaire au Développement
CUD	Coopération Universitaire pour le Développement
DANIDA	Danish International Development Agency
DENR	Department of Environment and Natural Resources
DO	Dissolved Oxygen
DTI	Department of Trade and Industry
EDTA	Ethylene Diamine Tetra-Acetic Acid
EEAA	Egyptian Environmental Affairs Agency
EEZ	Exclusive Economic Zone
ESRI	Environmental Systems Research Institute, Inc.
ETA	Effective Temperature Accumulation
FAC	Fishery Adjustment Commission
FAO	Food and Agriculture Organization of the United Nations
FMC	Fishing Monitoring Certificate
GBR	Great Barrier Reef
GI	Gonad Index
GIS	Geographic Information System
GMR	Galapagos Marine Reserve
GNPS	Galapagos National Park Service
GPS	Global Positioning System
H&E	Haematoxylin & Eosin
HCSM	Malaysian Network for Holothurians Conservation and Management
IHSM	Institut halieutique et des sciences marines

IMA	Interinstitutional Management Board
INSTAT	National Institute of Statistics
IOC	Indian Ocean Commission
IUCN	International Union for the Conservation of Nature and Natural Resources
KFCA	Kutsugata Fisheries Cooperative Association
MMC	Merchant Monitoring Certificate
MPA	Marine Protected Area
MSL	Minimum Size Limit
NFA	National Fisheries Authority
NGO	Non Governmental Organization
NMAC	National Management Advisory Committee
NT	Northern Territory
NTZ	No-Take Zone
OHS	Occupational Health and Safety
ONET	Association nationale des exploitants du trépang
PADI	Professional Association of Diving Instructors
PCAMRD	Philippine Council for Aquatic and Marine Research and Development
PCF	Perivisceral Coelomic Fluid
PMAC	Provincial Management Advisory Committee
PMB	Participatory Management Board
PSB	Photosynthetic Bacteria
PVC	Polyvinyl Chloride
QECBIA	Queensland East Coast Beche-de-mer Industry Association
QFS	Queensland Fisheries Service
RIA3	Research Institute for Aquaculture No. 3
SARS	Severe Acute Respiratory Syndrome
SCUBA	Self-Contained Underwater Breathing Apparatus
SEM	Scanning Electron Microscopy
SEVE	Society for the Exploration & Valuing of the Environment
SFA	Seychelles Fishing Authority
SFAC	Sea-area Fishery Adjustment Commission
SFCA	Semposhi Fisheries Cooperative Association
SLG	Special Law for Galapagos
SPC	Secretariat of the Pacific Community
TAC	Total Allowable Catch
TAD	Transport Authorization Docket
TL	Total Length
TOP	Technical Operational Procedure
ULB	Free University of Brussels
UMH	University of Mons-Hainaut
UNDP	United Nations Development Programme
UP	University of the Philippines
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
UV	Ultraviolet Radiation
WA	Western Australia
WIOMSA	Western Indian Ocean Marines Sciences Association
WWF	World Wide Fund for Nature

INTRODUCTION

From 14 to 18 October 2003, the Fisheries Department of the Food and Agriculture Organization of the United Nations (FAO) organized an international workshop on the "Advances in Sea Cucumber Aquaculture and Management" (ASCAM) in collaboration with the Chinese Ministry of Fisheries in the northern Chinese coastal city of Dalian, Liaoning Province. The main reasons behind the organization of this activity were the current intense fishing efforts on an increasing number of sea cucumber species, the constantly growing market pressure for these species and the recent advances in farming technologies. The workshop was organized into three main sessions focusing on the status of resources and utilization (Session I), on resource management (Session II), and on aquaculture advances (Session III). During the workshop, 35 presentations were delivered by international experts from 20 countries including Australia, Canada, China PR, Cuba, Egypt, France, Malaysia, New Caledonia, Papua New Guinea, Seychelles, Tanzania and Viet Nam.

The status of resources and utilization session (Session I) was opened by Prof. Chantal Conand, a respected scientist in the field of holothurian research from the University of La Réunion (France) and also editor of the "Beche-de-Mer Information Bulletin" produced by the Secretariat of the Pacific Community (SPC). Prof. Conand's paper provided an overview on the present status of world sea cucumber resources and utilization focusing on traditional and commercial tropical and temperate fisheries in the Western Pacific and Indian oceans. Ensuing presentations gave updated information on resources, fisheries, aquaculture and trade in some of those countries where sea cucumber plays an important role in the rural economy of fishing communities. Prof. Chen Jiaxin, former director of the Yellow Sea Fisheries Research Institute in Qingdao (Shandong Province), delivered a comprehensive report on China, which provided information on the past and current activities in China PR. Among the other countries, Cuba and Egypt reported the exploitation status of their sea cucumber resources for the first time.

In the resources management session (Session II), chaired by Dr Steve Purcell (WorldFish Center, New Caledonia) and Dr Sven Uthicke (Great Barrier Reef Marine Park Authority, Australia), 12 reports presented existing management and conservation plans, restocking and enhancement strategies and ongoing research activities. The last session of the workshop (Session III) centred on recent advances in aquaculture farming technologies, and featured many speakers from Chinese research institutions and the private sector. This session was chaired by Dr Jean-François Hamel and Dr Annie Mercier from Canada (Society for the Exploration & Valuing of the Environment). Presentations dealt with hatchery and farming techniques covering diseases, nutrition and other important topics related to sea cucumber reproduction and farming.

At the end of each session the participants took part in group discussions to deliberate on the major issues raised. Comments from these group discussions provided the basis, on the last day of the workshop, for the production of a list of recommendations developed by the Session Chairpersons and the FAO Fisheries Department officer, Mr Alessandro Lovatelli. These recommendations are designed to help international and regional development organizations and national governments prioritize their activities concerning sea cucumber conservation and exploitation. The full and edited papers presented at the three sessions of the workshop are reproduced in this FAO Fisheries Technical Paper.

WORKSHOP RECOMMENDATIONS

From the reports presented during the workshop on sea cucumber fisheries and aquaculture, it is clear that sea cucumbers in most countries are suffering from severe exploitation and population depletion. The discussion sessions were used to develop recommendations agreed by the participants.

SESSIONS I and II - Recommendations for sea cucumber fisheries and management

During these discussions, it was recognized that a critical need is to establish and implement management plans towards sustainability of adequate breeding populations of all fished species. Countries should also aim to develop management plans prior to opening further fisheries – only one of the counties reported at this workshop (Cuba) had data of virgin stock biomass.

An overriding issue is the lack of information on appropriate management approaches and analytical tools. The fact that overfishing and stock depletion is still occurring indicates that specific approaches are needed for managing sea cucumber trading and fisheries.

Catches and processed products records

In order to manage the existing resources and regulate trade, data at the national level (on catches, processing and exports) need to be collected. Because these activities demand human resources, governments should incorporate the costs of these activities into the fishery section of their national budgets.

Statistics at national and international levels should be standardized to ease cross referencing between countries.

Major points to be considered, as inaccuracies still appear in several countries, are:

- Records on the main species or taxonomic groups should be made available to the public.
- Wet weights should be recorded for landings, and it should be clearly defined if these are gutted or whole animal wet weights (and, if possible, conversion factors between the two).
- The grades and sizes need to be recorded in order to quantify the extent of harvests and processed products.
- The numbers of animals should also be listed in records, to allow an estimation of the sizes.
- Data from processors should reflect the actual weight of the product forms (e.g. fresh, frozen and dried).
- Compilation of the statistics should be the responsibility of the national authority.
- If data are collected through exporters/traders at the national level, regulations (and possibly penalties) should be placed on the non-reporting of exports.
- Double reporting in trading (import and re-export) needs to be monitored and documented by regional/ international bodies.
- A uniform taxonomic guide is needed for fishery workers and traders. This point will need some agreements between scientists, as the names of several species changed recently.

Harvesting and post-harvesting methods and information

In many sea cucumber producing countries, a large section of the harvest is produced as a sub-standard product that enters international trade as low value items. In many cases, both fishermen and exporters fail to realize the maximum value of the resource. Therefore technical assistance on post-harvest handling, processing and quality assurance is required in developing countries. This may reduce pressure on the existing sea cucumber resources if fewer animals need to be harvested to earn equivalent money.

A strong recommendation was for the development of manuals and training courses/workshops for best practices in post-harvest handling and processing. These should be presented in local languages and in simple terms.

These manuals should include, but not be restricted to, the following:

- Fishing and handling methods to minimize damage of harvested animals.
- Post-harvest handling techniques.
- Updated and reliable methods for processing, established from both research (i.e. to document new methods), and sourcing of existing information. These should be described for different species, but recognizing differences in needs of different buyers and markets.

Additionally, research is needed to analyse the supply and demand for sea cucumbers with projections for the next 15-20 years. In particular, it should be investigated as to what effect the large increase in production of *A. japonicus* in China will have on the global market.

Socio-economics and legislation

Public awareness of sea cucumber fisheries should be raised at a range of levels to highlight their importance and vulnerability to overfishing. Networking and cooperation among researchers and fishery workers should be promoted. This could be achieved by forming associations for processors and traders, researchers, fishery managers and farmers. Additionally, newsgroups via e-mail or the Internet would be valuable for exchange of information.

Sea cucumber fishing is very important to the livelihoods of coastal communities, particularly artisanal and small scale fishers in developing countries. Therefore, socio-economic issues in sea cucumber fisheries are important and should be recognized and incorporated in fishery management programmes. In particular, livelihood options should be made available to fishers if management regulation put restrictions on the fisheries, such as bans on fishing.

International intervention (e.g. FAO; International Union for the Conservation of Nature and Natural Resources – IUCN; Convention on International Trade in Endangered Species of Wild Fauna and Flora – CITES) may be needed to assist in the conservation and management of sea cucumbers. However, caution should be exercised when intervening in or regulating trade for all regions, as there are regional differences in the status of populations of sea cucumbers, habitats and environment. The possibility to initiate listing in CITES Appendix 2 or 3 for certain countries should be examined and the effects analysed. A sea cucumber species from South America and the Galapagos Islands were the first such animals listed in CITES Appendix 3.

Legislation should involve the following:

- Participation of stakeholders (including fishers, processors, policy-makers, managers, exporters) in formulating management plans.
- Authority divested at local/customary level, in certain circumstances (e.g. Melanesian artisanal fisheries with customary tenure).
- Enforcement to ensure protection of sea cucumbers and their habitats.

Stock assessment

Common methods of data collection and presentation of results should be developed for commercially-exploited species. However, it should be clearly recognized that ecological traits differ markedly amongst species, thus managing sea cucumbers as a multispecies fishery with the same regulations for all species is strongly discouraged.

Initial stock surveys should be conducted before a fishery commences in order to obtain information on the virgin biomass. Monitoring the recovery of stocks after fisheries have been closed should also be encouraged.

Several key recommendations:

- Habitat types (e.g. cover of sea grass or corals, sediment or substratum characteristics) should be recorded for each survey unit (e.g. transect).
- Global Positioning System (GPS) waypoint referencing should be applied where possible. This technique will allow sites to be visualized using Geographic Information System (GIS) technology and can allow more accurate calculation of stock densities and, in certain circumstances, distances between individual holothurians.
- The size and spatial context of the populations need to be defined, in particular, the area surveyed and the likely area occupied by the sub-population.

Management plans

Management plans for sea cucumbers fisheries should be conservative because stocks are vulnerable to overfishing. The most incipient threat is the depletion of sustainable breeding populations that endangers natural replenishment of populations.

The participants identified a number of recommendations for fisheries managers that should be followed to prevent depletion of breeding stocks:

- The collection of sea cucumbers using compressed air (either SCUBA gear or "hookah") or weighted hooks should be restricted. Bans on using compressed air can protect deep stocks, but caution should be given because shallow stocks may be more important for spawning. In cases where SCUBA or "hookah" diving is permitted, the divers need to be trained to avoid risk to life of the divers and adhere to accepted Occupational Health and Safety (OHS) guidelines, including the use of safe equipment.
- A "code of conduct" should be developed and promoted for responsible fishing practices. This would involve common sense fishing practices such as not collecting undersized sea cucumbers and preserving a proportion of the populations to act as breeding stock.
- Habitats should be protected as well as the resource. Authorities should endeavour to protect the ecosystems in which sea cucumbers live and, conversely, recognize the important role that sea cucumbers play in ecosystem processes. Where sea cucumber habitats have been damaged, rehabilitation should be considered.
- Attention should be given to evaluating the occurrence and significance of sea cucumbers as by-catch in trawl nets and dredges. These indiscriminate fishing methods can impact populations and habitat. By-catch of sea cucumbers in other fisheries needs to be both researched and documented.
- Sea cucumbers should be recognized as significant marine resources, whether fished or not. The management of sea cucumbers should be embodied within the broader context of sustaining marine resources.
- Regular monitoring of populations should be employed and, in the case of restocking or use of *moratoria*, the recovery of depleted populations should be evaluated.

Fisheries regulations should aim to protect ample breeding populations of each species. If the populations of any species are fished below levels perceived to be minimal for breeding populations, then bans or moratoria should be placed to halt further fishing. For areas that have been closed to fishing by moratoria, the lifting of fishing bans should only proceed after it is established that stocks are viable for reproduction and can sustain fishing.

Critical research needs

Research and assistance should have a stronger emphasis in countries where sea cucumber fisheries are important, where exploitation has been high, or where knowledge is critically lacking. Research should also be promoted in a range of countries to test generalities among regions and cultures. The main research topics needing attention are listed below.

1) Parameters for fishery models: Growth, mortality and recruitment

Most crucial is the need for research on growth rates, particularly in early stages (juveniles) in the wild. This information must be gained from individual species, and obtained from laboratory and field studies. In addition, data from several locations need to be available in order to know if patterns are general or location specific. Information on mortality and longevity in the wild is also needed, to allow sustainable catch rates to be estimated.

Research on larval ecology and recruitment processes of holothurians is also needed to develop fishery models, and these processes will be widely variable in space and time.

Maximum sustainable yields for fishing sea cucumbers should be estimated for different types of fisheries, based on surveys of stock size and estimates of recruitment, growth and natural mortality.

In many cases, however, these data may not be available. If this is the case, Total Allowable Catches (TACs) should be set conservatively (e.g. assuming less that 10% of virgin biomass can be taken per year) until subsequent monitoring of stocks, recruitment and catch data indicates that catch rates could be increased without jeopardizing larval production and subsequent recruitment.

Moreover, TACs alone are not sufficient for the management because this tool does not consider the size structure of existing stocks. A fishery could be made up of small animals, which are harvested at the expense of egg production of the site.

2) Minimum stock size for viable breeding populations

Populations need to be maintained at a minimum threshold level to ensure successful reproduction in the wild. This is because sea cucumbers use chemical cues to spawn and need to be close to mates to allow fertilization of oocytes. Below such threshold densities of adults, populations will fail to repopulate naturally. A disproportionate reduction of recruitment when densities of spawners are reduced has been termed the "Allee" effect in the general ecological literature.

Studies are needed to establish the thresholds for minimum size of effective breeding populations to avoid Allee effects. Some literature exists for other taxa, but research is needed to establish the research tools to determine this threshold for each species. Therefore, substantial information on fertilization kinetics, reproduction and chemical cues in holothurians is required. Research related to population size-dependent reproductive success exists, but these studies have long been considered theoretical aspects with little practical use and therefore not used by the fisheries industries / programme managers. This means, not only more research but also better distribution and application of the existing literature is needed.

3) General ecological studies

In addition to studies on larval recruitment (see above), other studies should examine the factors affecting the movement of sea cucumber larvae within the water column and factors influencing settlement. An understanding of larval movement and settlement processes will improve predictions on dispersal and the likelihood of self-recruitment and natural replenishment of populations. Specifically, more information is needed on the source and sink of recruits for local populations.

General research techniques and approaches are needed for collecting and analysing quantitative data on the ecology of sea cucumbers, taking into consideration their seasonal and diurnal behaviours.

Information on the ecology of juvenile holothurians is sparse but is needed, particularly, for aquaculture grow out and restocking programmes.

Little research exists on the effects and benefits of sea cucumbers on ecosystems. Studies indicate that removal of these animals could lead to major changes to the ecosystem, such as decreased overall productivity. However, to confirm this effect, large-scale experimental work in multiple areas with natural densities and overfished areas must be conducted.

4) Effectiveness of Marine Protected Areas or No-Take Zones and methods of management

Different modes of management have been used for sea cucumber fisheries but few cases, either of failures or successes, have been documented. There is a need for a review that summarizes case studies where management has worked and how participatory management can be used.

Knowledge on the effectiveness of Marine Protected Areas (MPAs) (especially *No-Take Zones*) and comparison of a range of management methods (such as broad fishery closure) should be collated. Research should also be encouraged to determine the appropriate sizes, numbers and spatial design of MPAs, and to investigate if "spillover" effects from these zones into fished areas occur. This could also include a review of existing literature and case studies on MPAs.

Research is needed generally for understanding which management tools/approaches are best for sea cucumber fisheries and under which circumstances. These could include imposition of tax, regulating the number of fishers, fishing effort, fishing seasons, sites, or minimum legal size limits.

5) Stock delineation

Stock delineation and quantifying the spatial extent of populations are important for managing stocks and understanding recruitment. Such information is particularly relevant for restocking over broad spatial scales, due to likely adverse effects on genetic diversity if genetically different stocks are mixed.

6) Taxonomy

The taxonomic status of some of the most valuable holothurian species is uncertain and recent studies indicated the potential for the existence of a number of cryptic species among holothurians. Classical and genetic taxonomic studies are needed to clarify the status of sea cucumber species.

7) Restocking

Restocking is generally only a last resort if other management measures to recover a depleted fishery have failed. Good management to preserve breeding populations should be the first solution because there are risks of changing genetic diversity of existing stocks when juveniles are released for restocking or stock enhancement.

Recommendations for restocking:

- Definitive studies are needed about the economic viability and returns from restocking programmes in which hatchery-produced juveniles are released into the wild.
- The value and significance of restocking to ecosystem functioning and long-term repopulation needs to be included in cost-benefit analyses.
- Release of hatchery-produced juveniles should only be conducted at sites with the same genetic stock as the broodstock used for production. Translocation of animals into foreign grounds should be prohibited.
- Spawners (both male and female) should be chosen in sufficient numbers to provide genetic diversity and gene frequencies in the offspring similar to that in the receiving areas.
- The danger of the transfer of disease, parasites and introduced species from restocking programmes needs to be controlled. Transfer protocols and disease checks need to be developed to ensure healthy juveniles are used for restocking.
- The carrying capacity of the habitat (in terms of both number and biomass) should be evaluated before restocking.
- Methods on the best strategies for releasing juveniles should be researched prior to restocking.

SESSION III - Recommendations for sea cucumber aquaculture

Dissemination of available information on sea cucumber aquaculture

The presentations and following discussions brought to light a huge amount of knowledge. Several ways to disseminate and share this information were proposed, as summarized below.

1) Publication of a manual or guide on sea cucumber aquaculture:

The chief recommendation made by the participants of the workshop was to prepare and publish a reference manual that would compile the various aquaculture techniques currently available or being developed for the main commercial species of sea cucumbers. This practical guide should be well illustrated and be written in a clear accessible language that would address the needs of prospective aquaculturists and farmers. It would indirectly provide basic information on sea cucumber aquaculture to stakeholders and policy-makers. Although it should first be published in English, the book could eventually be translated to reach a broader audience, especially the Chinese community who has made a significant contribution to this field. Topics that are likely to be covered in such a manual include:

Hatchery techniques

- Broodstock collection and handling
- Spawning induction
- Larval rearing
- Early juvenile rearing

Farming/sea ranching techniques

- Juvenile grow out
- Pond preparation/management
- Co-culture with other species (polyculture)

General advice

- Summary of cautions and known difficulties
- Main components and basic costs of a sea cucumber aquaculture project
- Glossary of technical and popular terms

2) Enhancement of international exchanges:

The bringing together of experts from the scientific, technical and business aspects of sea cucumber aquaculture was another important outcome of the workshop. In order to encourage collaboration and technology transfer, it was suggested that a directory of specialists from the different fields of work be compiled and made available. It could include a complete listing of available references pertaining to the main commercial species as well as a list of available directories/contacts pertaining to import/exports and markets. This index of literature and experts should be accessible in print as well as through the internet.

Benefit would be gained by creating working groups and networks, perhaps through international agencies and societies.

Because communication relies on a certain degree of uniformity, consideration should be given to the standardization of the vocabulary used to report the data in the future.

Suggestions for future research and development

The presentations and discussions showed that although significant breakthroughs and advances have been made by many teams in the field of sea cucumber aquaculture, a number of aspects still need to be investigated in order to allow further development. This is especially true for tropical species of sea cucumbers being cultivated in developing countries.

1) Fundamental biological research:

Several problems in the culture and grow out of sea cucumbers stem from the lack of basic knowledge on the general biology of both adults and juveniles. Main areas of research should include reproduction, feeding ecology, substrate selectivity, predation on all life stages and chemical defences.

It has been suggested that hatchery-produced juveniles could develop behavioural deficits that would lower their survival rate once they are released in the field for restocking. This has to be studied as well as the potential effect of captive breeding on the presence or levels of bioactive substances in the tissues, which have various roles: some can serve as defence mechanisms and others have properties that are valued in processed products sold for human consumption.

A better knowledge of the diseases and parasites that affect all the life stages has to be acquired in order to identify the causal agents of the major culture failures. Discrimination should be made between the deleterious and potentially beneficial species that live in association with sea cucumbers.

2) Hatchery techniques:

Most of the existing methods used to induce spawning in sea cucumbers are still not very reliable. Furthermore, the common practice of shocking the broodstock (thermally or mechanically) is suspected to result in the shedding of immature or deteriorated gametes. Alternative methods for spawning induction should be investigated to maximize both the quantity and quality of gametes obtained, and optimise the reproductive success of spawning.

Metamorphosis from pelagic to benthic forms remains a crucial step in sea cucumber aquaculture during which high mortality rates are recorded. Hence, investigation of settlement requirements and preferences of the larvae should remain a priority. The formulation of feeds should also be studied in order to improve the growth and survival rates of the larval and juvenile stages.

The control of disease outbreaks in culturing sea cucumbers needs more research and documentation. The uncontrolled use of antibiotics is a growing concern. Their effect on the sea cucumbers themselves, on the environment and on the eventual consumers should be investigated closely and alternatives developed and promoted.

3) Farming/sea ranching:

For the species that have been successfully reared to the juvenile stage, grow out methods should be improved to maximize cost effectiveness. More specifically, research and documentation is needed on successful approaches for pond management and on the choice and preparation of sea ranching sites (e.g. habitats, substrates, enclosure materials, control of environmental factors).

The possibility of recycling abandoned infrastructures used to grow other marine species to meet the needs of sea cucumber aquaculture should be assessed, as well as the prospects for co-culture of sea cucumbers with other commercial species, either simultaneously or successively.

General preoccupations

Even though the purpose of the workshop was to gather knowledge from different experts in order to promote and help the development of sea cucumber aquaculture, several participants have expressed a number of concerns. One of the concerns is the potential effect that commercial-size aquaculture facilities could have on the environment. As the industry develops, the benefit and usefulness of farming and sea ranching in different environments and countries should be addressed and weighed against the cultural and environmental costs. Ultimately, guidelines for ethics and conservation measures should be developed and promoted.

GLOSSARY

Beche-de-mer: the name in some Western Tropical Pacific countries for the dried product processed through several steps. "Trepang" is the name in Indian Ocean countries for the same product.

Egg: a fertilized oocyte.

Juvenile: young sea cucumber before reaching sexual maturity.

Marine Protected Areas (MPAs): several definitions for MPAs exist, a generally accepted one is from the Intrenational Union for the Conservation of Nature and Natural Resources (IUCN): '… any area of the intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment'. Thus, an MPA is not necessarily completely closed to commercial or recreational fishing.

Maximum Sustainable Yield: the highest level of harvesting of wild animals that can be sustained without reducing average future yields of the fishery.

No-Take Zones (NTZ): sections of intertidal or subtidal terrain and overlying water delineated and legislated where no fishing or collection of certain species or groups of animals or plants can occur for a defined period. Often a No-Take Zone may be a special zone within an MPA.

Oocyte: a female gamete before it is fertilized and becomes an egg.

Recruitment: the process by which new individuals of a species are added to a population, often by the supply of larvae that survive to become juveniles in the population.

Restocking: the act of rebuilding stocks of spawning adults in wild populations, for example by releasing hatchery-produced juveniles or adults to a depleted population.

Sea cucumbers or **holothurians:** marine animals belonging to the Phylum Echinodermata, Class Holothuroidea. Certain (>20) species are fished for human consumption, traditionally in small artisanal fisheries.

Spawners: reproductively mature animals in a population.

Stock enhancement: the activity of increasing fishery yield in wild populations, for example by releasing hatchery-produced juveniles to an existing, fished population.

Total Allowable Catch (TAC): the total number or weight of animals that are legally permitted to be collected or fished in a season or year.

Session I
Status of resources and utilization

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

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Abstract

In this report the data on traditional and recent world-wide tropical and temperate sea cucumber fisheries for the last decade (1992-2001) are summarised. The data are based on FAO statistics, from various issues of the Beche-de-mer Bulletin and other available publications. There has been an increase in interest for 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 SAR (China), Singapore and Taiwan (Province of China), all three important Asian markets for sea cucumber as well as being ports for re-exporting to other markets such as China mainland. These trade flow mechanisms, particularly in Singapore and Hong Kong SAR (China), are difficult to quantify and to keep track of as products are re-exported based on regional demand and quality. The analysis of various qualitative indices clearly shows that over-exploitation is becoming obvious on a world-wide scale 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 set the general and current picture on the state of affairs within this industry. The need for further actions is emphasized particularly with regards to the development of standardised stock assessment methodologies and collection of statistical data.

Keywords: Holothurian, sea cucumber, trepang, world fishery, market, management

世界海参资源和利用现状的回顾

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摘要

本文中所论及的过去14年间（1986-2000）有关热带和温带的海参数据系来自于世界粮农组织（FAO）的统计资料、各种有关海参的报告和其他出版物。总体上说，人们对底栖生物及其渔业的发展兴趣不断增长，同时海参渔业的迅速扩展在渔民、加工业者和资源管理当局产生了冲突。 一般说，加工后的产品由生产国出口到中国香港、新加坡和中国台湾，这是亚洲的三大海参市场，再由此转口到其他市场，如中国大陆。这些产品的市场流向很难作定量跟踪，尤其是新加坡和香港的转口贸易。通过定性的资料分析说明，由于市场对海参需求的增长，全球的海参资源显然处于过度捕捞的处境。在资源可持续利用共识的支持下，制定一个有效的管理行动计划已成为当务之急。本文从各个不同层面研讨“海参系统”，就该产业的全貌和现况做了全面的概述。下一步工作重点主要是制定资源评估标准和收集有关统计资料。

关键词：海参、世界渔业、市场、管理

Introduction

The most important sea cucumber product is the dried body wall which is marketed as beche-de-mer (trepang or hai-som) (FAO, 1990) (Figure 1). In some countries medicines are produced, for example "gamat oil" in Malaysia (Baine & Choo, 1999). The status of the world holothurian fisheries has been presented and updated several times (FAO, 1990; Conand, 1998, 2001; Conand and Byrne, 1993). Holothurian fisheries are mostly based on about thirty species amongst the more than one thousand existing aspidochirote holothurians. Beche-de-mer fisheries have a long history, as the Chinese have sought sea cucumbers for a long time and there are many old stories about holothurians in the Japanese literature. During the 18th and 19th centuries, traders gathered them in a wider area with a "boom and bust" mentality and overexploitation started in several places. Nevertheless these fisheries are still poorly documented and, in many cases, not managed.

During the last decade (1992-2001), from the FAO statistics and other sources, it appears that the interest in these resources has increased markedly in different directions, through: 1) an increased demand for product; 2) a spatial extension of these fisheries, 3) developments in mariculture in many countries which are regularly presented in the Beche-de-mer Bulletins, and 4) an increased interest in the resource biology and management and the desire to disseminate the information obtained more widely. These goals have greatly benefited from the SPC (Secretariat of the Pacific Community), as the Information Section produces Information Bulletins, such as the one on sea cucumbers, The Beche-de-mer Bulletin. This bulletin also provides an international network. The analysis of the contents of the 18 bulletin issues points out the widening interest on this subject. The 'Advances in Sea Cucumber Aquaculture and Management' (ASCAM) workshop organized by FAO (2003) will help set the general and current picture on the state of affairs within this industry. The need for further actions will be emphasised particularly with regards to the development of standardised stock assessment methodologies, collection of statistical data and development of mariculture and restocking.

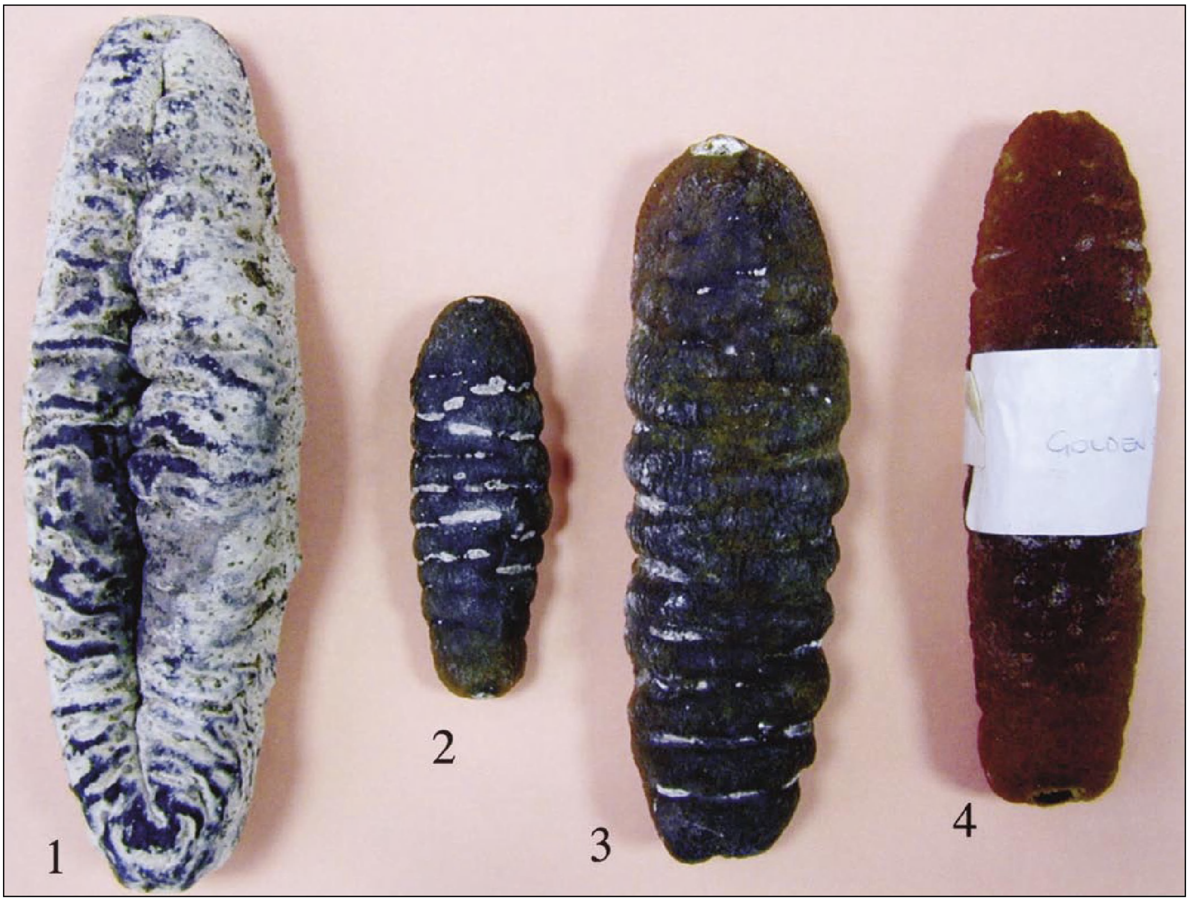

Figure 1. *Beche-de-mer high quality products; 1* H. nobilis, *2* H. scabra - *small, 3* H. scabra - *large, 4* H scabra versicolor.

The whole "Holothurian Fishery System" has been presented earlier (Conand & Byrne, 1993; Conand, 1998, 2001), using the example of the tropical Indo-Pacific fishery for beche-de-mer. The five levels of this system between the resource on the sea-floor and the plate of the consumer are very important both for fishery evaluations and for durable management. At each level and between the levels, different participants intervene.

Commercial sea cucumber species are harvested according to the main geographical areas. In general, more interest has been given to the biology of the species targeted in traditional fisheries than to more recent ones. Despite the abundance and the large size of these animals and their importance in benthic communities, little information is published on their population biology compared with other living marine resources.

The fisheries can be presented according to the geographical area and the species harvested. Tropical fisheries from the Indo-Pacific are multi-specific, whereas temperate fisheries are generally mono-specific. Traditional tropical fisheries in the Western-Pacific and Indian Oceans produce dry product. Recently, some countries have started exploitations on the Eastern-Pacific coasts. Temperate fisheries for fresh or frozen product were long limited to the North-Western Pacific Ocean and there are now other countries interested. Fishery statistics have been collected from several sources, including producer countries (catch and export statistics) and international FAO data (annual yearbooks for catches, 1992 to 2001). These data are synthesised for the last decade to show where most product originates and what are the new trends. The gaps or inaccuracies will be discussed to help formulate recommendations for a future better fishery knowledge and management.

World fisheries in 2001

Table 1 and Figure 2 present the main world fisheries by regions and by country from FAO data (FAO, 2003) and other sources for the period 1992 to 2001. It is important to separate the fisheries into groups to better analyse their characteristics, with on the one hand tropical and temperate fisheries and on the other hand traditional and recent fisheries. The first analysis will look at the more recent data (2001).

Traditional tropical fisheries from the Western Pacific and Indian Oceans

Tropical fisheries in the Indian (refer to IOW in Table 1) and Western Pacific (refer to PWC & IOE in Table 1) produce dry product in two main regions: Western Central Pacific (which is the main producing region in the world) and Indian Ocean.

Western Central Pacific - Indonesia was always the major world producer and exporter of beche-de-mer product with 2 280 tonnes from the Pacific coast and 970 tonnes from the Indian Ocean, (which corresponds to more than 32 500 tonnes fished, as statistics generally refer to processed products). Tuwo (in press) describes the situation of the fishery using the example of Sulawesi. Local consumption by Chinese people in Indonesia is not evaluated, but probably does not exceed a few hundred tonnes.

The Philippines were considered once as the second largest producer in the world with a "boom" around 1996 (Schoppe, 2000), but catches have fallen to 800 tonnes (dry weight) in 2001 according to FAO. It appears however to be somewhat higher as presented by Gamboa *et al.* (2004).

In Malaysia the situation is complex, as the country appears simultaneously to be a producer, exporter, importer, and consumer and the product appears under different categories (live, fresh or chilled and frozen) (Baine and Choo, 1999). The data do not appear any more in FAO statistics, but Choo (2004) shows that in 2001 the fishery is important in Sabah, while in Peninsular Malaysia stichopodids are exploited for their medicinal properties (gamat products).

Many Pacific Islands exploit sea cucumber traditionally. The FAO statistics in 2001 show the predominance of Papua New Guinea (Polon, in press), Fiji and New Caledonia. However for this last territory the FAO data are one order of magnitude higher than the local detailed statistics (provided by species, date of export and exporter; Hoffschir, pers. comm.); this inaccuracy of the data referring either to fresh or processed product is a very important source of error and has to be checked in many statistics.

Australia has an old fishery history; overexploitation has long been recognised before the fishery for black teat fish was closed on the Great Barrier Reef in 1998 (Uthicke, 2004). Different agencies are now committed to ecological sustainability as in Northern Australia (Shelley and Puig, 2004) and the interest has also increased in Western Australia (Shiell, 2004).

Table 1. Beche-de-mer production and Apostichopus japonicus *catches by country for the period 1992-2001 (metric tonnes - dry weight except for* A. japonicus*).*

		Production (tonnes dry weight except for *A. japonicus*)										
	FAO region(1)	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**Mean**
Holothurioidea												
Chile	P SE	237	13	4	106	115	1	30	108	1 510	107	223
Cuba									*20*	*20*	*13*	
Ecuador	P EC	29	12	12	12	12	12	15	15	15	15	15
Egypt	IOW						-		-	20	139	16
Fiji	P WC	447	191	400	835	850	790	400	880	800	824	642
Indonesia	IOE					269	338	630	689	903	970	380
Indonesia	P WC	3 130	2 364	3 130	2 562	2 800	2 800	2 428	1 928	2 138	2 280	2 556
Solomon	PWC	715	720	700	700	750	203	253	376	48	50	452
Kenya	IOW	277	14	41	55	15	41	38	15	30	13	54
Kiribati	PWC					-	136	154	89	64	60	50
Madagascar	IOW	423	450	1 800	1 800	1 800	1 800	482	500	500	500	1 006
Malaysia	PWC	...	...	...	...	...	...					
Maldives	IOW	119	72	66	94	145	318	85	54	205	226	138
Mexico	PEC						-	271	234	426	481	141
Mozambique	IOW	0	0	0	6	54	7	2	8	12	12	10
New Caledonia	PWC	1 090	777	798	480	493	565	402	493	615	489	620
New Zealand	PSW	0	0	0	4	1	0				2	1
Palau	PWC	2	2	2	2	6	7	7	6			3
Papua New Guinea	PWC	600	650	600	640	650	1 515	2 037	1 185	1 824	1 453	1 115
Spain	M					4	4	4	1	9	4	3
Philippines	PWC	3 679	3 109	1 497	2 062	2 123	1 191	830	849	730	791	1 686
Sri Lanka	IOW	65	65	92	100	100	272	203	170	145	120	133
Tanzania	IOW	535	980	1 591	1 460	1 644	1 527	1 800	189	372	340	1 044
Tonga	PWC	...	...	...	...	86	80	90				26
Canada	PNE	0	0	1 505	0	1 288						279
USA	ANW					1 288? (2)		2 406	3 504	4 309	1 504	1 301
USA	PNE	481	472	636	729	491			228	274	300	361
Vanuatu	PWC	39	40	40	50	45	50	50	50	50	50	46
Yemen	IOW	48	65	63	60	60			1			30
Total Holothuroidea		11 916	9 996	12 977	11 757	13 801	11 657	12 617	11 592	15 019	10 743	12 331
Apostichopus japonicus												
Japan	PNW	6 072	5 996	6 106	6 602	7 226	7 160	6 952	6 662	6 957	7 229	6 696
Korea Rep.	PNW	1 583	2 068	2 117	1 892	1 979	2 217	1 439	1 204	1 419	900	1 682
China											358	
Total *A. japonicus*		7 655	8 064	8 223	8 494	9 205	9 377	8 391	7 866	8 376	8 487	8 378

(1): **ANW**: Atlantic, Northwest; **IOE**: Indian Ocean, Eastern; **IOW**: Indian Ocean, Western; **M**: Mediterranean and Black Sea; **PEC**: Pacific, Eastern Central; **PNE**: Pacific, Northeast; **PNW**: Pacific, Northwest; **PSE**: Pacific, Southeast; **PSW**: Pacific, Southwest; **PWC**: Pacific, Western Central.

(2): This amount is either for Canada either for USA and therefore not included in the total figure.

Indian Ocean Countries - In the Eastern Indian Ocean, Sri Lanka and India are traditional producers (120 tonnes dry weight in 2001 for Sri Lanka). The Maldives has been an important newcomer since 1988, and in 2001 the production is very high with 226 tonnes dry weight.

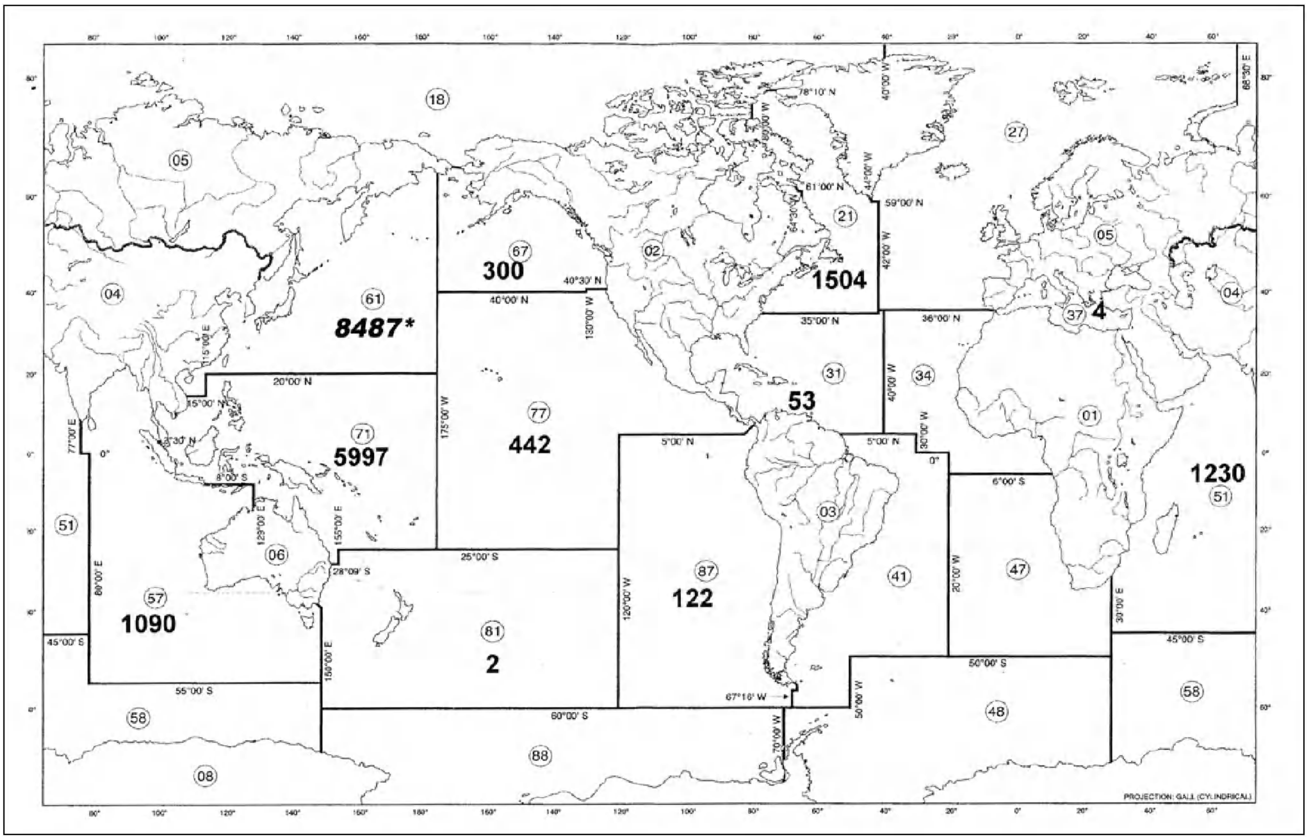

*Figure 2. Beche-de-mer production (tonnes) in bold, for 2001, according to FAO zones and different data. *captures (tonnes) for Zone*

In the Western Indian Ocean, many African and Arabic countries produce and export beche-de-mer on a regular basis. In 2001, Madagascar (500 tonnes dry weight) and Tanzania (340 tonnes dry weight) were the leaders. The problems encountered and the projects for a better management are presented (Mmbaga and Mgaya, 2004; Rasolofonirina and Jangoux, 2004). Other countries such as Egypt (Lawrence *et al.*, 2004) and the Seychelles (Aumeerudy and Rondolph Payet, 2004) have recently started the exploitation. As elsewhere, they are rapidly experiencing problems in the evaluation and the management of the resources.

Other tropical fisheries

An increasing interest has developed in different tropical countries along the Atlantic and Pacific coasts. In these regions the biodiversity is less than in the tropical Indo-West Pacific; these fisheries are therefore concentrating only on one or a few species.

Along the East Pacific coasts, in Ecuador and Galapagos Islands, the fishery for *Stichopus fuscus* has brought many debates (see Martinez, 2001 and other contributions in the Beche-de-mer Bulletins). A participatory management program to assess the resource has been initiated in Galapagos (Toral-Granda and Martinez, 2004; Altamirano and Toral-Granda, 2004). In Chile, a fishery exists for a denchirote species but it is very poorly documented (Ravest Presa, 2000); the FAO statistics show 107 tonnes in 2001 after a peak of 1 510 tonnes in 2000; it is not clear if these data are fresh or dried weights. The same problem arises with the data of the fishery from this coast of Mexico which peak in 2001 with 442 tonnes and causes socio-economic problems (Ibarra and Soberon, 2002).

On the Atlantic coast, the Mexican fishery seems less active (39 tonnes in 2001), while Venezuela does not appear in the statistics. The fishery started in the 1990s with legal and illegal activities in which Korean entrepreneurs were involved (Rodriguez-Millet and Pauls, 1998). Cuba is another example of a very recent fishery that was monitored from its beginning (Alfonso *et al.*, 2004).

Temperate fisheries

The temperate fisheries are more or less mono-specific, based essentially on *Apostichopus japonicus* in the Western Pacific (refer to PNW in Table 1) and on *Parastichopus californicus* in the Eastern Pacific (refer to PEC in Table 1).

Traditional Western Pacific temperate fisheries in the East Pacific comprise the Japanese fisheries particularly important in Hokkaido, presented by Akamine (2004), the Chinese fisheries presented by Jiaxin (2004) (and also includes smaller Korean fisheries and Russian fisheries). They are largely for fresh product and are therefore presented separately in the capture figures (Conand, 1998). The FAO statistics indicate 7 229 tonnes (2001) production for Japan and only 900 tonnes for Korea.

In the Eastern Pacific fisheries have developed in the United States (Alaska, Washington State and California) (Bradbury, 1997; Bradbury *et al.*, 1998) and Canada (British Columbia) for beche-de-mer and fresh frozen products, where the five longitudinal muscles are stripped from the body wall and frozen for export to Japan and Taiwan (Province of China). The body wall is then processed into beche-de-mer for export. The dive fishery is controlled by the Department of Fisheries, USA. Recent research on the biology of *P. californicus* provides a scientific basis for the management of the fishery. Limited-entry legislation was also approved in 1990 and the number of boats licensed declined (Conand, 1998).

The FAO statistics for 2001 give 300 tonnes for USA, but Canada does not appear.

In the Northwest Atlantic, the FAO statistics for 2001 give 1 504 tonnes for USA which is very important and not well documented, and again Canada does not appear.

Trends for the last decade (1992-2001)

The data presented in Table 1 show the statistics for that decade. Earlier data can also be compared to extend the period (FAO, 1990; Conand, 1998, 2001; Conand and Byrne, 1993) to analyse the trends on a longer time frame. The following main trends appear according to the main producer countries which do not have domestic markets for beche-de-mer.

In Indonesia, as in other countries, the production appears to be regularly increasing since 1988-89 (Tuwo, 2004).

The Philippines seems to show a marked decrease since 1992.

The Maldives has presented a huge increase in 1997 (318 tonnes), followed by a steep drop for two years and then a more recent increase; these fluctuations seem characteristic of unregulated sea cucumber fisheries, and likely to soon experience overexploitation.

The production of the tropical countries has not significantly declined during the decade, as new countries (Egypt, Kiribati, and Cuba) compensate for the decrease of some traditional producers. Landings by traditional temperate countries (mostly Japan and the Republic of Korea) show little changes from 1992 to 2001. The recent extensions of the fisheries into the South Eastern tropical Pacific (Chile) and tropical Atlantic (Cuba) are noticeable. An interesting point is the conflict between users which are reported inside a country, as well as between countries. Illegal fishing is an important problem of management, as capture of sea cucumber often occurs in marine reserves. It appears that developments of the recent fisheries raise more controversies and conflicts than the traditional ones, probably as people are now more aware of conservation needs.

World markets: quantities and prices

The world beche-de-mer market is largely controlled by Chinese traders (FAO, 1990; Conand, 1989, 1994, 2001). Trends in the quantity and value appear from statistics for the three main markets, Hong Kong SAR (China), Singapore and Taiwan (Province of China). These markets are also the major re-exporting centres. Trade statistics can be collected from several sources including main markets (data for import and re-export from Hong Kong SAR, Singapore and Taiwan Province of China) and international FAO trade data (annual yearbooks for commodities from 1988 to 1998). The reliability of some data remains doubtful.

Hong Kong SAR (China) is still the major world market. Singapore is the second most important market and it appears rather stable. Its major suppliers come from the Indian Ocean (Tanzania, Madagascar), but Papua New Guinea is also significant. Taiwan (Province of China) is the third largest market. The trade statistics are very detailed, the sea cucumbers appearing under many categories such as: "live, fresh or chilled", "frozen", "dried spiked", "dried not spiked" and "dried other".

The interactions between the markets with the reciprocal exchanges between Hong Kong SAR (China), Singapore and Taiwan (Province of China) are not easy to understand and this complicates the evaluation of catches from the market data. In fact the same product can appear twice, or even three times, in the imports if it has been re-exported. The general flux is always from Singapore to Hong Kong SAR (China). The reciprocal exchanges between Taiwan (Province of China) and the other markets are limited.

The recent trends are presented by Ferdouse (2004) following previous papers (Ferdouse, 1999).

Discussion and conclusion

Overexploitation and sustainable management

Although sea cucumbers have been exploited for a several hundred years, the resource is fragile. The world fishery and market statistics are generally not sufficiently detailed and trustworthy to give evidence of overexploitation, thus qualitative signs of overexploitation must also be looked for, amongst the trends and changes. Baine (in press) discusses the problems associated with the collation of the statistics on catches, effort and trade, using published information and an exploratory questionnaire.

In Madagascar, for example, detailed information (Conand *et al*., 1998; Rasolofonirina and Jangoux, 2004) has been obtained during the Environment Programme of the Indian Ocean Commission (EU/COI). Fishing pressure seems very high nowadays, a fact also apparent from market and FAO data. Evaluation and management programmes have started locally through the collaboration between the administration, traders and the scientists. A National Trepang Traders Group (ONET) was set up in 1996. The follow up of this experience or the reasons why it collapsed is of interest for other countries. In a regional context, holothurians are one of the resources studied to develop a durable management system. Some qualitative indications are apparent from these fisheries: 1) all species, available on reef flats or in shallow waters, regardless of size or commercial interest, are collected, including rare and unidentified species, for example *Bohadschia atra* has been found during sampling surveys (Massin *et al*., 1999); 2) SCUBA divers are complaining that they have to dive deeper and look for other fishing grounds, and diving accidents have increased markedly; 3) the sizes of the different species (and the processed products) are diminishing; and 4) strong competition appears among collectors, leading to a decline in processing quality. These observations, found at different levels of the "fishery system" are indicative of overexploitation. Similar experiences of "integrated management" seem to start in different countries, but will they be durable?

Plan of Action

A plan of action is now necessary with several components: assessment of stocks, improvement of statistics, improvement of collecting and processing procedures, legislation for management and farming experiments (Figure 3). The durable management of the fisheries requires production models that combine data on fishery activity, on population dynamics of the species targeted and on socio-economic aspects, the latter being particularly important for these small artisanal activities. The paucity of data on catches, as well as on biomass, is the main reason why management generally does not exist on a durable basis. In a few countries, regulations (generally bans) are introduced when overexploitation has already occurred and the regeneration of the stock is therefore long and difficult and when there is some illegal fishing.

Figure 3. Action Plan for the different levels of the "Holothurian System"

Fishery system		Management actions	
1	Natural resources of commercial species	1a	Research on biology and stock assessment
		1b	Hatcheries - production of juveniles
		1c	Sea ranching - mariculture
2	Fishermen catches collected by wading, snorkelling, scuba diving	2a	Respect of fishery legislations: size (bans of juveniles), period, zones, national or international (CITES?) legislations
		2b	Collection of standardized statistics
		2c	Education
3	Processing by fishermen or processors	3a	Improving the quality during all phases of processing
		3b	Storage, grading
		3c	Education
4	Fishery services national, then international trade	4a	Communication between the actors
		4b	Storage, grading
		4c	Standardized statistics
		4d	Access to information - legislations
5	Import and consumption	5	Information on market regulations and preferences

The resource level - The life history traits and the ecology of the populations of many of the commercial species are still poorly documented. Very little is known concerning larval stages, recruitment, growth and mortality of most species, temperate as well as tropical. Many species appear to be slow-growing and very vulnerable and the stocks are therefore fragile. This basic biological knowledge is also needed for any mariculture programme.

More research to quantify the population parameters is still necessary. Previous studies have shown that the holothurian resource is very vulnerable and that the maximum sustainable yields for tropical species are probably low, between 2 and 30 kg per hectare per year, depending on the species (Conand, 1989) or even less (Uthicke, 2004). More studies are needed on these multi-specific tropical fisheries. Stock assessments are necessary in most regions and must take into account the variety of habitats and the different commercial species. The use of marine reserves for comparative evaluations (Schroeter *et al.*, 2001; Uthicke, 2004; Lawrence *et al.*, 2004) seems promising.

The fishermen level - At this level, fishery regulations, sometimes empirical, exist in some countries often based on a minimal export size of the processed product. This is applicable in mono-specific fisheries, but should be based on biological parameters when concerning several species. Other regulations, as for other resources, concern limitations of catches (by quotas or zone rotation or period of closure), or the access to the fishery by permits.

The processor level - It is important to emphasise the importance of the processing (Conand, 1999). The methods used are very important for the profitability of the activity. Many countries should be more aware on how important good processing is to the viability of the industry.

The fishery services, trade and custom and international levels - It appears that the number of producing countries has recently increased both in tropical and temperate regions, but catch records are still incomplete. It remains important to improve collection and standardisation of statistics at the different levels of the "Holothurian system", at national as well as international levels. At the international level, for the first time officially, CITES has become involved (Bruckner, 2003; Baine, 2004). A number of consequences and issues must be considered carefully and discussions are needed.

In conclusion, despite an important increase in interest during the last decade by the scientific community, the managers and the users, further studies are needed on different issues for a durable exploitation of sea cucumbers. They should focus on biology and ecology of the species, economics and management and protection of the stocks by alternative solutions (Purcell, 2004). The recent conflicts appearing within, or between, several countries is interpreted as a sign of overexploitation of the resource and of a high level of demand. The management has to be appropriate for each case and stock assessments are needed. Some fishery regulations are urgently needed (followed by close monitoring) to limit the present depletion of most stocks. Development of networks and discussions will help improve management of these important resources.

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Present status and prospects of sea cucumber industry in China

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Abstract

In China there are about 20 species of edible sea cucumbers that have long been considered as a traditional medicine and tonic food. Nutrient analyses show that either the body wall or the intestine of sea cucumber has a higher nutrient value. The protein content of dried sea cucumber is more than 50 % in most edible species, while glucosaminoglycan has been detected in sea cucumber providing evidence of the pharmaceutical value of the sea cucumber. The clinical function of sea cucumber is reviewed in this paper. In order to meet the increasing demand and to protect the natural resources, the highest priority for fisheries authorities has been given to seed production of sea cucumber (*Apostichopus japonicus*) and to development of techniques for farming and ranching. Sea cucumber farming and ranching is a key part of the aquaculture sector in northern China, including the Liaoning and Shandong Provinces. The total landings from farming reached over 5 800 tonnes (dry weight) in 2002, with the sea cucumber either directly sold to restaurants or processed as dried edible and medicinal products. China has become the largest producer of sea cucumber worldwide. Farming methods and ranching techniques were introduced. The confusion of the quality of and species used for processed products have become the main issues retarding market development, while over-exploitation of earthen ponds used for farming sea cucumber could possibly induce a disaster similar to the shrimp viral diseases experienced in the early 1990s. Suggestions for further development involves seed production, new models of farming and ranching, quality control of final products as well as proper resource management to protecting these endangered species.

Keywords: *Apostichopus japonicus*, nutrients, farming and ranching, trade

中国海参产业的现状和前景

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摘要

中国有20多种可食用海参，长期以来被视为中药或是补品。营养分析表明，无论是海参的体壁还是海参的肠道都有着较高的营养价值。大多数可食用的、干海参的蛋白质含量在50%以上，此外，海参中含有的葡糖胺聚糖是海参药用价值的有效成分，本文还介绍了海参的临床应用价值。为了满足日益增长的市场需求和保护好海参资源，渔业当局将海参苗种生产作为发展刺参（*Apostichopus japonicus*）产业的重中之重，以满足海参增殖和养殖之需。海参的增养殖业已经成为中国北方地区，尤其在辽宁、山东两省，水产养殖业的新宠。2000年的总产量已达到了5800吨（干品）。部分产品直接销往餐馆、饭店，大部分被加工成干品或是制成保健品。本文对养殖技术和增殖方法作了详尽的介绍。加工产品质量的参差不齐将成为阻碍海参市场发展的一大问题，而海参池塘养殖的过度发展有可能步90年代对虾养殖业疾病暴发的后尘。本文还对海参苗种生产，增养殖的模式，以及产品质量等方面提出了若干建议可供发展海参产业参考。

关键词：仿刺参、营养、增殖和养殖

Introduction

There are about 134 species (Liao, 1997) of sea cucumbers distributed in China's seas. Of these, about 28 species (Table 1) are considered edible (Zhang, 1954, 1958) or have pharmaceutical properties (Fan, 1979). Most of the species are distributed in subtropical and tropical areas, with a few species, including *Apostichopus japonicus*, a high value species, existing in temperate waters. While most of the edible species belong to the Order Aspidochirotida, a

Table 1. Edible sea cucumber distributed in China seas.

Latin name	Common name	Commercial value	Distribution
Order Aspidochirotida			
Family Holothuriidae			
Genus *Actinopyga*			
A. echinites	Deep-water redfish	++	Taiwan, Guangdong, Xisha Archipelago, Hainan Island
A. lecanora	Stonefish	++	Xisha Archipelago, Hainan Island
A. mauritiana	Surf redfish	++	Taiwan, Hainan Island and Xisha Archipelago
A. miliaris	Blackfish	++	Hainan Island and Xisha Archipelago
Genus *Bohadschia*			
B. argus	Tigerfish	++	Taiwan, Hainan Island and Xisha Archipelago
B. marmorata		++	Hainan Island and Xisha Archipelago
Genus Holothuria			
H. (Halodeima) atra	Lollyfish	+	Taiwan, Hainan Island and Xisha Archipelago
H. (Halodeima) edulis	Pinkfish	+	Hainan Island and Xisha Archipelago
H. (Lessonothuria) pardalis		+	Taiwan, Hainan Island and Xisha Archipelago
H. (Mertensiothuria) fuscocinerea		+	Taiwan, Guangdong, Hainan Island and Xisha Archipelago
H. (Mertensiothuria) leucospilota		+	Fujian, Taiwan, Guangdong, Guangxi, Hainan Island, and Xisha Archipelago
H. (Mertensiothuria) pervicax		+	Taiwan, Hainan Island, and Xisha Archipelago
H. (Metriatyla) scabra	Sandfish	+++	Guangdong, Hainan Island, and Xisha archipelago
H. (Microthele) fuscogilva	White teatfish	+++	Xisha Archipelago
H. (Microthele) nobilis	Black teatfish	+++	Taiwan, Hainan Island, and Xisha Archipelago
H. (Selenkothuria) moebii		+	Fujian, Guangdong, Hainan Island
H. (Semperothuria) cinerascens		+	Taiwan, Guangdong, Hainan Island, and Xisha Archipelago
H. (Thymiosycia) arenicola		+	Taiwan, and Xisha Archipelago
H. (Thymiosycia) impatiens			Taiwan, Hainan and Xisha Archipelago
Family Stichopodidae			
Genus *Apostichopus*			
A. japonicus	Prickly sea cucumber	++++	Liaoning, Shandong, Hebei, Jiangsu
Genus *Stichopus*			
S. chloronotus	Greenfish	++	Hainan Island, and Xisha Archipelago
S. horrens	Dragonfish	+	Taiwan, Hainan Island, and Xisha Archipelago
S. hermanni		++	Taiwan, Guangxi, Guangdong, Hainan Island, Xisha Archipelago
Genus *Thelenota*			
T. ananas	Prickly redfish	++	Xisha Archipelago
T. anax	Amberfish	++	Xisha Archipelago
Order Dendrochirotida			
Family Cucumariidae			
Mensamaria intercedens		+	Fujian, Guangdong, Hainan Island
Order Moldavia			
Family Caudinidae			
Acaudina leucoprocta		+	Zhejiang, Fujian, Guangdong, Hainan Island

Note: symbol "+" means commercial value, the values gradually increase from + to ++++. The price is doubled 1 to 2 times approximately for each +.

few species are also in the Order Dendrochirotida. *Acaudina leucoprocta* in the Order Moldavia is the only species in this Order to be used for edible purposes and is often called the "sea potato" in China (Fu, 1994).

The Chinese advocate the use of sea cucumber as a folk remedy. As early as the Ming Dynasty (1368-1644 BC), sea cucumbers were first recorded as a 'tonic' food in the Bencao Gangmu (Li, 1596 reprinted in 1994). Later, sea cucumber was also recognized as a tonic and a traditional medicine in other ancient literatures, i.e. Shiwu Bencao (Yao, Ming Dynasty, reprinted in 1994) and Bencao Gangmu Shiyi (Zhao, 1765, reprinted in 1954).

Chinese philosophy has long considered that food and medicine are one entity. It is, therefore, very popular for Chinese to regard food as a medicine for prevention and treatment of disease. For example, Sun Simiao, a court physician in the Tang Dynasty, said: "Treat an illness first with food. Only if this fails should medicine be prescribed." Hence, Chinese cooks have revered the sea cucumber since ancient times leading to a long tradition, especially amongst the coastal population, of consuming sea cucumber to the point where it has become part of the culture and customs of the coastal communities.

According to the principles and theory of traditional Chinese medicine, the sea cucumber nourishes the blood, vital essence (*jing*), kidney (*qi*) (treats disorders of the kidney system, including reproductive organs) and reduces dryness (especially of the intestines). It has a salty quality and warming nature. Common uses include treating weakness, impotence, debility of the aged, constipation due to intestinal dryness and frequent urination. Therefore, the Chinese consider sea cucumber as a tonic rather than a seafood item. Hence, the popular Chinese name for sea cucumber is "*haishen*", which means, roughly, "ginseng of the sea".

Since the 1980s, the economic development of China has greatly improved the living standard of people and stimulated the consumption of tonic food and luxurious seafood, including sea cucumber. The consumption of sea cucumber has increased significantly. In order to meet the increasing demand, research and development of sea cucumber seed production, farming and enhancement has become a priority since the 1980s.

As early as the 1950s, artificially produced seeds of sea cucumber were tested (Zhang, 1954, 1958). However, the main progress was only achieved in the 1980s (Sui, 1985; Zhang and Liu, 1993). The advanced techniques dealing with seed production, culture and resources enhancement of sea cucumber, especially *Apostichopus japonicus*, involve three aspects:

- The technique of seed production of *A. japonicus*;
- Establishing three on-growing systems: pond farming, pen culture and sea ranching;
- Establishing conservation zones and maintenance of the original stock of *A. japonicus*.

As a result of this work, the output of sea cucumber reached 6 335 tonnes in 2002 (Anon, 2003), of which 5 865 tonnes were from cultured production and 470 tonnes from captured production (Table 5). Nevertheless, the output cannot meet the increasing demand; hence, China imports a great deal of dried sea cucumber from other countries via brokers in Hong Kong SAR (China). Owing to the lack of reliable data sources, it is difficult to provide precise figures of import levels of sea cucumbers, but prosperous businesses reveal that volumes are large.

In general, mariculture and sea ranching of sea cucumber have quickly become a prosperous sector in the northern part of China, and have gradually expanded towards the southern part including Fujian, Guangdong and Hainan Provinces. The total output of sea cucumber accounts for a small part in the entire output of fisheries, but its higher production value cannot be ignored. Recently, under the stimulation of large profits, capital investment has been continuously flowing into the sector and farming areas have sharply expanded. Hence, the rational development of, and further research into, sea cucumber production should be thoughtfully considered by relevant authorities, investors and farmers, as well as academic institutes.

Nutritional and medical value of sea cucumber

From the nutritional viewpoint, sea cucumber is an ideal tonic food. It is higher in protein and lower in fat (Table 2) than most other foods. The amino acids profile, especially for the essential amino acids (Table 3) and the presence of necessary trace elements (Table 4) makes sea cucumber a healthy food item.

Table 2. Comparison of main elements of different species of sea cucumber.

Item	Protein (%)	Fat (%)	Moisture (%)	Carbohydrate (%)	Ash (%)
Fresh body wall of AM[1]	11.52	0.03	87.83	0.38	0.99
Dried AM	68.53	0.55	8.25	--	7.56
Fresh body wall of TA[2]	16.64	0.27	76.97	2.47	1.60
Dried TA	69.72	3.70	8.55	--	9.51
Dried AJ[3]	55.51	1.85	21.55	--	21.09

Source: Wang F. G., 1997; modified by Chen J. X. 1 = Acaudina molpadioides; 2 = Thelenota ananas; 3 = Apostichopus japonicus.

Table 3. Comparison of amino acid levels in seven species of sea cucumber.

Amino acid	A	B	C	D	E	F	G
			Non-essential amino acids				
Asp	3.69	6.59	5.20	3.26	3.50	4.84	5.78
Ser	1.31	2.91	2.53	1.33	1.48	2.16	2.07
Glu	6.43	11.13	9.82	5.72	6.75	8.30	7.86
Pro	3.08	3.32	4.57	2.40	3.35	4.11	1.03
Gly	8.09	17.08	10.02	4.50	7.32	8.43	10.03
Ala	4.10	8.41	5.54	2.69	4.10	4.80	5.02
Cys	0.46	-	0.49	0.52	-	1.17	-
Tyr	0.99	1.65	1.55	1.12	1.06	1.70	1.41
Phe	1.15	1.45	1.78	1.40	1.12	1.99	1.67
Sub-total	*29.30*	*52.54*	*41.50*	*22.94*	*28.68*	*37.50*	*34.87*
			Essential amino acids				
Lys	0.64	1.02	1.59	0.38	1.09	1.45	0.92
His	0.17	0.37	0.45	2.82	0.24	0.42	0.40
Arg	3.40	6.60	4.95	1.63	3.45	4.23	4.46
Val	1.59	2.64	2.23	1.09	1.78	2.50	2.43
Met	0.89	1.03	1.40	1.21	0.90	1.49	0.86
Ile	0.76	1.39	1.45	1.93	0.98	1.51	1.64
Leu	1.49	2.64	2.64	1.74	1.75	2.63	2.59
Thr	1.68	3.44	2.68	-	1.89	2.48	2.58
Sub-total	*10.62*	*19.13*	*17.39*	*10.80*	*12.08*	*16.75*	*15.88*
Total	39.92	71.67	58.89	33.74	40.76	54.25	50.75

A: H. (Metriatyla) scabra; ***B:*** H. (Microthele) nobilis; *C:* H. (Thymiosycia) impatiens; ***D:*** H. (Lessonothuria) insignis; ***E:*** H. (Lessonothuria) multipilula; ***F:*** Actinopyga echinites; ***G:*** Thelenota ananas.

Besides the elements mentioned above, vanadium is as high as 12 ppm in the intestine of *A. japonicus*, which has been used for treating gastrointestinal ulcers (Zhonghua Yaohai, 1993).

The body wall of sea cucumber consists of insoluble collagen, which is similar to that of other herb medicines like "E-jiao", soft-shell turtle collagen and deer-horn collagen. All of these medicines have been used for treating anaemia and as a nutrient supplement of haematogenesis (Liu *et al.*, 1984). Besides higher levels of lysine and arginine, the level of tryptophan is also high in the sea cucumber body wall. This is why the gelatine of sea cucumber is more valuable than other gelatins.

Another characteristic of sea cucumber is the presence of holothurian glucosaminoglycan (HG) and holothurian fucan (HF) in its body wall. It is confirmed that the two mucopolysaccharides (Fan *et al.*, 1979, 1983) are idiographic

Table 4. The amount of inorganic elements of seven species of sea cucumber (ppm).

Element	A	B	C	D	E	F	G
Ba	2.0	6.4	1.7	1	2.9	3.6	2
Co	0.4		0.2	0.4	1.7	0.7	0.4
Cr	10.1	12.9	15.3	9.3	4.4	11.5	10.1
Cu	6.1	1.3	5.9	2	2.5	1.8	6.1
Li	2.0	1.2	1.7	1	1.9	1.4	2
Mn	19.1	2.6	4.1	5.8	11.6	36.1	4.1
Ni	2.9	2.5	5	2.3	1.9	2.1	5
Si	110	12.9	170	11.5	77.6	65	46.6
Sr	616	181	119	57.8	874	64	162
V		0.51	0.51	0.34	0.97	0.72	1.01
Zn	28.6	7.77	40.9	10.4	9.71	26	70.9

A: H. (Metriatyla) scabra; *B:* H. (Microthele) nobilis; *C:* H. (Thymiosycia) impatiens; *D:* H. (Lessonothuria) insignis; *E:* H. (Lessonothuria) multipilula; *F:* Actinopyga echinites; *G:* Thelenota ananas.

components of sea cucumber, are found in higher levels in the sea cucumber body and are called "poly-anion elements". Hence, sea cucumber has been nominated as "poly-anion-rich food" that has a physiologically active function, for example, (a) inhibition of some cancers including lung cancer and galactophore cancer (Ma *et al.*, 1982); (b) enforcing immune function (Li *et al.*, 1985; Chen *et al.*, 1987; Sun *et al.*, 1991); (c) anti-aggregation of platelet (Li *et al.*, 1985); and (d) other functions of pharmaceutical value.

Since the 1990s, sea cucumber has been used as a source of chondroitin sulphate, also known as "sea chondroitin", which is well known for its function to reduce arthritic pain. Recently, an increasing number of commercial products containing sea cucumber or its extracts are available in the market place, such as ArthriSea®, SeaCuMAX®, and are being used for treating rheumatoid arthritis, osteoarthritis and ankylosing spondylitis.

The medical efficacy of sea cucumber is convincing because of the increasing market demand, and consequently this stimulates the development of both farming and fishing of sea cucumber.

Review of sea cucumber production

According to a recent report (Fishery Weekly, China Ocean Daily; 4 July, 2003), Shandong Province has become the second largest producer of sea cucumber. The total farming area reached 17 000 ha, and the total output from culture will achieve 2 250 tonnes in 2003. This means that the wet weight is about 45 000 to 67 500 tonnes (the ratio of wet vs dry is about 1:20-30 depending on the salt level and processing methods). The output in Shandong Province accounts for about one third of national production this year. The largest producer of farmed sea cucumber is in Liaoning Province. According to estimates, the total area of sea cucumber farming will reach about 51 000 ha and the total output will reach 6 750 tonnes (dry weight), equivalent to 135 000 to 202 500 tonnes of fresh weight.

Prior to 2001, the output or landing volume of sea cucumbers was included in other aquatic products in the Annual Report of Fisheries, implying that these products accounted for a small share of the total fishery production. Since then the official statistics categorise sea cucumber separately (Table 5).

In Table 5, farmed sea cucumber is represented by only one species, *Apostichopus japonicus*, but the wild species include *Thelenota ananas* (Prickly redfish), *Holothuria nobilis* (black teatfish), *Holothuria scabra* (sandfish), *Actinopyga mauritiana* (surf redfish), *Bohadschia argus* (Tigerfish), *Stichopus hermanni* (Squarefish), *Stichopus chlononotus* (greenfish) in Hainan and Guangdong Provinces (Li, 1990), *Apostichopus japonicus* (Prickly-fish) in Liaoning and Shandong Provinces and *Acaudina leucoprocta*, *Mensamaria intercedens* and others in Zhejiang and Fujian Provinces.

Table 5. *The output of sea cucumber in 2001 and 2002 (Annual Report of Fisheries).*

	Output of sea cucumber (kg)			
	2001		2002	
Zone and Provinces	Farming	Capture	Farming	Capture
Hebei	1 000			
Liaoning	3 837 000	230 000	4 021 000	390 000
Shandong	1 253 000	102 000	1 844 300	46 000
Fujian	-	14 000	-	28 000
Guangdong	-	340	-	1 232
Hainan	-	12 100	-	5 000
Sub-total	5 091 000	358 440	5 865 300	470 232
Total	5 449 440		6 335 532	

There is an indication that the output from aquaculture may be a little higher than that of official statistics as many farmers sell their products directly to restaurants and consumers in live form and semi-processed products (Figure 1)., It is popular to eat raw sea cucumber with vinegar or as a steamed product, particularly in the Shandong and Liaoning provinces. Nevertheless, the official figures reflect the developing trends of the contribution of sea cucumber farming and ranching. In fact, sea cucumber farming and ranching has developed such that:

- Farmed sea cucumber will take over from captured sea cucumber as the main source of raw material;
- *Apostichopus japonicus* has become the dominant species cultured in the northern part of China including Liaoning, Shandong and Hebei Provinces; whereas, in the southern part of China, including Guangdong and Hainan Provinces, aquaculture is still in its infancy. The candidates for farming will be sandfish (*H. scabra*) and black (*H. nobilis*) or white teatfish (*H. fuscogilva*) due to their higher commercial value in these regions.
- The development of sea cucumber in China will, no doubt, reduce the pressure on supplies caused by overfishing worldwide.

Figure 1. *Processed products of sea cucumber,* Apostichopus japonicus*; left are fully dried products; right are semi-processed products.*

Figure 2. *A diver armed with heavy-diving facilities collecting sea cucumber.*

Capture Methods

Capture methods vary from area to area. In general, there are two methods; (a) SCUBA diving, or (b) heavy-diving facilities (Figure 2), which are used in the northern part of China

In the southern part of China, especially in Hainan Island, fishermen have designed special facilities for harvesting (Li, 1990). Almost all captured sea cucumber are processed into dried products. The processing methods depend on the species and areas. In the northern part of China - Liaoning, Shandong and Hebei - processors use the same processing procedures (Figure 3).

In the southern part of China, the species are different with most of them being larger than *A. japonicus*. This means that drying is more difficult. In order to preserve the quality, it is common to use burning charcoal to dry the boiled sea cucumber.

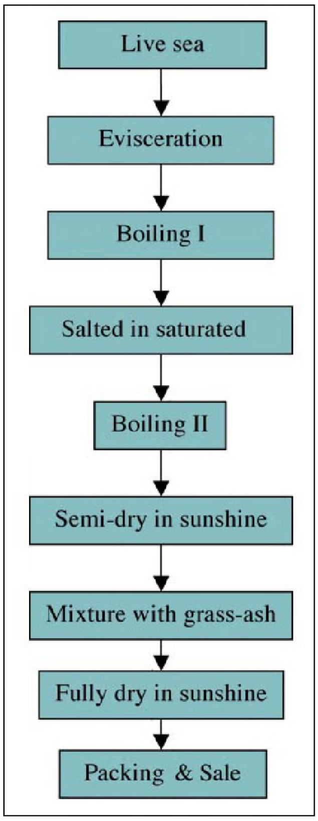

Figure 3. *Processing procedures of sea cucumber in northern part of China.*

Farming Methods

There are three methods (Jia and Chen, 2001; Chen, 2003) used for farming sea cucumber: 1) pond culture, 2) pen culture, and 3) sea ranching or sometimes called "bottom culture". In view of its lower investment and higher return, bottom culture accounts for 75 % of total area of culture. For example, in Shandong Province, the total culture area is about 17 000 ha, of which 13 000 ha are in the form of bottom culture; pond culture and pen culture cover 1 800 ha and 2 500 ha, respectively. On other hand, many shrimp ponds left over from the 1990s are becoming much in demand. For example, the rent of a hectare of shrimp pond was about US$ 350 per hectare per year before farming sea cucumber. Now it has risen to US$ 1 800 to 2 000, and can even be as high as US$ 9 000 per hectare per year. From this point of view, sea cucumber farming has been lucrative for coastal fishermen. However, the investment has risks considering that about US$ 5 000 to 6 000 are needed for the preparation of a one hectare pond. Nevertheless, the sector has attracted investment from different sources including funds from local authorities.

Pond culture

Farming sea cucumber in ponds is very popular in China. Furthermore, most existing shrimp ponds can be adapted to meet the ecological demands of sea cucumber. The ideal conditions for a pond culture site are: (a) to be near to the low tide mark so that seawater can be fed into the pond by gravity; (b) no pollution; (c) 28-31 salinity; (d) sandy or sandy-muddy bottom; (e) two metres depth or more; (f) 1 to 4 ha pond size; and (g) presence of shelters to protect the cultured organisms against typhoons or strong wave attack.

The sea cucumber (*A. japonicus*) is benthic and lives on organic debris and small benthic organisms, therefore, providing more substrate is a necessity. The reason is that the substrate can protect the sea cucumber from predators, while benthic organisms attached to the substrate can be used as a food source. Before introducing seawater into ponds, stones (weighing 20-40 kg each) or other non-toxic material like tiles and bricks can be used and are laid in rows or in a pile (Figures 4 and 5). These materials are used to build the "home" for the sea cucumbers.

Figure 4. *The layout of stone substrate in sea cucumber ponds; top picture shows the substrate in row form; bottom picture shows the substrate in cone form.*

If the stones (or tiles, etc.) are laid down in rows, each row is usually 3 m wide by 1.5 m high. The interval between rows is about 3-4 m. A pile of stones usually has a base of 4-5 m in diameter and 1.5 m high. The volume of stone used for these purposes is around 2 250 m^3 per hectare. Figure 5 shows a pond ready for sea cucumber farming.

Figure 5. *Ponds ready for farming sea cucumber; the hut in the top figure is for guarding and monitoring and a sluice gate for introducing seawater from the main supply channel; the bottom figure shows a pond ready for use.*

Pen culture

As shown in Figure 6, the ponds are located near to the seashore. At high tide, the seawater naturally flows into the pond by the means of gravity; at low tide, the water in the pond is about 80-100 cm in depth. This method saves a great deal of energy that would otherwise be used for pumping water; meanwhile, incoming seawater brings organic debris into the ponds which provide a good feedstuff for the sea cucumber. It is, therefore, a low cost method and is a highly efficient model, but it is confined to a limited area along the coast.

Figure 6. *Pen culture model of sea cucumber in Shandong Province.*

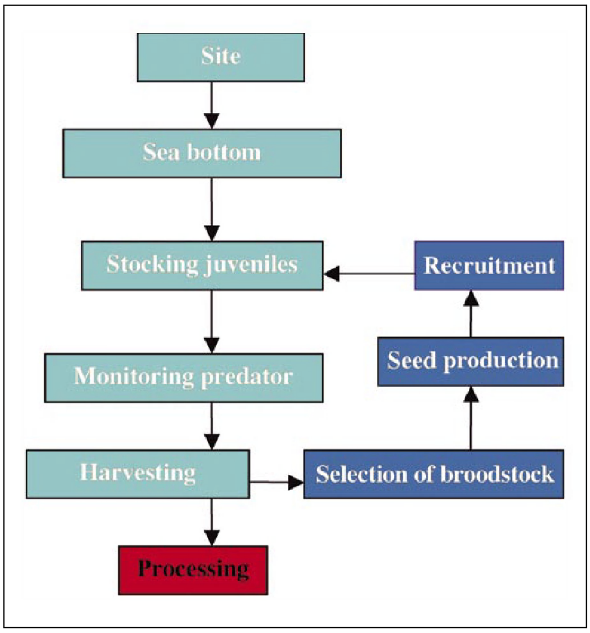

Figure 7. *Sea ranching flowchart of sea cucumber* (A. japonicus).

Sea ranching

Due to the high investment cost for the infrastructure and water management needed for the previous culture methods, sea ranching becomes a more reasonable model for farming sea cucumber as it is more akin to "animal husbandry" in the sea. Successful sea ranching of sea cucumber requires that three main criteria are considered: 1) proper site selection, which includes presence of food sources, suitable salinity and temperature ranges, flow rate, and favourable bottom conditions; 2) environmental improvement, especially the provision of shelter for the farmed sea cucumber; and 3) the release of large size seed material (>5 cm in length is desirable for a good return rate). This model is shown in Figure 7.

Sea ranching experiments of sea cucumber were initiated in the 1950s in Hebei Province (Zhang, 1958), and later, research and demonstration projects were conducted in Liaoning Province (Sui and Liao, 1988) and Shandong Province (Zhang and Liu, 1998) in the 1970s. Convincing results from this earlier work indicated that sea ranching is an effective culture method that could additionally help the recovery of wild sea cucumber stocks.

Example 1:

Location:	Gangdong Village, Qingdao.
Historical record of capture:	The highest record was 350 kg/day/fishing boat equipped with heavy-diving facilities in 1958; average output was 150-200 kg/day/boat during the 1950s and 1960s. During the 1970s the output declined to zero.
Experimental duration:	From 1976 to 1980.
Experimental plot:	3 hectares. The plot was separated into 9 sub-plots, where stones (35-40 kg/piece) were added. Total volume of added stone in the plot reached 600 m^3.
Restocking seed number:	8 461 and 5 715 sea cucumbers in 1976 and 1977, respectively.
Results:	See Table 6.

***Table 6**. Collecting record in the experimental plot of sea ranching of sea cucumber* (A. japonicus) *from 1976 to 1980.*

Sampling date	Sampling record (No. individuals/hour)	Factor increase from base figure
15/01/1976	30	1[1]
11/01/1977	120	4.0
12/01/1978	144	4.8
05/06/1978	54 in aestivation period	1.9
02/11/1978	174	5.8
26/11/1979	300	10.0
08/01/1980	480	16.0
19/11/1980	474	15.8
25/12/1980	426	14.1

Source: (Zhang and Liu,1998). 1 = The sampling record value of 30 was taken as the basis for comparison.

In 1981, a tentative capture was conducted. A total of 318 sea cucumbers weighing 56.6 kg were collected during one hour. This indicated that the resources had recovered to historic levels.

Example 2:

Location:	Magezhuang Town, Penglai.
Experimental duration:	1984-1988.
Experimental plot:	3.5 hectares. 7 000 m^3 of stone blocks and 40 artificial reef made of concrete were added to this plot from 1984 to 1985.
Census before experiment:	Conducted in 1984 and shown in Table 7.

Table 7. Sea Cucumber census before ranching experiment started in 1984 (Zhang and Liu, 1998).

Item		Sampling point					
		I	II	III	IV	V	VI
Density (individuals/m^2)		1.2	1.2	1.0	0.7	1.0	1.2
Mean weight (g/m^2)		82.8	89.4	81.1	62.8	80.2	97.8
Distribution by	> 85g	35.0	39.5	46.5	42.2	46.5	50.0
B.W*. (%)	< 85g	65.0	60.5	53.5	57.8	53.5	50.0

** B.W. = Body Weight.*

Juvenile restocking: Juvenile size: 1-2 cm in length - 0.48 million, 0.50 million and 0.15 million juveniles were stocked in 1984, 1985, and 1986, respectively.

Feeding protocol: Chicken manure and formulated feed were used for feeding during March to May, and November to December annually.

Ban period for fishing: From April 1984 to April 1986.

Results: Results have shown that the distribution density reached 12.9 individuals/m^2. Total quantity in the plot was 47 769 kg (about 430 021 individuals). There were 118 256 individuals that had reached marketable size (>150 g/individual). The mean output per hectare reached 273 kg (Table 8).

Table 8. *Results of sea cucumber sea ranching experiment (*A. japonicus*) from 1985-1987.*

Sampling site	Sampling date	Distribution density (individual/m^2)			Distribution by body weight (%) *Ranges in grams*					
		highest	lowest	mean	1-15	16-55	56-85	86-125	126-175	>176
I	4/1985	23	17	19.4	6.2	72.2	16.5	5.1		
	4/1986	30	16	23	3.1	47.4	36.9	11.3	1.3	
	4/1987	15	5	9.5	2.1	42.1	37.9	15.8	2.1	
II	4/1985	19	16	17.4	2.3	66.7	20.7	8.0	2.3	
III	4/1985	18	11	13.8	1.5	43.1	37.7	13.3	2.9	2.5
	4/1986	26	13	19	7.9	55.2	25.7	10.0	1.2	
	4/1987	14	5	7.7	6.5	70.4	9	10.4	13.9	
IV	4/1985	3	0	1.6	1	20	20	13.3	20.0	26.7
	4/1986	14	0	5.1		11.8	23.4	37.2	17.6	9.0
	4/1987	6	3	4.1		12.2	22	36.6	19.5	9.7
V	4/1986	14	3	7.9		9.9	16.4	24.1	38.9	11.7
	4/1987	5	2	3.9		12.8	30.8	46.2	10.2	
VI	4/1985	4	1	2.4		14.3	21.4	42.8	21.5	
	4/1986	26	7	16.1		13.0	27.4	33.5	21.7	2.5
	4/1987	9	3	5.2	1.9	15.4	34.6	44.2	3.8	
General census in the plot	1988	Mean density: 12.9 individual/m^2 Total number in the plot (3.5 ha): 430 021			Number > 150g (body weight): 118 256 (27.5% of total number) Mean output: 273 kg (dry weight)/ha					

Source: Zhang and Liu, 1998.

The results from the experiments mentioned above confirmed that sea ranching is an efficient model for recovering and increasing the resources and relieve the burden on natural resources. These experimental results provide valuable experience to farmers. In recent years, sea ranching of sea cucumber (*A. japonicus*) has become a prosperous part of the fisheries sector.

The key to success involves at least three main points: site selection, improving bottom culture conditions and monitoring predators. The ideal conditions for a desirable site are as follows:

- Salinity: 28-31;
- pH: 7.9-8.4;
- Temperature range: 2 to 26 ºC, the optimum temperature (10 to 20 ºC) for 6-8 months or more;
- Water current speed: 10-30 cm/s; no more than 50 cm/s;
- Substratum: muddy or sandy bottom, preferably with eel grass;
- Depth: 3-10 metres.

Following site selection, it is most important to improve the sea bottom conditions in order to meet the habitat needs of the sea cucumber. As in pond culture, stone blocks are stocked into the selected site 3-5 months prior to the releasing of the juveniles.

Monitoring is a very important task in order to check the viability of the sea cucumber and, especially, to make sure that predators like sea-stars are eradicated. Monitoring should be done twice per month.

Seed production is the limiting factor in aquaculture and sea-ranching. Seed production research began in the 1950s. In the 1980s, a project was supported by the Ministry of Agriculture (MoA) that achieved significant progress in this field. Since then, about 6-8 billion juveniles have been produced in the hatcheries and have been distributed along the coastline of Liaoning, Shandong and Hebei Provinces. Among them, Liaoning Province is in a leading position. The techniques of seed production were presented at the FAO 'Advances on Sea Cucumber Aquaculture and Management' (ASCAM) workshop (see also Shui, 1985, 1988; Zhang and Liu, 1998).

Marketing and trade of sea cucumber in China

As mentioned earlier in the paper, sea cucumber has been considered a tonic food for many years. Native people living in Liaoning and Shandong Provinces consider sea cucumber (*A. japonicus*) as a delicacy and are prepared to pay high prices for fresh, dried and processed products. As an old saying in Western countries goes, "An apple a day keeps the doctor away", so now there is a new saying in China, "A sea cucumber a day keeps the doctor away". Hence, we can imagine how large the market for the sea cucumber is. The natural resources of *A. japonicus* have been badly damaged from the 1950s to the 1970s. For example, the output of beche-de-mer (dried sea cucumber) was 130-140 tonnes and 130 tonnes in Shandong and Liaoning Provinces, respectively, in the 1950s. By the 1970s, the landing volume (dried weight) had declined to 30-40 tonnes and 26 tonnes, respectively. Until to the end of 1970s, capture production had dropped to almost zero. The retail prices of beche-de-mer have increased dramatically since the 1980s. In 1960s, one kilogram of beche-de-mer (*Apostichopus japonicus*) was RMB 18; in the 1980s the price increased to RMB 500 per kilogram, and in the 1990s it reached RMB 600-1 000 per kilogram. At present, the price exceeds RMB 3 000 (about US$ 400) per kilogram.

The soaring price and the benefits obtained by farmers and investors have stimulated the development of the sea cucumber industry of China. Although the total productivity from sea farming and sea ranching has reached more than 6 000 tonnes (dry weight), the consumption is much higher than domestic production can supply, and therefore, imports of beche-de-mer will certainly continue.

In November 2002, during the Twelfth Meeting of the Conference on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) held in Chile, a special session dealt with the sea cucumber. The report stated: "The Hong Kong Special Administrative Region (Hong Kong SAR) import statistics show an increase from 25 source countries in 1987-1989 to 49 countries that exported beche-de-mer in 2000-2001."

The total trade in holothurians increased substantially in the late 1980s, and by 1995 had reached a global annual volume of over 13 000 tonnes, valued at about US$ 60 million (Jaquemet and Conand, 1999). Beche-de-mer is primarily exported from producer countries to a central market in Hong Kong SAR, Singapore or Chinese Taipei, and then re-exported to Chinese consumers' worldwide (Conand and Byrne, 1993). Since the 1980s, the economic status of mainland China has entered into a new era. Economic growth has increased the consumption of sea cucumber in both restaurants and private homes. The consumption of seafood, especially luxurious seafood like geoduck, scallop, shrimps, crabs, groupers, shark-fin, as well as sea cucumber is undergoing a rapid rise.

Also mentioned in the same report are statements relating to the pharmaceutical value of sea cucumbers. Since the 1990s, different health foods or functional foods based on sea cucumber have appeared in drug stores, supermarkets as well as retail shops all over China PR. It is likely that the demand for these products will continue.

According to the investigation of Prof Conand, "In 1989, a worldwide catch of 90 000 tonnes was recorded, consisting of about 78 000 tonnes from the South Pacific and SE Asia and 12 000 tonnes from temperate fisheries. Holothurian fisheries have continued to expand, with a total worldwide harvest of 120 000 tonnes by the early 1990s" (Conand, 1997). The author estimates that the tendency will slow down due to the increasing output from aquaculture and sea ranching sector of sea cucumber in China. This year the output from aquaculture and sea ranching will reach 6 750 tonnes equivalent to 135 000 to 202 500 tonnes of wet weight. This figure almost equals the harvest worldwide from capture. That is why the Chinese participants of CITES claimed that "artificially bred" sea cucumbers have almost replaced sea cucumbers caught in the wild.

Issues and prospects in next decade

Based on the general principle and policy of fishery authorities, aquaculture and sea ranching have been considered a priority sector in the fisheries industry. Further development of farming and ranching of sea cucumber will continue particularly as the allure of high profits will fuel investment into the next decade.

Issues

The expanding farming area and increased output will likely induce the outbreak of diseases. In the aquaculture sector, the emergence of infective diseases has caused serious problems since the late 1980s in salmon, shrimp, shellfish and other farmed species. Sea cucumber could be a new victim in the future. Until now, few researchers have dealt with this issue and farmers have not worried about it. The author is concerned that this could pose a real threat to the newly established sector if the expansion continues at this fast rate and does not consider preventative measures.

The development of sea cucumber farming has been in a status of imbalance. As mentioned earlier, there are about 20 species of edible sea cucumber. Besides *A. japonicus* in the temperate zone, most of edible species are distributed in southern part of China PR, especially in Guangdong and Hainan Provinces. So far there are no farming operations established. Although the commercial value of tropical species is lower than that of *A. japonicus*, some species like sandfish, white teatfish and black teatfish, do have a high value. These species are threatened if farming and sea ranching options are ignored.

A national conservation zone of *A. japonicus* has been established in Liaoning Province although many such zones existed at the county and village level in both Liaoning and Shandong Provinces. Hence, the wild resources and biomass of *A. japonicus* are close to optimal, but the resources of tropical species are not in as good a shape as the temperate species.

The processing methods and the quality standards for the final products need to be improved. In following the Chinese traditional method of processing sea cucumber, not only is the salt level in the final product higher, but valuable components are lost during processing and cooking. Furthermore, some dishonest processors place uncertified products on the market deceiving consumers with regards to the quality of the product purchased. It is necessary, therefore, to develop a new standard.

Prospects

- In next decade, sea cucumber farming and ranching will become a prosperous industry in China. The industry will involve an entire industrial supply chain from seed production to processing, including formulated feed, specific chemical products for sea cucumber farming, special culture and ranching facilities and a range of processed products.

- New processing techniques will be used in farming, harvesting and processing.
- Health food items derived from sea cucumber will be more popular.
- The price of sea cucumber will decline year by year owing to the increasing output from aquaculture.
- Some species will be listed as endangered species. However, the resource management of sea cucumber will be improved and relevant protocols developed to protect endangered species.
- The aquaculture sector for sea cucumber will continue to develop towards its full potential, making a net contribution to global ecological systems and the resources of sea cucumber, human nutrition, and economic development for coastal people and society in general.

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The status of the sea cucumber fisheries and trade in Japan: past and present

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Abstract

Dried holothurian has been a major export commodity from Japan for at least 350 years, although recently it has become less important. On the other hand, the Japanese holothurian, "namako," is mainly consumed raw in the domestic market as slices soaked in a mixture of vinegar and soy sauce. The ovaries are dried, called "konoko," and the intestines are salt-fermented, called "konowata." These products are rare, expensive and a good source of income for holothurian processors. In order to discuss suitable resource management systems, this paper reviews the history of holothurian fisheries and trade in Japan. Information on recent holothurian exploitation is also presented, including fishing regulations in Japan, holothurian species and products and, finally, resource management programs being implemented in northern Hokkaido.

Keywords: Fisheries Cooperative Association, fisheries regulations, holothurians, resource management

日本海参开发利用和贸易回顾

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摘要

干海参（iriko），曾经是日本主要的出口商品，其历史至少可追述到350年以前，但现在已经不占主导地位。在日本国内，日本海参（namako）的消费方式是以生食为主，将海参切成薄片，佐以醋和酱油。干制的海参性腺叫做“konoko”，而海参肠经盐制和发酵制成的产品叫做“konowata” 。这些副产品既稀少又名贵，是海参加工业者的一项可观收入。为探讨合适的资源管理系统，本文首先回顾了海参加工业的历史，包括干海参贸易和海参的捕捞和加工；其次，提供了当今日本海参开发的信息，包括日本海参捕捞的法规，对海参的种类和产品作了简要的讨论，最后，介绍了在日本北海道北部的资源管理项目的执行情况。

关键词：渔业合作组织、日本渔业法规、海参利用的多种方法、自发的海参管理

Introduction

The current dried holothurian - also known as trepang, beche-de-mer or iriko - market is almost exclusive to Chinese culinary culture, within which it is called "hai shen" or "hai san"[1]. In other words, most trepang producers do not consume the product themselves. This is one characteristic of the holothurian fishery industry. Another characteristic is its high value. The animal is dried for at least a month in storage and the dried form must then be soaked in water overnight, followed by repeated simmering for about a week, before use. Thus production is a complicated and time-consuming process. This is one of the reasons why trepang is considered such a delicacy.

Growing concerns regarding biodiversity conservation and environmental protection have made these important issues in the trepang industry worldwide. In order to better understand the structure of the industry, especially between Chinese consumers and other producers, it is necessary to look at its historical development, how it has expanded and how neighbouring nations became involved. Japan provides an ideal case study as the Japanese not only prefer raw holothurian but have also exported trepang to China for at least the last 350 years.

How could Japan continue to produce trepang for such a long time? How did the Japanese exploit their holothurian resources? What is the fisheries system in Japan? To provide answers to these questions, this paper will briefly introduce (a) the history of the trepang industry in Japan, (b) fisheries regulations regarding resource management, and (c) current efforts to manage holothurian resources by local fisheries cooperative associations in the Rishiri district, northern Hokkaido.

History of the trepang industry in Japan

The date when trepang became popular in China is controversial. FAO (1990) simply noted that for a thousand years or more, the Chinese sought trepang in Indian, Indonesian and the Philippine waters, without any particular sources cited. However, from a socio-economic and historical viewpoint, the beginning of the trepang industry and its development should be more precise. This is because Chinese trepang culinary culture has involved neighbouring maritime peoples and that most of the producers, except the Japanese and possibly the Koreans, did not eat trepang themselves and thus began to produce trepang only in response to an outside demand.

Although it is difficult to provide historical evidence on exactly when the trepang culinary culture began, it is possible to conclude that the popularity of trepang increased in China around the 16th to 17th centuries. This conclusion is supported by Chinese literature and the occurrence of trepang trade between China and neighbouring nations at these times.

In Chinese literature, the earliest record of trepang as food is said to come from a book entitled "Miscellanies of Five Items (Wuzashu)" written by Xie Zhaozhi in 1602 in the late Ming period. In this book, it is explained that trepang mildly invigorates the human body similar to "ginseng", which is the reason it is called "hai-shen" (sea ginseng) (Dai, 2002). Another literary reference is "Suiyuan's Culinary Companion (Suiyuan Shidan)" written by Yuan Mei, in 1792. Illustrating food delicacies, Yuan Mei noted that in the old days (pre 1790s) the Chinese had poorly appreciated marine foods, but this trend has since changed. He described eight marine delicacies such as bird's nest, shark's fin, abalone and trepang (Yuen, 1980). From the descriptions in the two books mentioned it can be concluded that trepang became a popular food item in China at the end of the 16th century.

The second piece of evidence to enforce the above supposition is trepang trade between China and neighbouring nations. For example, the Shogunate government in the Edo period (or Tokugawa in Japan, 1601-1867) controlled all foreign trade. At that time the Japanese officially began exporting trepang, called "iriko" in Japanese, to the Qing dynasty in 1698 in exchange for Chinese silk and medicines. Prior to this date, it is confirmed that in 1861 three Taiwanese ships exported a total of 0.9 tonnes of trepang (Nagazumi, 1987) and an Annan ship also exported some amounts of trepang in 1683 (Yamawaki, 1995). Korea also exported trepang to China by land in 1648 (Sasaki, 2002). During the same period, trepang harvested from tropical waters was also an important trade item that Europeans brought into China in exchange for tea, silk, and porcelains. Macknight (1976), who wrote an exhaustive archeological study on Makassan trepang fisheries in northern Australia, assumed the beginning of the trepang industry to be between 1650 and 1750.

Japan produced trepang as early as the 8th century. It was used as a kind of tax to the ruler, though it is not clear how it was cooked and consumed in those days. In this sense, it was different from other neighbouring trepang producers such as the Philippines and Pacific islands where people had never produced trepang for their own consumption. In other words, Japan already had the knowledge and techniques to produce trepang when China's market expanded in the 16th and 17th centuries. However, this does not mean that Japan simply exported surplus trepang out of the domestic market. The Tokugawa feudal government not only encouraged coastal people in the maritime communities to produce more trepang for export, but also encouraged Hokkaido, in the northern most part of the Japanese archipelago, to become a major producing area.

Under Tokugawa's trade regulations, trepang was gathered by several traders in Nagasaki, an official trading port, and classified into 10 categories depending on quality and size[2]. Figure 1 illustrates a trend of trepang exports from Japan in the 17th and 18th century based on the "Catalogue of Imports and Exports in Chinese Trades" compiled by Nagazumi Yoko (Nagazumi, 1987)[3]. Although the catalogue is not complete, it greatly contributes to reconstructing

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[1] *The present paper uses 'holothurian' for fresh animals and 'trepang' for dried holothurian products*

[2] *Trepang was the top export commodity in value followed by kelp, and second highest export commodity in volume after the kelp.*

Sino-Japanese trade as there are no other valid materials available. In practice, a considerable amount of trepang was exported every year, but the original record was only marked by the number of straw bags instead of the volume unit "kin." This is the reason it is impossible to draw a bar in Figure 1[4].

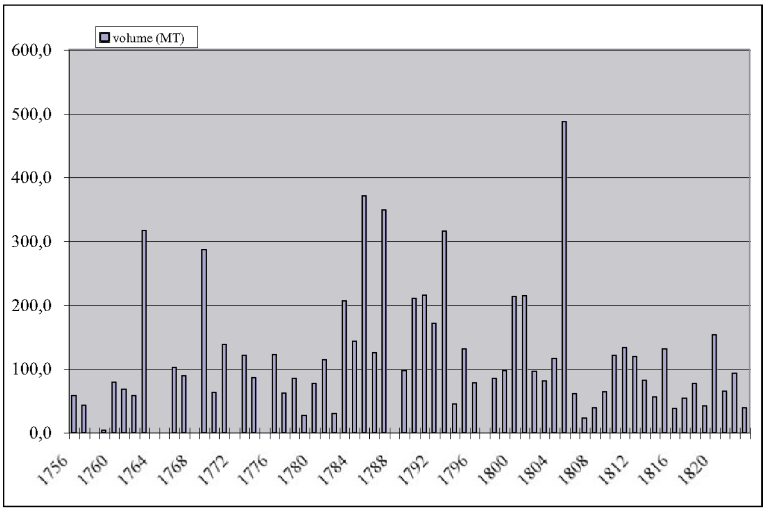

***Figure 1**. Trepang export from Japan 1756-1823 (Nagazumi 1987).*

In 1763, the volume reached 317 tonnes. This was the year that imports of gold and silver from China began and the Tokugawa government needed more trepang for its trade with China. Since the Tokugawa government did not produce as much copper as demanded by China, they needed more trepang for export as compensation. Thus, in 1785, the Tokugawa government appointed contractors to collect trepang throughout the archipelago, and exports reached 371 tonnes (Arai, 1975). This increased effort in trepang production made it possible to export 487 tonnes of trepang in 1805.

Tokugawa's monopoly in the trepang trade lasted until 1865, after which European and Chinese traders became involved. Two years later, Japan experienced the Meiji Restoration and free trade was enhanced. In the Meiji Government, trepang continued to be one of the main cash earning commodities. This encouraged the Government to open more fishing grounds in Hokkaido and led to the establishment of inland cultivation sites. Hakodate, in southern Hokkaido, in addition to Nagasaki, became one of the leading trading centres for the Japanese trepang trade.

Though holothurians in Hokkaido are small, they have spiny bodies, which are highly appreciated by the Chinese market, especially in northern China. Thus, trepang produced in Hokkaido became important and this is why Hakodate played such an important role in the trepang trade.

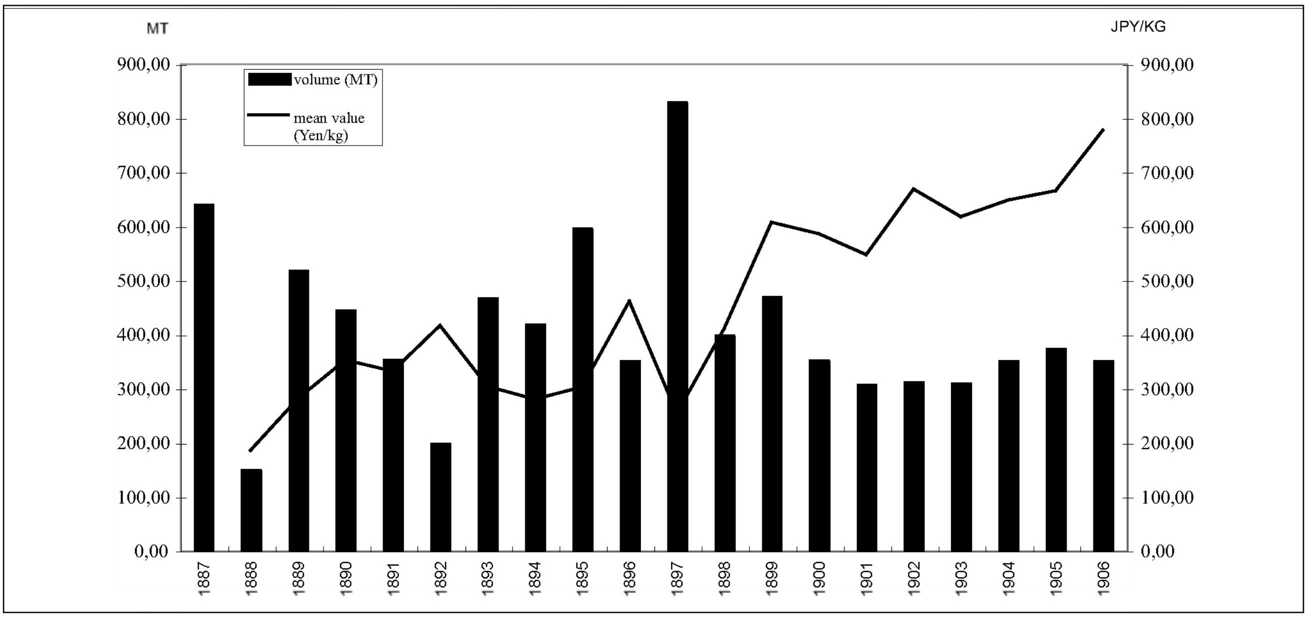

***Figure 2.** Volume and mean value of trepang production in Japan 1887-1906.*

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[3] *Nagazumi researched Dutch archives on Japanese trade with China because there are, unfortunately, few records on Sino-Japanese trade left both in Japan and China. Interestingly the Dutch were so concerned about their Chinese competitor that they recorded considerable information on Sino-Japanese trade.*

[4] *For example, in 1788, a total of 4 630 bags of trepang, at least, was exported by11 ships. These bags, originally used to pack rice, would be equal to 120 kin (72 kg). Thus, it is estimated that about 333 tonnes of trepang were exported.*

Unfortunately, there are no concrete trade statistics of trepang exports available after the Meiji period[5]. Trepang production statistics from 1887 to 1906 are shown in Figure 2. An average of 435 tonnes were produced annually during this period, which is more than the highest record in the Tokugawa period. Since there was little domestic trepang demand in Japan, it is likely that almost all of it was exported.

In contrast, we have conclusive holothurian landing statistics from 1894-2000 as shown in Figure 3. In 1968 holothurian landings reached a peak of 13 023 tonnes but a low in 1993 of 5 996 tonnes. After 1993, the holothurian catch remained at the 6 000 tonnes level. Some possible reasons for the current landings are: (a) local fisheries cooperative associations practiced stock enhancement since 1977 as shown in Table 1a and Table 1b, (b) due to aging fishermen, fishing pressure may have decreased, and (c) holothurian fisheries are well managed under the current fisheries policy.

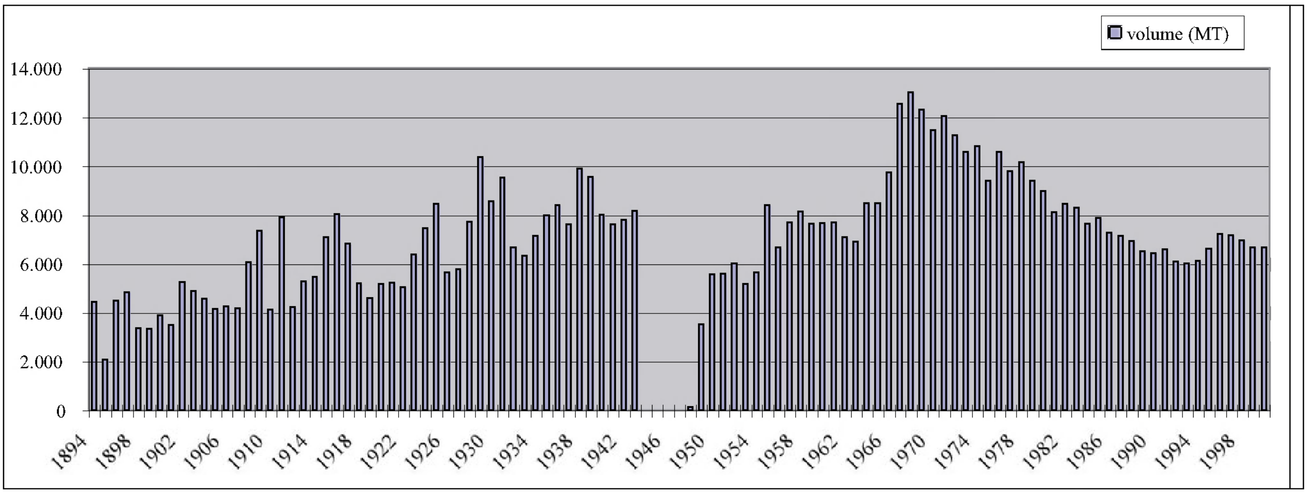


Figure 3. *Holothurian catch in Japan from 1894-2000 (Source: Ministry of Agriculture, Trade Statistics, Fishery and Mariculture Production Statistics).*

Table 1a. *Holothurian stock enhancement in Japan from 1977-1989 (Stock Enhancement Report).*

Location	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Soya													
Oshma													
Aomori									0	0	4	1	24
Miyagi										249	275	473	50
Isikawa							3	1	1	20	12	76	119
Fukui												308	174
Aichi							24		26	39	24	35	170
Mie													
Hyogo						11	28						
Okayama													
Ehime													
Hirosima													
Yamaguchi													
Fukuoka	85						900	15	21	77	140	15 153	25 624
Saga				24	1 705	270	262	99	183	1	69	58	196
Nagasaki		69		7	1 111	773			501	380	17	240	117
Kumamoto													
Ooita										84		415	282
Total	85	69	0	31	2 816	1 054	1 217	115	732	850	541	16 759	26 756

Unit: 1 000 individuals.

[5] *In contemporary Japan, there are no independent statistics available on trepang export since it is lumped together with other marine animals.*

Table 1b. Holothurian stock enhancement in Japan from 1990-2001 (Stock Enhancement Report).

Location	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Soya			54		143	140	200	150	202	203	220	258
Oshma						22					6	2
Aomori	35	20	5	26	41	221	166	204	200	250	200	210
Miyagi	15	30	77	111								
Isikawa	1											
Fukui	711	568	300	592	192	573	400	209				
Aichi	150	200	200	100		700	700	700	700	700	700	700
Mie			1	2	3	7	15	7	2			
Hyogo												
Okayama			346	230	930	2 144	945	758	753	521		
Ehime			200	65	42	52	80	10	12	33	25	1
Hirosima								55				50
Yamaguchi				12	390	755	444	16				
Fukuoka	936	444	31	181	62	140	64		24	10	11	10
Saga	220	224	367	521	506	1 035	397	491	315	349	59	209
Nagasaki	283	656		7	4	14	2	215	33	114	446	349
Kumamoto								2	6			
Ooita	287	310	600	583	244	765	335	516	106	720	188	88
Total	2 638	2 452	2 181	2 430	2 557	6 568	3 748	3 333	2 353	2 900	1 855	1 877

Unit: 1 000 individuals.

Fisheries legislation in Japan [6]

Fisheries Law

The objective of the Fisheries Law, established in 1949, is to establish a fundamental management system and to ensure fishery productivity with multi-layered exploitation of the water resources and democratisation of the fishery industry. The basic premise of the law is to maintain order in all fisheries by using the "fishery rights" system in the case of stationary fisheries and by using the "fishery permit" systems in the case of mobile fisheries. In addition, the law directs that decision-making concerning important matters be administrated by the Fishery Adjustment Commissions (FACs), which are mainly composed of fishery operators and fishery employees.

Fishery Rights

Some types of fisheries, e.g. the fixed net fishery and culture fishery, cannot be administered unless fishing areas are controlled to a certain extent. In order to adjust these operations among the operators and to maintain order, a system of fishery rights over public waters has been established. The fishery right, entitled by prefectural governors, is a right with which one can operate certain fisheries, exclusively, in given waters[7]. Only local fishery cooperative associations are eligible for the right. To apply and exercise the licence, fishery cooperatives have to determine regulations for exercising fishery rights, i.e. target species, fishing seasons and the method of catching. They also oversee the fisheries conducted by individual members.

Within the fishery rights, there are three categories: common fishery, fixed (set-net) fishery and demarcated fishery (aquaculture). For the first category, three types are further distinguished: (a) a fishery operated to gather seaweed, (b) a fishery operated to gather shellfish, and (c) a fishery operated to gather other stationary aquatic animals.

[6] *Information extracted from Kaneda (1995) and the Overseas Fishery Cooperation Foundation (n.d.).*

[7] *The fishe□*
Tokugawa's feudal system.

Holothuriana are one of the animals designated in type (c). Thus, no one can gather holothurians without a fishing right in given waters.

Fishery Permits

Certain types of fisheries may not be conducted without a fishery permit. A fishery permit is different from a fishery right. Issuing the permit means that there is an administrative action to lift a prohibition in a specific case for what is normally a prohibited fishery.

There are numerous types of fisheries permitted, and at present almost all the important fisheries have a fishery permit. There are two types of permits: those issued by the Minister of Agriculture, Forestry and Fisheries and those issued by the prefectural governor. The latter type is called a "governor permitted fishery" and these observe the regulations of each prefecture. Small-scale trawl fisheries that use a powered vessel of less than 15 gross tonnes are regulated under the governor permitted fishery. The dredge net fishery for holothurians falls under this category and, therefore, requires a permit issued from the prefectural governor. The permit is valid for 10 years and every 10 years, the fishing ground plan is discussed for renewal of the permit.

Fishery Adjustment System

There are two types of fishery adjustment commissions: the Sea-area Fishery Adjustment Commission (SFAC) and the Broad-area Fishery Adjustment Commission (BFAC). Taking fishery conditions into consideration, the Minister of Agriculture, Forestry and Fisheries divides the sea into 66 areas across the nation. In principle, an SFAC is set up for each area in each prefecture and is under the authority of the prefectural governor. Each area is a unit for fishery adjustment and therefore, fishery management.

The SFAC is normally composed of 15 commissioners. Of the commissioners, 9 members are elected from fishermen through official elections and 6 are appointed by the governor (4 as academic experts with fishery expertise and 2 representing the public interests). The SFAC has an advisory function to the prefectural governor. Designating the fishery rights, and all other matters that the administrative agency handles in regard to the fishery right, must be carried out after consulting with the SFAC. As for the governor permitted fishery, each prefectural fishery adjustment regulation requires that a governor has to consult with the SFAC before granting a permit. In addition, the SFAC has the authority to make any decisions concerning the arbitration, instruction and authorization of the permit.

To conclude this section, according to the observed Fisheries Law in Japan, no-one can freely collect and gather holothurians without a fishing right, as the animal is designated a common fishery right species. Even if one has the fishing right, they can fish only by using hooks, clips and twists, or by diving. Those who wish to fish holothurians with dredge nets have to apply for a permit to the prefectural governor because the dredge net fishery is designated as a governor permitted fishery. Thus, the prefectural governor, together with the SFAC, plays an important role in resource management, especially for holothurian fisheries in Japan.

Holothurian fisheries in Japan

Species Fished

Aside from species found in the subtropical waters in Okinawa, the most common species in the Japanese archipelago is *Apostichopus japonicus*. In his classic study, Choe (1963) noted two other holothurians that are commercially harvested, *Parastichopus nigripunctatus* ("okiko") and *Cucumaria japonica* ("kinko"). However, currently these two species are rarely harvested and thus only a small quantity is processed[8]. In the following discussion, 'holothurian' or 'trepang' refers only to *A. japonicus*.

Until the 19th century, wealthy Japanese often consumed trepang, but it is not common nowadays. On the other hand, holothurians are commonly consumed raw in the domestic market in slices soaked in a mixture of vinegar

[8] *In 1999, the author observed dried P. nigripunctatus in retail shops in Chinatowns in Yokohama and Kobe, where dried A. japonicus sold for 25 000 yen/kg and dried P. nigripunctatus for18 000 to 20 000 yen/kg. P. nigripunctatus production was estimated to be not more than 200 kg.*

and soy sauce. The ovaries ("konoko") are dried and the intestines ("konowata") are salt-fermented. These products are rare and expensive, and are a good source of income for the trepang processors. For the Japanese, holothurians are a seasonal delicacy preferred only in winter, especially at the winter solstice and during the New Year. For raw consumption, the red *A. japonicus* variety is preferred and its price is almost double that of the green and black varieties. Most of the processors, therefore, process the green and black into the dried product.

An Example of a Fishery Organization: Semposhi Fisheries Cooperative Association, Northern Hokkaido

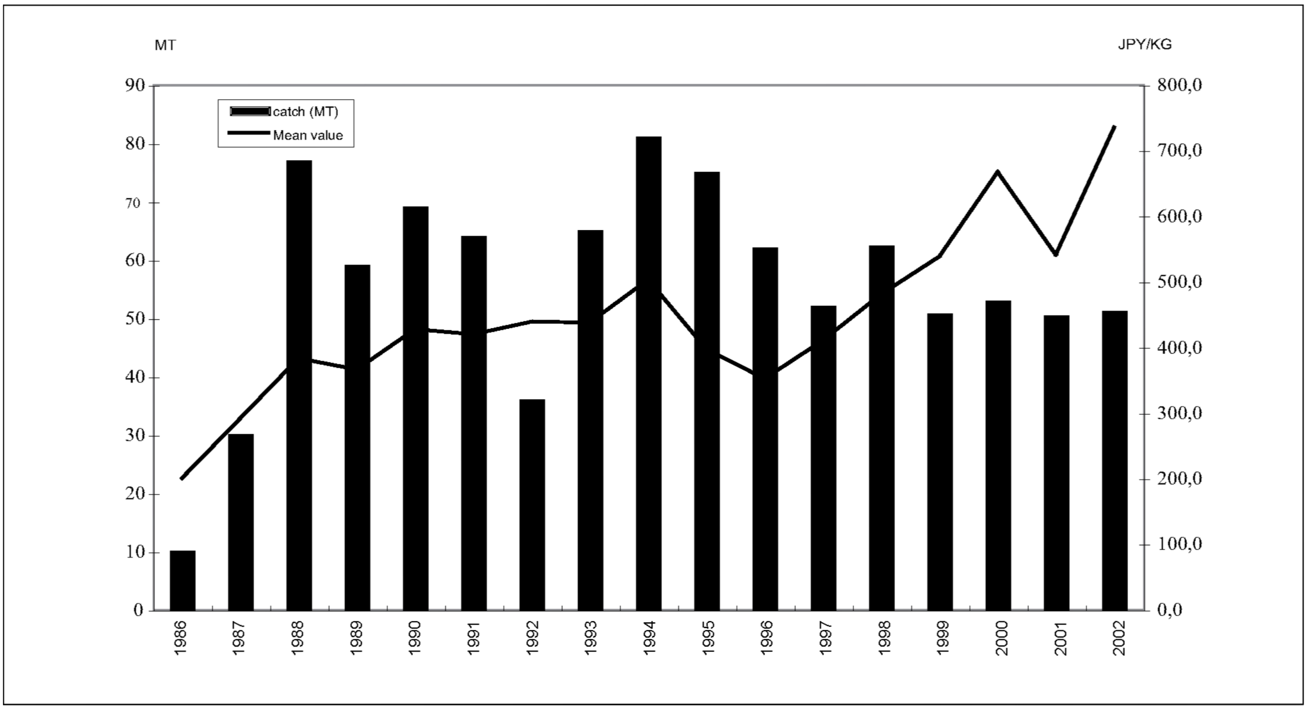
Rishiri is a small island divided into two municipalities lying on the northern tip of Hokkaido. Rishiri Town currently has a population of about 3 000 and 400 are engaged in fishing. Aside from holothurians, Rishiri is also famous for kelp (*Laminaria ochotensis* Miyabe), sea urchin (*Strongylocentrotus intermedius* and *S. nudus*) and Atka mackerel (*Pleurogrammus azonus*) fisheries. There are two fishery cooperative associations in Rishiri Town: Semposhi Fisheries Cooperative Association (SFCA) and Kutsugata Fisheries Cooperative Association (KFCA).

The *A. japonicus* fishery is classified by the fishing gear used: dredge net fishery, hook fishery, clip and twist fishery, or diving. The spear and dart fishery is not common because of the damage caused to the body of the holothurian during fishing. In the SFCA, more than 98 % of the catch is from dredge net fishing. As of July 2003, there were 11 dredge net operations permitted.

In the Semposhi district, dredge net fishing was once very common and the fishermen processed their catch into trepang. However, dredge net fishing stopped after World War II. It became active again in 1982 with three fishing vessels (Figure 4). Governmental agencies may have played an important role in the revival of this fishery. The Hokkaido Fisheries Experimental Station tried to diversify and expand holothurian processing in 1974 (Hokkaido Fisheries Experimental Station, 2001). The work of the station may partly be responsible for the revival of the dredge net fisheries in the district.

Dredge net fishing is conducted in waters 40-50 metres deep, as few holothurians are found in shallow waters. The closed fishing season is regulated by the association. In the case of the Rishiri district, holothurian fishing is not permitted from May 1 to June 15 as this is considered the spawning season. Therefore, there are two fishing periods: from March to April (spring season) and from the end of June and July (summer season).

Figure 4. *Volume and mean value of holothurian traded at the SFCA from 1986-2002.*



Resource Management at SFCA

The SFCA practices an integrated resource management programme that combines several management tools.

Size limit - In 1990, the SFCA decided that holothurians under 130 g in weight should be released and not retained in the catch. Undersized holothurians are in fact not profitable as the trepang processors in mainland Hokkaido offer low prices. As mentioned earlier, the Japanese prefer to eat raw holothurian only in winter and therefore the SFCA catches are processed directly into trepang. Approximately 100 to 120 processed sea cucumbers make up 1 'kin' in weight (Chinese traditional unit) equivalent to 600 g (80 % of the weight is lost when trepang is processed reducing a specimen of 130 g to 5-6 g)[9]. The market prices are very low for specimens under the indicated size therefore justifying the minimum size of 130 g imposed by the association.

Quota - From 1999, the SFCA voluntarily limited their annual catch to not more than 50 tonnes. The reason for the quota is economic rather than scientific. At that time, there were 10 vessels engaged in dredge net fishing and the SFCA discussed how much quota was reasonable for each operator. The result was 0.5 tonnes per vessel for one season. Thus, the quota limit may change if the situation changes. However, the SFCA does not expect to have more fishermen begin dredge net fishing due to the high initial investment required.

Closed season - The dredge net fishermen have long felt that the spawning season should be different from that ordained by the SFCA. In 2001, research indicated that the spawning season effectively starts at the end of July to August (Rishiri District Fisheries Extension Office, 2001) and based on this research the SFCA have since requested to move the close fishing season to July 20th to the end of September. The proposal is still being examined by the local authorities.

Others - The SFCA is still not fully convinced on what actions are required to properly manage the local holothurian fishery. Currently a stock enhancement programme is in place, however the additional sea cucumber juveniles required are not available locally or from other private and public facilities. Furthermore, the SFCA is eager to exchange ideas and learn more from other organizations. In January 2001, holothurian fishermen and representatives from the association visited the Aomori City Fisheries Experimental Station and held meetings with similar associations in Southern Hokkaido and the Aomori Prefecture to exchange ideas on resource conservation.

Observations for the future

The dredge net fishermen do not rely only on holothurians only at the SFCA. Most of them are engaged in kelp and sea urchin fishing when they are in season. Some fishermen work part-time as carpenters and construction workers. Variation in resource use is an important factor in managing marine resources. Unregulated fisheries and concentration on one or two species may soon deplete those resources.

Monitoring and understanding the holothurian market is a key factor in resource management. In this sense, the SFCA has been successful in monitoring the market, as evidenced by the provision of a size limit for *A. japonicus*. In a different fishery, the SFCA totally closed abalone fishing in 2003, for resource conservation reasons. In 2002, they opened abalone fishing only twice and discovered that the abalones were too small. The sea urchin fishery is another example of understanding the market. Even during the sea urchin fishing season, the SFCA does not allow its members to fish sea urchin every day. By monitoring the market price, the SFCA decides when to fish and what to fish - either *Strongylocentrotus intermedius* or *S. nudus*. If the market is low, they ban sea urchin fishing.

Situations are different from region to region and from country to country. It may be difficult to establish holistic or comprehensive regulations for resource management. The problem lies in how to set up the division of management, as the Japanese SFAC did, and how to take into consideration the regional characteristics for planning resource management. Toward this end, we have to understand ecology, culture and human nature.

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[9] *According to a processor in Yamaguchi Prefecture, very large holothurian specimens are not always preferred. There are two dried product-size demanded by the Chinese market: 11-17 g and 18-23 g equivalent to 220-340 g and 360-460 g in the fresh form. Thus, fresh specimens weighing over 500 g are not suitable for processing.*

Acknowledgements

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Status of sea cucumber fisheries and farming in Indonesia

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Abstract

Indonesia is the largest single-country archipelago in the world (8.3 million km^2) consisting of 17 508 islands with 81 000 km of coastline. The estimate of the annual sustainable catch from Indonesia's marine resources is approximately 6.2 million tonnes. Coastal and marine areas of Indonesia provide a favourable habitat for many sea cucumber species that have been exploited for hundreds of years. Indonesia is the main exporter of sea cucumber in the world.

Fishermen exploit sea cucumber by using small and medium size fishing boats (<10 gross tonnage). They generally have a low capital base and limited technical skills in product handling and processing. Handling and post harvest processing practices are not of a high standard and as a consequence the quality and price of products are very low (US$ 1.92/kg at the fisherman's level). Other factors influencing the low price are the decline in the individual size being caught and also the catching of less valuable species.

There are four important regions for sea cucumber farming in Indonesia: Papua (378 tonnes wet weight per year), Central Sulawesi (200 tonnes), South East Sulawesi (3 tonnes) and East Kalimantan (1 tonne). However, not all of the sea cucumber reported as sea-farmed product is farmed, as some fishermen retain their catch, generally *Holothuria scabra*, in the cage or pond until the number of specimens is large enough to sell or process. The two main problems of sea cucumber farming in Indonesia are the long farming period and the low number of seeds available from the wild.

Continuous overfishing can affect the sustainability of Indonesian sea cucumber production. Over exploitation can accelerate destruction or depletion of sea cucumber populations. Based on internal (overfishing) and external (market) factors that influence Indonesian sea cucumber fishing and farming, new management and technical strategies have been proposed. These are: (1) promoting sustainable use/fishing; (2) restocking and seafarming; (3) introducing regulations on marketable size; and (4) improving post-harvest handling and processing.

Keywords: Exploitation, aquaculture, fisheries, trade

印度尼西亚的海参渔业和海参养殖业

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摘要

印度尼西亚是世界上海岛最多的国家，大小岛屿多达17 508个，有着81 000千米的海岸线。渔业年可持续捕捞量是620万吨。众多的岛屿水域是海参优良的栖息地。数百年来，海参一直是印度尼西亚的传统渔业对象，直到现在，海参依然是印度尼西亚的主要出口水产品。

海参渔业中所用的渔船大多是一些总吨位1-10吨的小型船，渔民资金投入不足，以及对渔获物的加工缺乏技术，所以，印度尼西亚的海参品质较差，价格也很低（1.92美圆/千克，收购价）。影响印度尼西亚海参开发的另一个问题是过度捕捞。根据有关统计资料，印度尼西亚的海参年出口量大约是2500-3000吨 ，不同种类的海参价格在1.44--15.06美圆/千克之间。但由于捕获物规格太小，低品质的海参又居多，以致出口价格持续下降。

印度尼西亚有四个地区从事海参养殖，即1）巴布亚，约年产鲜海参378吨，2）中苏拉威西，年产200吨，3）东南苏拉威西，年产3吨，和4）东加里曼丹，年产在1吨左右。这里所报道的数字并非真正来自养殖，而是将所捕捞到的小规格海参，如糙海参放养在网箱或池塘里，待长到商品规格后，再加工、出售。当前，印度尼西亚的海参养殖存在两个问题，一是养殖时间过长，二是苗种来源匮乏。

过度捕捞和养殖的失败将危及印度尼西亚海参渔业的可持续发展。过度捕捞将加速海参群体结构的变化和资源的衰退。内外因素的结合直接影响到印度尼西亚的海参渔业和海参养殖业，为此，提出四点发展措施：1）推进可持续发展战略，2）发展海参增养殖业，3）制定捕捞规格，和4）完善产后加工技术。

关键词：开发、出口、养殖、生产、战略、产值、产量

Introduction

Indonesia is the largest single-country archipelago in the world (8.3 million km^2). Seventy per cent (5.8 million km^2) of this area is ocean with 17 508 islands and 81 000 km of coastline. Indonesian coastal and marine areas are habitats for numerous renewable marine resources, such as fish and shrimp. The maximum sustainable yield of the Indonesian marine fishery is approximately 6.2 million tonnes per year, comprising large pelagic fish (1.05 million tonnes), small pelagic fish (3.24 million tonnes) and demersal fish (1.79 million tonnes) (Dahuri, 2002). Moreover, Indonesian coastal and marine areas are a favourable habitat for many sea cucumber species. There are at least 56 species of sea cucumber found in these areas (Massin, 1999). Some commercial species that are heavily exploited in Indonesia are *Actinopyga echinites*, *A. mauritiana*, *A. miliaris*, *Bohadschia argus*, *B. vitiensis*, *Holothuria atra*, *H. edulis*, *H. fuscogilva*, *H. fuscopunctata*, *H. nobilis*, *H. scabra*, *H. scabra* var. *versicolor*, *H. coluber*, *Stichopus chloronotus*, *S. hermanni*, *Thelenota ananas* and *T. anax* (Basri, 1997; Conand and Byrne, 1993; Conand and Tuwo, 1996; Darsono, 2002; Daud, 1989; Tuwo and Conand, 1996).

Trade

As of today, Indonesia is the largest sea cucumber exporter in the world. The main export destination is Hong Kong SAR (China) and indeed 40-80 % of Hong Kong`s import of sea cucumber comes from Indonesia (Ferdouse, 1999; Tuwo and Conand, 1992). Other export markets for Indonesian sea cucumber are Japan, Korea Rep., Singapore, Taiwan PC, Malaysia and Australia.

The price of sea cucumber from Indonesia in the Hong Kong SAR (China) market is lower than that from Pacific island nations (Ferdouse, 1999). This lower price has also been observed in statistical data issued by the Industrial and Trade Office of South Sulawesi. The average annual price of Indonesian sea cucumber exported from South Sulawesi from 1996 to 2002 ranged from a high of US$ 15.06 per kg to a low of US$ 1.44 per kg during this period (Table 1).

Table 1*. Annual volume and export value of sea cucumber from South Sulawesi, Indonesia (Anon, 2003).*

	1996	1997	1998	1999	2000	2001	2002
Volume (tonnes)	359	853	399	192	146	457	241
Total Export (US$ million)	5.403	3.867	0.576	0.493	0.505	1.085	0.435
Unit value (US$/kg)	15.06	4.53	1.44	2.57	3.46	3.04	1.80

The price also fluctuates depending on target export market. During 2001 and 2002, the price was in the range of US$ 1.30-13.17 per kg (Table 2). This large price range is the result of the species composition of the catch, size and quality accepted in the markets. The acceptance in the market place of sea cucumber of different sizes can promote the over-exploitation of the natural sea cucumber resources.

In 2001, Taiwan PC imported significantly more valuable species than in 2002; whereas Hong Kong SAR (China) imported lower value species during both 2001 and 2002 (Table 2).

Table 2. *Volume and value of sea cucumber exported from South Sulawesi, Indonesia, to different countries (Anon, 2003).*

Destination	Volume				Value (US$)			
	2001		2002		2001		2002	
	tonnes	%	tonnes	%	Total	per kg	Total	per kg
Australia	0.3	0.1	-	-	550	2.00	-	-
Hong Kong SAR	256.0	71.7	194.9	81.0	344 687	1.35	253 581	1.30
Japan	83.5	23.4	-	-	667 457	7.77	-	-
Korea Rep.	8.5	2.4	9.4	3.9	45 816	5.39	70 534	7.50
Malaysia	0.6	0.2	0.2	0.1	1 200	2.00	641	3.62
Singapore	7.4	2.1	33.6	13.9	14 003	1.90	105 356	3.14
Taiwan PC	0.8	0.2	2.7	1.1	11 560	13.71	4 792	1.78
Total	357.1		240.8		1 085 275	3.04	434 905	1.81

Moreover, the prices also depend on size. This is even evident in local markets where the price of large *H. scabra* (8-12 specimens/kg) is around US$ 80 per kg, whilst small specimens (20-30 specimens/kg) are only US$ 7-8 per kg (Ngitung, pers. comm.).

The low price might also reflect a lower standard of post-harvest processing. Commonly, these three factors influence the export price of sea cucumber. However, it should be noted that exporters also influence the price, as they have been known to manipulate the price to reduce taxes. It is very likely that the price of sea cucumber exported from South Sulawesi has been manipulated as, for example, the local price at Barrang Lompo Island (Table 3) is much higher than the export price issued by the Industrial and Trade Office of South Sulawesi (Table 2).

Table 3. *Species and price of sea cucumber at Barrang Lompo Island, Spermonde Archipelago, South Sulawesi, Indonesia .*

Species	Makassar Name	English Name	Price* (US$ per kg dry weight)			
			Varying sources of data	Source of data - Salamba (2003)		
				Patrons	Collectors	Exporters
Actinopyga echinites	Kassi	Redfish	9.41 - 10.00 [1]	6.38	7.33	7.65
A. mauritiana	Ballang ulu	Surf redfish	9.41[1]	8.03	9.88	-
A. miliaris	Kassi	Blackfish	9.41[1]	6.38	7.33	7.65
Bohadschia argus	Binti, Patola	Leopard fish	1.06 - 1.18 (fs**)[1]	3.14	3.88	4.12
B. vitiensis	Gatta, olok olok	Brownfish	1.06 - 1.18 (fs) [1]	-	-	-
Holothuria atra	Cera	Lollyfish	1.18 (fi, rc) [1]	0.41	1.06	1.32
H. edulis	Cera	Pinkfish	1.18 (fi, rc) [1]	0.41	1.06	1.32
H. fuscogilva	Bissawa, koro, susu	White teatfish	14.12 (fs) [1]	24.20	26.62	24.31
H. nobilis	Batu, susu	Black teatfish	-	6.35	8.82	10.59
H. fuscopunctata	Kunyi	Elephant trunk	(rc, so) [1]	0.82	1.18	1.18
S. hermanni	Tai Kongkong	Curryfish	17.65 - 23.53[1]	11.09	14.37	15.92
Thelenota ananas	Pandan	Prickly redfish	2.94 (fs) [1]	7.06	9.22	9.41
T. anax	Donga	Amberfish	1.18 - 2.35 or 0.29 (fs) [1]	0.34	0.94	-
H. scabra	Bangkuli	Sandfish	35.29 - 47.06 [2]	-	-	-
H. scabra var. *versicolor*	Bangkuli	Spotted sandfish	47.06 - 58.82 [3]	-	-	-
H. scabra / H. scabra var. *versicolor*	Bangkuli	Sandfish/ Spotted sandfish	7.06 - 8.24 (ss); 70.59 (bs) [4]	-	-	-

**: exchange rate 1 US$ = Rp. 8 500.*

*** **bs**: big size; **fs**: fresh specimen; **ss**: small size; **rc**: rarely captured; **so**: soliter.*

*Sources: **1**. personal communication with collector at Barrang Lompo Island; **2**. Makassar collector; **3**. Surabaya exporter; **4**. personal communication with patron at Saugi Island.*

Fishery

The total catch of Indonesian sea cucumber cannot be estimated properly as some captured specimens are not recorded by the Fishery Office. This under estimation of catch is due to very limited access of the fisheries officers to the sea cucumber landing sites. A simple calculation from the catch and export data (Table 4) shows that the total catch figures, as issued by the Fishery Office, are less than 25 % of the real capture levels as evidenced by export figures.

Most of the Indonesian sea cucumber production is from natural populations. Fishermen catch the sea cucumber from small and medium fishing boats of less than 10 tonnes gross weight. The patron or *ponggawa* is usually the owner of the boat.

The exploitation of sea cucumber in Indonesia is an important contributor to the economic development of coastal and small island communities. For this reason, the sea cucumber population has to be managed properly to sustain its economic, and also ecological, benefits. The decreasing export volume is an important indication to the stakeholders that more effective management needs to be in place. During the last twenty years, the statistics show fluctuations in the catch figures (Table 4).

Table 4. *Sea cucumber catch (wet weight), total export and export to Hong Kong SAR (dry weight) from Indonesia during the last twenty years (Anon, 2002a; Tuwo and Conand, 1992).*

	Volume (tonnes)									
	1981	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**
Catch (ww*) *(Anon, 1991, 2002a)*	n.a.	275	232	456	351	478	351	840	1 450	1 722
Total Export (dw*) *(Tuwo and Conand, 1992)*	878	840	1 518	2 161	3 890	3 670	4 605	4 755	4 888	4 679
Export to Hong Kong SAR *(Tuwo and Conand, 1992)*	658	608	1 232	1 266	3 185	2 342	2 877	3 644	3 040	3 438
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Catch (ww*) *(Anon., 1991, 2002a)*	2 465	2 113	2 364	3 132	2 562	2 442	3 138	3 058	2 617	3 041

** **ww**: wet weight; **dw**: dry weight.*

Exploitation of sea cucumber in Indonesia has increased rapidly during the last 10 years. In Barrang Lompo Island, the number of medium-sized fishing boats (10 tonnes gross weight) increased from 4 to almost 50 boats in 2003 (Ical, pers. comm.).

The indication of over-exploitation is also evident from a low catch per unit effort (CPUE). The CPUE of medium-sized fishing boats in Indonesian waters is very low, with each one month trip (with 6-8 divers) recording only 1 000 specimens, or 33 specimens per day. The same classification of boat operating in Australian waters in 1997 caught 2 500 specimens during a five-day trip, equivalent to 500 specimens per day (Ical, pers. comm.).

Some studies on natural populations of sea cucumber in Indonesian waters show that the exploitation rate is more than 0.5 (the maximum limit for sustainable exploitation). The exploitation rate of sea cucumber, *H. scabra,* in Saugi Island waters was 0.62 in 1999 (Eyrika, 1999). Ten years ago, fishermen using *dogol* (small trawls) caught 10-20 specimens per night or 3-7 specimens of *H. scabra* per trawl (generally three trawls per night, three hours per trawl). But today, *dogol* catch only 1-2 specimens per night or 0.33-0.66 per trawl (Ngitung, pers. comm.). In fact, the fishermen catch only small *H. scabra* that are found in shallow waters. The fishermen at Saugi Island catch *H. scabra* with a size of about 3 specimens per kg wet weight. These are sold at US$ 0.12 for each specimen (Ngitung, pers. comm.).

Over exploitation is also happening in other parts of the Spermonde Archipelago, i.e. in waters of Bangko-Bangkoang Island. In 1997, the exploitation rate of curryfish, *S. hermanni,* captured by fishermen was 0.69. Any *S. hermanni* that are captured are generally of a small size. From 1 000 specimens of *S. hermanni*, 36.0 % were about 16.5 cm in length, 24.5 % were 27.3 cm, 19.9 % were 33.8 cm and 10.0 % were 40 cm (Basri, 1997).

Farming

Growing

The potential area for sea farming of sea cucumber in Indonesia is 720 500 ha (Dahuri, 2002). However, only a few areas are used, e.g. in East Java, West Nusa Tenggara, North Sulawesi, Central Sulawesi, South-East Sulawesi, Molucca and Papua. The four most important regions are Papua (378 tonnes wet weight per year), Central Sulawesi (200 tonnes), South East Sulawesi (3 tonnes) and East Kalimantan (1 tonne) (Anon, 2002b). However, a part of the catch volumes reported as sea farming products were not really a product of sea cucumber farming, as some fishermen retain their catch, generally *Holothuria scabra*, in a cage or pond until the number of specimens is large enough to sell or process.

Sea cucumber farming in Indonesia is very important; utilising only 10 % of the potential farming area could increase sea cucumber production to about 180 125 tonnes dry weight per year. This figure is based on a density of 10 individuals per square metre, a harvest size of 250 g wet weight, a survival rate of 50 % and a water content of 80 %.

Sea cucumber (generally *H. scabra*) is farmed in cages of 20x20 m^2 or 40x20 m^2. The cage is generally located in shallow coastal areas (water depth: 75-100 cm). Other fishermen rear sea cucumber in fish ponds located near the coast.

Organic matter used to enrich the sediment includes paddy bran and animal dust (ratio 1:1) and is used at a level of 0.2-0.5 kg per m^2 every two weeks. The organic matter is put into gunnysacks which are porous and allow a slow release of the nutrients. Each gunnysack can be filled with 10-15 kg of organic matter.

Holothuria scabra are harvested after 6 months of rearing when the individual size reaches 200-250 g (length 15-20 cm). The growth rate of *H. scabra* is quite slow during farming. Martoyo *et al.* (1994) reported that *H. scabra* grows only 28-33 g wet weight per month. Experimentally, the growth rate of *H. scabra* can be increased to 32-73 g wet weight per month by treatment with different doses of organic matter (Pirdausi, 1989).

Seed Production

Recently, sea cucumber juveniles or seeds have been collected from the natural population. However, the demand from farming for seed is very high. For example, a cage of 400 m^2 needs about 6 000 seeds at a density of 15-20 individuals per m^2 (wet weight 30-40 g, length 5-7 cm) or 4 000 seeds for a cage density of 10-15 individual per m^2 (wet weight 40-50 g, length 7-10 cm). To optimally utilise 10 % of the potential farming area, Indonesia needs about 7.2-14.4 billion sea cucumber seeds per year.

The mass production of seeds in Indonesia faces many biological and technical problems. The main problem is how to find viable broodstock (Handoko, 2002). Even though the sea cucumber, *H. scabra*, spawns continuously during the year (Tuwo, 1999), it is difficult to find mature broodstock. Generally, *H. scabra* releases its intestine (evisceration) and dies just after catch and these specimens cannot be used as broodstock. Another problem is that artificial spawning methods, such as thermal shock and desiccation, can also lead to evisceration.

Martoyo *et al.* (1994) and Tuwo *et al.* (1996) have tried to obtain mature eggs by dissection of sea cucumber and by taking the egg or sperm for fertilization. This method is ineffective and the number of eggs fertilized is very low, less than 20 % of total eggs spawned. Mass production of seeds in hatcheries has been tried on many occasions, but the results have been so far unsatisfactory due to low hatching rates (1-20 %) and larval survival rates (0.1-0.2 %) (Handoko, 2002).

Handling and post-harvest process

Post-harvest processing of sea cucumber can be done on the fishing boat or on land. A medium sized fishing boat (10 tonnes gross weight) usually processes their catch on board and returns to port with dried products (Ical, pers. comm.). Generally, onboard processing produces higher quality sea cucumber which, in turn, increases the price.

In contrast, small fishing boats process their catch on land. Generally, fishermen are poorer and have a lower skill level in proper handling and processing. As a consequence, the quality and price of the products are low (about US$ 2/kg at the fishermen level). Improving the handling and post-harvest practices can increase the economic return.

The processing steps used to produce the final product in Indonesia are the following: removing the internal organs, boiling the clean sea cucumber, air drying, fumigation, sun drying, packing and storage. The internal organs are removed by slicing lengthwise on the ventral face. The sea cucumber is then boiled in seawater for 20-30 minutes. Air drying is used to remove the surface water after boiling and the product is fumigated using wood and/or coconut shells for 10-20 hours. Finally, the sea cucumbers are sun dried.

Final remarks

From the above description, it is apparent that there are five main problems found in sea cucumber fisheries and farming in Indonesia. These are (1) unsustainable use/fishing; (2) low seed availability; (3) low growth rate; (4) no market regulation; and (5) poor post-harvest handling and processing.

Continued overfishing can affect the sustainability of Indonesian sea cucumber production. Over-exploitation can accelerate destruction and/or depletion of the sea cucumber population. Based on internal factors (such as the vast sea cucumber resources, over-exploitation and poor post-harvest processing) and external factors (such as a high market demand) that influence the Indonesian sea cucumber fishing and farming sectors, it is proposed that some alternative development strategies are used.

These are: (1) promoting sustainable use/fishing by co-management; (2) improve restocking and seafarming by developing sea cucumber hatchery and farming practices; (3) introducing a minimum size for each species of sea cucumber; and (4) upgrading post-harvest handling and processing by improving the skill levels of fishermen.

Therefore, the general objectives of these strategies are: (1) to sustain the production and ecological benefits; (2) to rehabilitate habitats and populations that have been over-exploited and to increase production levels; (3) to produce environmentally friendly products; and (4) to improve competitiveness and economic benefits.

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Fisheries, trade and utilization of sea cucumbers in Malaysia

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Abstract

Sea cucumber fisheries in Malaysia are exploited off the coastal waters around the coral reef regions in Sabah in East Malaysia. In Peninsular Malaysia, this resource is minimally exploited because more than 90 % of the coral reef islands in both the east and west coasts have been gazetted as marine parks or as fisheries prohibited areas, where fishing activities are prohibited in the vicinity. In Sabah, in the 1980s, landings of sea cucumber recorded an annual catch of about 400-500 tonnes (inclusive of sea urchins), while landings in the 1990s had fallen 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*, orangefish (*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 SAR (China), Taiwan (Province of China) and China PR. They are processed by boiling and evisceration, and are then exported in the dried or frozen form. Sea cucumbers are also imported into Sabah from neighbouring Indonesia and the Philippines, and may be re-exported after processing. However, since the 1990s, the volume of imports has decreased drastically.

In Peninsular Malaysia, sea cucumbers (locally known as "gamat") belonging to the *Stichopidae* family, mainly curry fish (*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. *Stichopus horrens*, however, are still found in relative abundance in 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 is no fishing regulations aimed at preventing over-exploitation 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 nutritional properties of the Malaysian species are also described.

Keywords: Landings, commercial species, exports, imports, processing, pharmaceutical properties, management

马来西亚的海参渔业和贸易

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摘要

海参渔业是马来西亚东海岸沙巴州渔民的主要渔业生产项目之一。就整个马来西亚半岛而言，海参资源得到了很好的保护，其原因是马来西亚90%的珊瑚岛礁被规划为海洋公园，在该区域内严厉禁止任何渔业活动。在沙巴州，80年代，海参和海胆的年捕捞量是400—500吨，到了90年代下降到100吨左右。开发利用的食用海参种类有糙海参（*Holothuria scabra*）、黑乳参（*H. nobilis*）、黄乳参（*H. fuscogilva*）、奇乳海参（*H. fuscopunctata*）、玉足海参（*H. leucospilota*）、格皮氏海参（*Bohadschia graeffei*）、

图纹白尼参（*Bohadschia marmorata*），和梅花参（*Thelenota ananas*）。这些海参一部分销往沙捞越，大部分出口到新加坡、泰国、香港、台湾和中国大陆。加工方法也很简单，即去内脏、煮沸，部分晒成干品出口，也有成冻品出口。沙巴州也从邻国印度尼西亚和菲律宾进口，加工后再供出口。自从90年代以来进口量大幅度下降。

在马来半岛被叫做gamat的海参主要指刺参科（Stichopodidae）中的花刺参（*S. variegatus*）和糙刺参（*S. horrens*）具有药物开发价值。位于马来半岛西海岸吉打州的Pulau Langkawi海参加工业使得花刺参的资源遭到严重破坏，该种海参已被列为濒危动物。糙刺参的资源量在Perak州的Pulau Pangkor珊瑚礁区依然较为丰富。这类海参用传统的方法加工海参油、海参液，近来还被加工成海参软膏、牙膏和海参肥皂等名目繁多的产品。

本文还介绍了捕捞海参的渔具、资源量、渔场和资源增殖方法等。目前，除在海洋公园已制定有禁止捕捞的规定外，尚未制定有助于防止过度开发的渔业法规，仅在本文中提出若干建议供讨论。本文还介绍了马来西亚的海参贸易和马来西亚所产的海参的药用和营养性能等情况。

关键词：上岸量、商业种类、进出口、加工、药用性能、管理

Introduction

Malaysians value sea cucumbers for their medicinal benefits and also as culinary delicacies. Malays have traditionally utilized certain species of *Stichopus* (locally known as "gamat") for their medicinal properties and traditional medicines processed from gamat are used in wound healing, treatment of stomach ulcers and as a painkiller. The Chinese have long regarded sea cucumbers as a general health tonic, beneficial for treating tendonitis and arthritis, and as an aphrodisiac, among many other medicinal claims. The Chinese also consider sea cucumbers as culinary delicacies.

Globally, commercial species of sea cucumbers in many countries are overfished due to the ease in which sea cucumbers can be collected from shallow reef flats during low tide. In Malaysia, the lack of fishing regulations such as the minimum legal permitted size for harvesting, closed season and catch quota are also some reasons that contribute to the overfishing.

As a fishery, sea cucumber landings contribute only a small part of the total marine landings in Malaysia. Over-fishing of certain species of sea cucumbers has been observed in both Peninsular Malaysia and Sabah. This paper attempts to describe the fisheries, trade and utilization of sea cucumbers in Malaysia; it also discusses some of the management issues pertaining to over exploitation and ways for conservation of sea cucumbers in Malaysia.

Fisheries

Most of the commercial species of sea cucumbers utilized for medicinal purposes or as food are found in coral reef regions. Some of the edible but non-commercial species of sea cucumbers, however, are found in the vicinity of coastal mangrove mudflats; one such example is *Paracaudina* sp., locally known as "beronok", which is often served as a salad and consumed by coastal communities.

As a fishery, sea cucumber catches are relatively insignificant in terms of total tonnage and value compared to catches of prawns and fish landed in Malaysia. Except for some small scale, hand collection of sea cucumbers, there is no commercial scale sea cucumber fishery in Peninsular Malaysia and Sarawak. Sabah is the only state with a relatively important sea cucumber fishery.

Peninsular Malaysia

Although many commercial species of sea cucumbers are found in the coral reef regions in Peninsular Malaysia (see Forbes *et al.*, 1999), there is no commercial fishery mainly because most of the coral reef islands there have been gazetted as marine parks. In 1994, a total of 37 islands in both the east and west coasts were grouped into four island clusters (Payar Island in Kedah; Redang Island in Terengganu; Tioman Island in Pahang, Mersing Island in Johor) and have been declared as marine parks where fishing or collection of aquatic organisms are not permitted. Poaching and fish blasting in marine parks are relatively rare compared to situations in Sabah. Apart from the marine parks, three areas in the west coast of Peninsular Malaysia have been declared Fisheries Prohibited Areas, two in Melaka and one in Negeri Sembilan.

Ungazetted coral areas that have no restriction on fishing include: the Sembilan group of islands and Pangkor Island in Perak; small patches of coral reef flats in Langkawi Island, Kedah; Kendi Island and Song Song Island in Penang. The Malaysian Government is currently studying the proposal to gazette the Sembilan Island groups as a marine park. This move is strongly supported by *Stolephorous* fishers in Pangkor Island who have experienced dwindling catches over the years and believe that the establishment of the Sembilan Islands Marine Park will help improve stock recruitment in the coastal waters of Pangkor.

There is a small commercial fishery consisting mainly of *Stichopus horrens* collected by hand by a fisher and his family from the north-western reef flats in Pangkor Island. The sea cucumbers collected are used for the preparation of traditional medicinal products like gamat water and gamat oil. The fishery here is small scale and generally regarded as sustainable. Preparation of gamat water involves draining the coelomic fluid from the gamat, which is then returned to the net cages holding them (see Baine and Choo, 1999). Animals are only harvested when there is a demand for gamat oil. Gamat are then collected from the reef flats and boiled in oil together with some herbs. Apart from *S. horrens*, Forbes *et al*. (1999) documented the presence of *Holothuria atra* and *H. fuscopunctata* in the Pangkor Island area.

The *S. hermanni* (formerly known as *S. variegatus*) fishery in Langkawi Island dates back to the mid 1900s but disappeared in the early 1990s due to overfishing for the traditional medicine industry. Sea cucumbers can still be seen in small numbers in some reef flat areas such as in the Datai and Tanjung Rhu areas. Species documented by Forbes et al. (1999) from Langkawi Island include *S. horrens*, *H. leucospilota* and *H. hilla*.

Sabah

The sea cucumber fishery in Sabah is important not because it contributes significantly to foreign exchange, but because it provides a livelihood for, and supplements the income of, the poor coastal communities, many of whom are artisanal fishers living in the Semporna, Sandakan, Kudat and the Kota Kinabalu areas. Large tracts of ungazetted coral reefs and reef flats are available for sea cucumber collection. In Sabah, eleven islands (Pulau Tiga Park with 3 islands, Pulau Tunku Abdual Rahman with 5 islands and Turtle Islands with 3 islands) are gazetted as marine parks and managed by Sabah Parks. However, even in these restricted areas, poaching, fish dynamiting and cyanide fishing continue to be a problem. The Sabah Government is in the process of gazetting 325 km^2 in Semporna as a marine park (http://www.tracc.org.my/Borneocoast/CZM_ISSUES/semporna_MP.html), while the Lankayan-Bilean Islands, off Sandakan, have been established as a conservation area under the Wildlife Conservation Act.

Most of the sea cucumbers landed in Sabah are collected by hand from shallow reef flats or by snorkelling or diving. Although the Annual Fisheries Statistics, Sabah, indicate that relatively few fishers are registered as collectors or those using miscellaneous gears (in 2000, the number of fishers recorded in Semporna was 77, Sandakan 0, Kudat 112 and Kota Kinabalu 28), the actual number of collectors could be at least five or six times these numbers. This is because the collection usually involves the whole family of the fishers, who wade in the reef flats to collect sea cucumbers during low tide. Fishing is carried out during the day or at night as long as the weather permits and the tides are low enough to allow the fishers to walk on the reefs. The number of fishing days to collect sea cucumbers average 20 days a month.

The wholesale value of processed sea cucumbers (beche-de-mer or locally known as "trepang" or "balat") constitutes only a small fraction of the total wholesale value of fisheries commodities. In 2000, Semporna landings constituted 2.61 % of the wholesale value in that district, 0.09 % in Sandakan, 0.04 % in Kudat and 0.18 % in Kota Kinabalu. In terms of the whole state, sea cucumbers constitute only 0.17 % of the total wholesale fisheries value.

Species

About 20 species of sea cucumbers are commercially fished. Compared to five years ago, the present landings comprise a significant increase in landings of the less valuable species commonly known as the 'worm' species. They include *Holothuria leucospilota* (local name "patola") and species known locally as "tri kantos", "quadro kantos", black beauty, broam beauty, hot dog (*Holothuria edulis*), "lubuyoh tadik" and "bantunan" (*Holothuria pardalis*). Figure 1 shows some of the common commercial species in Sabah and their local names.

Figure 1. *Local names of commercial species of sea cucumber from Sabah. Top(L to R): boli-boli; kasut; gadol; talipan; bot-bot; legs; patola; leopard, black beauty. Bottom (L to R): susu; broam beauty (white); mother tadik; broam beauty (brown); powder; hotdog; patola; gadol; boli-boli; sandfish; tri kantos; tadik.*

Prices of sea cucumbers are related to the thickness of their body wall and their size. Species with a thick body wall (like teatfish) command higher prices than those with a thin body wall. For the 'worm' species, the 'large' category comprises 25-30 pieces to a kg, the 'medium category' 70-80 pieces per kg, the 'small category' 130-140 pieces per kg and extra small more than 180 pieces per kg. The wholesale price of some of the commercial species of beche-de-mer is shown in Table 1.

Gear and Landings

Statistics on sea cucumber landings from Sabah in the last decade averaged around 100 tonnes (see Table 2); statistics between 1980 and 1990 recorded landings of around 400 tonnes inclusive of sea urchins. Sea cucumber landings recorded by the Food and Agriculture Organization (FAO) showed that there was a small fishery from Peninsular Malaysia (with Sabah accounting for a substantial amount of the catch) in the 1980s and early 1990s. No records were available from FAO after 1993; the Annual Fisheries Statistics, Malaysia does not document landings of sea cucumber implying that the fishery is insignificant compared to the more important resources like fish and prawn.

Table 1. *Wholesale price of some species of beche-de-mer from Sabah.*

Species	Wholesale Price (US$/kg)
Teatfish (*H. nobilis*, *H. fuscogilva*)	42.10 or 78.95 (retail)
Sandfish (*H. scabra*)	10.53 (small) or 18.42 (medium) or 36.84 (large)
Kasut (*H. fuscopunctata*)	6.58
Patola (*Holothuria leucospilota*)	5
Tri kantos	1.58
Bantunan	1.32
Broam beauty (white)	9.21
Broam beauty (brown)	4.74
Gadol (*Stichopus* sp.)	17.89 (small) or 21.05 (medium) or 23.68 (large)
Boli-boli (*Actinopyga miliaris*)	17.11
Talipan or timpul (*Thelenota ananas*)	17.11
Legs (*T. anax*)	3.68
Mother tadik (*Bohadschia* sp.)	7.37
Leopard (*Bohadschia* sp.)	9.21

Semporna, Sandakan, Kudat and Kota Kinabalu are important areas for sea cucumber fisheries. Since the mid 1990s, Semporna is the most important sea cucumber fishery area, with catches ranging from 29 % to 62 % of the total landings from Sabah (see Table 3).

Table 2. *Sea cucumber landings in Malaysia and Sabah (metric tonnes).*

	Landings (tonnes)	
Year	Malaysia	Sabah
1980		300
1981	168	300
1982	430	400
1983	435	400
1984	367	300
1985	1169	900
1986	687	500
1987	800	600
1988	616	400
1989	800	200
1990	800	400
1991	780	37
1992	800	90
1993		64
1994		142
1995		155
1996		105
1997		90
1998		123
1999		178
2000		159

Source: Data from FAO & Annual Fisheries Statistics, Sabah. 1980-1990 Sabah figures include also sea urchin.

Table 3. *Sea cucumber landings in the various districts in Sabah (metric tonnes).*

	Landings (tonnes)						
Year	Semporna	Sandakan	Kudat	K. Marudu	K. Belud	K. Kinabalu	Total
1991	0	35	1	0	0	1	37
1992	0	74	4	10	0	2	90
1993	0	57	0	1	0	6	63
1994	30	24	41	0	0	47	142
1995	55	21	46	0	0	33	155
1996	34.38	23.75	24.04	0	3.10	19.49	104.76
1997	25.69	19.29	19.02	0	0	26.01	90.01
1998	52.36	24.04	14.68	0	0	31.48	122.56
1999	79.65	24.47	21.88	0	0	51.80	177.80
2000	98.65	22.67	15.88	0	0	21.71	158.91

Source: Data from Annual Fisheries Statistics, Sabah.

May to August are the best months for sea cucumber collection because of the calm seas. January to March appears to be the worst time of the year for sea cucumber collection because of the rough weather caused by the Northeast monsoon (see Table 4).

Table 4. Landings of sea cucumber in Sabah by months (metric tonnes).

	Landings (tonnes)												
Year	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
1991	2	3	2	4	3	5	2	3	4	2	3	4	37
1992	5	5	4	7	6	8	12	11	9	6	10	7	90
1993	7	6	8	9	9	7	3	5	4	2	2	2	64
1994	5	5	8	4	6	17	43	11	11	9	8	15	142
1995	6	3	4	16	13	29	19	13	12	8	10	22	155
1996	8.22	13.03	6.54	10.52	8.44	12.53	7.28	9.02	8.35	6.00	7.07	7.76	104.76
1997	9.18	4.07	9.96	5.94	6.02	8.25	5.17	7.72	6.04	8.69	13.02	5.95	90.01
1998	6.68	7.88	5.55	10.10	12.57	11.90	13.73	13.19	13.03	13.47	7.21	7.25	122.56
1999	8.51	8.68	15.26	16.09	19.02	16.63	16.25	22.01	14.04	17.65	10.24	13.42	177.80
2000	7.45	10.60	14.54	11.58	17.24	13.65	12.98	14.17	16.01	13.31	12.28	15.10	158.91
Total	65.04	66.26	77.85	94.23	100.29	128.96	134.41	109.11	97.47	86.12	82.82	99.48	1142.04

Source: Data sourced from Annual Fisheries Statistics, Sabah.

Starting from the mid 1990s, the majority of the sea cucumbers were caught by coastal communities by hand picking them from shallow reef flats during low tide or by diving in the deeper regions (see Table 5). Teatfish, black fish, elephant's trunk fish and the bigger-sized sand fish are rarely found in the shallow reef flats due to over harvesting. They are often collected by coastal fishers of Filipino origin (some may be illegal immigrants) from the deeper areas by snorkelling or diving. In Kudat and Sandakan, sea cucumbers are collected also with the trawl gear. Most of the sea cucumbers harvested by trawl gear are collected by trawlers of 10-24.9 gross tonnage and 25-39.9 gross tonnage fishing in waters within 30 nautical miles of the coast.

Table 5. Landings of sea cucumber in Sabah by gear group (metric tonnes).

Year	Trawl	Hook/ Line	Pick/Dive	Total
1991	36		1	37
1992	84		6	90
1993	58		6	64
1994	29	27	86	142
1995	23		132	155
1996	27.09	0	77.67	104.76
1997	24.02	0	65.99	90.01
1998	33.12	0	89.44	122.56
1999	38.55	0	139.25	177.8
2000	37.97	0	120.94	158.91

Source: Data sourced from Annual Fisheries Statistics, Sabah.

Processing

There are several ways of processing sea cucumbers. Most sea cucumbers are processed into either the dried or frozen beche-de-mer. Methods employed by fishers generally yield beche-de-mer that are semi-processed and of low quality, and the end products are still moist and contain considerable amount of sand in the coelom. Fishers process sea cucumbers by putting them into a "kuali" (wok) on low heat without adding water. After the initial cooking, the sea cucumbers are transferred into a "kuali" of boiling water where some papaya (*Carica papaya*) leaves or lime (calcium carbonate) have been added and mixture is left to boil in order to soften the skin of the sea cucumbers. The sea cucumbers are then smoked or sun dried. The fishers will sell the semi-dried sea cucumbers to the middlemen even when they are not thoroughly dried since the fishers need cash to buy food and other necessities.

Middlemen, who procure fresh sea cucumbers from fishers, also process sea cucumbers as a cottage industry. The processed products are sold to wholesalers who will then export the beche-de-mer to various countries. The processors and middlemen living in Semporna in the floating village, where stilt houses extend right into the sea, appear well to do (with cable TV and well-furnished homes) compared to the fishers that supply them with sea cucumbers. The processors generally pay RM 6 for a large sized (when dried, it will be about 400 g in weight) black fish, RM 15 for a sandfish and RM 24 for a teatfish. The sea cucumbers are either processed immediately or they are kept in a container filled with brine. The body wall of the teatfish, or other species with a thick body wall, is vertically slit. This is not required for blackfish and sandfish. The sea cucumbers are then put into a "kuali" of boiling seawater where they are left to simmer for 1½ hours over a slow fire. The sea cucumbers are boiled twice over a small flame and then dried under the sun.

If the sea cucumbers are previously preserved in brine, the salt is removed by washing the sea cucumbers with water before processing. They are then boiled over a slow flame for almost one day, and then dried in an oven at 120 °C until almost dried before transferring to dry under the sun or smoked over a fire. The dried sea cucumbers are then tossed in a kuali containing hot sand to remove the skin. After that they are boiled a second time, and the hard skin scraped off with a knife before they are dried again.

Frozen sea cucumbers are prepared by first boiling the animals for about 1½ hours. They are then transferred into plastic containers and covered with sand for two days. The sea cucumbers are then rubbed with sand to remove the skin. They are then boiled again over a slow flame until the body wall softens. The sea cucumbers are then left to cool before they are packed into plastic bags and put into the freezer.

Trade

Sea cucumbers are processed into beche-de-mer that are either chilled, fresh or frozen, or as other than these, which will include the dried or smoked variety. The chilled, fresh or frozen forms are exported mainly to Peninsular Malaysia and Singapore, while the main markets for the other than chilled, fresh, frozen products are Peninsular Malaysia, Singapore, Sarawak and Hong Kong SAR (China) (see Tables 6 and 7).

Table 6. *Beche-de-mer (chilled, fresh and frozen) exported from Sabah (metric tonnes).*

	Exports from Sabah (tonnes) to:									
Year	P. Malaysia	Sarawak	Singapore	Brunei	Japan	Hong Kong	Indonesia	Philippines	Total	US$
1984	3.26	1.47	0.40						5.13	14 081
1985	2.57		2.13						4.70	11 161
1986	1.43	0.12	0.22		0.20				1.97	5 318
1987	1.29		0.29						1.58	5 512
1988			0.02				0.21	3.58	3.81	1 486
1989			0.80					0.03	0.83	1 318
1990								0.12	0.12	20
1991	3.95								3.95	19 349
1992	1.87		0.55	0.25					2.67	11 021
1993	5.47	0.26	2.62						8.35	20 416
1994	3.56	0.67	4.29	0.30		0.20			9.02	22 168
1995	2.84	0.60	1.00						4.44	8 837
1996									0.00	0
1997									0.00	0
1998	1.05		0.40						1.45	7 500
1999	2.00								2.00	11 842
2000	0.55					1.30		2.55	4.40	9 763
Total	29.84	3.12	12.72	0.55	0.20	1.50	0.21	6.28	54.42	149 792

Source: Annual Report – Dept. Fisheries and Annual Fisheries Statistics, Sabah. From 1996 classified as trepang fit for human consumption.

Compared to the 1980s, only a small amount of beche-de-mer were imported into Sabah in the 1990s (see Tables 8 and 9).

The SITC code used for identifying beche-de-mer can be very confusing. In the Annual Fisheries Statistics Sabah in the earlier part of 1990s, live, fresh and chilled sea cucumbers had the code number 36353110, frozen ones had the number 036393111, while other than fresh, chilled or frozen beche-de-mer had the code 036393911. From 1996 onwards, a new category, 'fit for human consumption' was given the code number 036393110; this category replaces the other than fresh, chilled or frozen category

Table 7. *Beche-de-mer (other than chilled, fresh and frozen) exported from Sabah (metric tonnes).*

Year	Exports from Sabah (tonnes) to:											
	P. Malay.	Sarawak	Singapore	Brunei	Hong Kong	Taiwan	Thailand	Philip-pines.	S. Korea	USA	Total	US$
1984	2.89	32.64	48.45								83.98	102 132
1985	51.54	137.19	62.80								251.53	158 355
1986	17.58	27.43	75.02	0.16	4.18						124.37	209 150
1987	13.51	31.66	70.20		58.21						173.58	345 501
1988	12.20	34.46	34.46	0.05	23.45	2.21					107.43	279 747
1989	19.57	17.98	26.19	0.10		0.12			0.50		64.46	147 934
1990	25.20	25.11	61.92	0.15	0.77	0.03		0.11	3.93		117.22	260 386
1991	43.25	9.79	3.85	0.14	9.35		1.34	0.43	0.35		73.50	300 551
1992	26.37	5.30	16.22	0.25				1.43			50.56	139 036
1993	21.47	11.82	2.17								35.46	69 566
1994	67.71	6.71	2.60	0.25	4.85						82.12	293 780
1995	45.76	16.15	6.58		0.55	3.42	0.30				72.76	300 686
1996	25.70	7.94	0.80		0.10		1.01	2.58	0.09		38.22	145 447
1997	28.53	9.69	3.83	0.78	7.10			0.30			50.23	231 754
1998	14.72	2.58	3.50	0.12	15.65	1.31		0.87		0.24	38.99	206 852
1999	30.24	0.61	0.09	0.36	12.22						53.13	267 510
2000	20.52	3.95	5.30	0.65	78.50						108.92	542 211
Total	466.76	381.01	423.98	3.01	214.93	7.09	2.65	5.72	4.87	0.24	1526.46	4 000 598

Source: Annual Report - Dept. Fisheries Sabah and Annual Fisheries Statistics, Sabah. From 1996 classified as trepang fit for human consumption.

Table 8. *Chilled, fresh and frozen beche-de-mer imported into Sabah (metric tonnes).*

Year	Imports into Sabah (tonnes) from:										
	P. Malay.	Australia	Singapore	India	Japan	Hong Kong	Indonesia	Philippines	Taiwan	Total	US$
1984			0.86							0.86	691
1985			0.36		0.01		0.06			0.43	448
1986			0.22	0.05			0.17			0.44	498
1987	0.15		0.12				0.03			0.30	313
1988							0.21	3.06		3.27	408
1989	0.29	0.02	1.13	0.54		0.10	0.08	2.74	0.01	4.91	2 907
1990	0									0	0
1991	0									0	0
1992	0									0	0
1993	0									0	0
1994	0									0	0
1995								0.20		0.20	154
1996								0.03		0.03	12
1997								0.04		0.04	11
1998	0									0	0
1999	0									0	0
2000								1.08		1.08	568
Total	0.44	0.02	2.69	0.59	0.01	0.10	0.55	7.15	0.01	11.56	6 010

Source: Annual Report - Dept. Fisheries and Annual Fisheries Statistics, Sabah. From 1996 classified as trepang fit for human consumption.

Table 9. *Main imports of beche-de-mer (other than fresh, chilled and frozen) in Sabah (metric tonnes).*

	Imports into Sabah (tonnes) from:						
Year	Australia	Hong Kong	India	Indonesia	Philippines	Singapore	P. Malaysia
1984	0.04	0.03	2.36	0.26	64.23	1.89	
1985		0.08	2.22	0.14	41.62	0.17	0.37
1986	0.07	0.14	1.49	0.29	38.19	0.43	
1987	0.01	0.08	0.61	0.31	7.65	0.43	0.86
1988	0.02	0.07	1.32	0.17	5.65	0.75	0.82
1989	0.02	0.10	0.54	0.08	2.74	1.13	0.29
1990	0.02	0.05	0.18	0.04	1.83		0.35
1991							
1992				0.08	0.16		0.35
1993					0.04		
1994					0.47		0.50
1995							
1996				3.50	0.03		
1997				0.50			
1998					0.70		1.22
1999			0.02				13.89
2000							4.38

Source: Annual Report - Dept. Fisheries and Annual Fisheries Statistics, Sabah. From 1996 classified as trepang fit for human consumption.

Utilization

Sea cucumber, apart from being sought after as a food delicacy and as a traditional cure for many illnesses, are also exploited for their potential nutritional and pharmaceutical properties. Apart from the traditional gamat water and oil, sea cucumbers have been incorporated into products which include juice, balm, liniment oil, cream, toothpaste, gel facial wash, body lotion, facial wash and soap.

Sea cucumber is cholesterol-free. It is high in protein (55 % of dry body weight) and contains 10-16 % mucopolysaccharides (substances used for building cartilage) and saponins; it is helpful in reducing arthritic pain and arthralgia (due to the mucopolysaccharides content) and pharmacological studies indicate that the saponins of sea cucumber have anti-inflammatory and anticancer properties (Dharmananda, undated). Scientists from the University of Malaya working on *S. hermanni* reported on the painkilling, anti-inflammatory and anti-itching properties of this sea cucumber (Awaluddin, 2001).

Research carried out by Malaysian scientists indicated that three types of antimicrobial agents, namely atratoxin A, B_1 and B_2 were found in *H. atra*, and these agents exhibited high activity against various species of yeast and fungi, but bacterial species showed resistance against these agents (Ibrahim *et al*., 1992). Shaharah *et al*. (1999) demonstrated that ethanol extracts from *H. atra* have antifungal properties effective against the yeasts, *Saccharomyces lypolytica* and *Candida lypolytica*. Studies carried out by Hawa *et al*. (1999) showed that the coelomic fluid of *S. badionotus*, *S. hermanni* and *B. mamorata vitiensis* demonstrated antioxidant activity.

Discussion

Except for the Marine Parks Act, which prohibits the collection of all aquatic organisms in the vicinity of the gazetted area, no other management measures are in place to specifically regulate the sea cucumber fishery. A lack of effective enforcement has resulted in activities like poaching, cyanide fishing and fish blasting which are still rampant in Sabah. The latter two activities have destroyed the reefs and affected the abundance of reef-related organisms. The situation in Sabah is rather delicate, since illegal fishers from neighbouring countries carry out many of these illegal activities. The indiscriminate dumping of garbage and sewage pollution in the Sandakan area has been attributed to illegal squatters (Anon, 1998). Problems of illegal fishing and pollution will be difficult to solve if the bigger challenge of illegal immigration is not successfully resolved.

Other anthropogenic factors that destroy or degrade reefs include various activities related to ecotourism like anchoring boats on corals and treading on corals. The number of tourist arrivals exceeding the carrying capacity of the coral islands may lead to problems related to the disposal of solid wastes and sewage, thus posing a great pollution threat to the environment.

A study conducted by World Resources Institute in 2002 (quoted from Chou *et al.*, 2002) reported that out of the 4 006 km^2 of reef areas in Malaysia, 13 % of the reefs are classified under the Threat Index to be at low risk, 44 % medium risk and 38 % at high risk. A recent study on coral cover in the east coast of Peninsular Malaysia showed that an estimated 42.2 % of the sites studied were in fair condition, with some sites in good condition, and the percentage of recently killed coral was a relatively low at 5.3 % (Harborne *et al.*, 2000). A study conducted in June 2002 in some reefs off Kudat, Sabah found living coral ranging from 27.5 % to 71.3 % at the reef crests and from 10.6 to 60.6 % at reef slope depths between 3 and 6 m (Chou *et al.*, 2002).

A recent study carried out on the coral reefs off the east coast of Peninsular Malaysia showed that edible species of sea cucumbers were frequently seen [density/100m^2, with standard deviations in bracket: Redang Island - 4.7 (4.2); Tioman Island - 2.8 (2.6); Tinggi Island - 11.9 (17.8)] suggesting low fishing pressure (Harborne *et al.*, 2000). Studies conducted by researchers in Sabah indicated that invertebrates, including sea cucumber, are wantonly exploited, and that their numbers are greatly reduced or have disappeared from many reef areas. (http://www.tracc.org.my/Borneocoast/CORAL_REEFS/recent_reefsurveys_summary.html).

Although most fishers interviewed by the author reported a decrease in sea cucumber landings, none of them expressed the need for urgent conservation measures, indicating a general lack of awareness on the seriousness of the situation. This lack of urgency is also apparent among government planners and managers - due partly to the small scale of the sea cucumber fishery and its insignificance when compared to the other more abundant and valuable fisheries.

Measures such as the imposition of a closed season for a few months in each year or limiting fishing to a few days a month are some of the steps that the government can implement immediately. Research on the biology and ecology of the commercially important sea cucumber species will help managers to formulate regulations such as the minimum size for harvesting and closed season to be imposed during the spawning and breeding periods.

The loss in catch per month can be compensated by teaching the fishers how to process better quality beche-de-mer, which may subsequently fetch higher prices in the wholesale market. Research on value addition to processed sea cucumbers should also be given priority. The centuries old method of preparing beche-de-mer with so many rounds of boiling and drying, and again the many rounds of boiling and soaking before they are used for food preparation, would probably lead to the leaching of a considerable amount of valuable nutrients from the sea cucumbers. Processors should look into modern methods that would result in a more hygienic and wholesome sea cucumber product.

Stock enhancement of natural populations through the aquaculture of sea cucumber can also be explored. Presently, KO-NELAYAN (a fishers' association in Sabah) has initiated plans to culture and ranch sea cucumbers but so far they are concentrating on fattening wild sea cucumber stocks in pens located in Bum-Bum Island in Semporna, while they acquire the skills needed for culturing these organisms. Working in partnership with institutions such as the WorldFish Center, which has made considerable progress in the culture and stock enhancement of sand fish in the Solomon Islands, Viet Nam and New Caledonia can accelerate implementation of the culture and stock enhancement program (see Battaglene, 1999; Pitt and Duy, 2003).

Better success could be realized if the government works closely with the stakeholders to put in place co-management plans, which are derived from joint decisions between managers, fishers and processors. Managers must realize that the loss of the sea cucumber fishery will have a great impact on the poor artisanal fishers, who are dependent on sea cucumbers for their livelihood. Moreover sea cucumbers play an important role in the marine ecosystem as detritus and suspension feeders acting like the earthworms of the sea, and their role in the coral reef ecosystems must not be under estimated. We must ensure the sustainability of the sea cucumber fishery.

Conclusion

In Malaysia, a significant sea cucumber fishery exists only in the East Malaysian State of Sabah. Signs of overfishing of the more valuable species such as teat fish and sand fish are evident by the decrease in landings and the decrease in overall size of the animals landed. An increase in landings of the less valuable species such as the 'worm' species is noticeable. Threats to sea cucumber fishery include overfishing and degradation/destruction of aquatic habitats, especially coral reef habitats.

Except for the establishment of marine parks with the overall objectives of conserving corals and coral-reef related organisms, there are no other management plans specifically for the conservation of sea cucumbers. Poaching, cyanide fishing and fish blasting occur quite frequently, even in marine parks. Control of pollution and illegal fishing are made difficult by the problems posed by illegal immigrants who seek out a livelihood in fishing.

Conservation through the imposition of a minimum legal size for harvesting, a closed season for fishing, better enforcement of marine park regulations and stock enhancement through aquaculture are some of the measures that can be implemented, and help to enhance recruitment and stock of sea cucumbers. Co-management involving the state and stakeholders can also increase the chances of success in implementing conservation plans.

Scientific research has proved that sea cucumbers have many nutritional and pharmaceutical values. The age-old method of processing beche-de-mer involves many cycles of boiling and drying, and nutrients may be lost during the processing process. Improved processing methods and value-addition in the preparation of sea cucumber products should therefore be given research priority.

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The status of sea cucumber fishery and mariculture in the Philippines

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Abstract

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 started only in the 1970s. Over the last two decades, export levels have been maintained at 1 000 tonnes annually with the decline in the volume of high value species compensated by the low value species. Hong Kong SAR (China), as the major export partner, likely serves as a transit point for other countries. 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 and beche-de-mer as an ingredient in Chinese dishes is common, but 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 a 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 localized depletion as narrated by the fishers during interviews. All those interviewed agree that their catch per 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* were initiated in 2000 with a long term objective of producing seeds for the enhancement of the wild populations. Studies at experimental scale were conducted to improve the survival rate of fertilized eggs to juveniles. Likewise, initial investigations on the growth of juveniles in cages in the field have been initiated. At full scale, the reseeding activity is envisioned to be a partnership between academia 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.

Keywords: Sea cucumbers, trade, depletion, *H. scabra*, reseeding, Philippines

菲律宾的海参捕捞和海水养殖状况

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摘要

菲律宾已知的海参大约有百种之多，其中25种有商业价值。虽然传统的出口贸易已经沿袭了几个世纪，但有关海参的统计数据监测从二十世纪七十年代才开始进行。在最近的二十年中，出口额保持在每年1000吨左右，但高价值种类的数量在减少，而低价值种类数量不断增多以补总额的不足。香港，作为主要的出口伙伴，起着向其他国家出口中转的作用。虽然海参被作为出口商品对待，但是，官方未将海参的国内贸易和消费列入统计资料。然而，加工过的产品可以在大城市的超级市场上找到踪影。海参是中国菜中的很普通的菜肴之一，但大多数当地客户并不了解这一点。在渔民和出口市场之间有着一系列的中间商，他们完全控制着国内价格，同时又受制于中国市场的变化。渔民或中间商对海参进行晒干和冷藏等初级处理后，在城市里卖给下一个中间商时获取一部分利益。这种商业活动的投资回报周期长达一周甚至几个月。

现有的有关海参的报道主要是关于海参分类和分布等方面的学术论文，而有关当地资源衰退状况则是在采访调查时由渔民口述提供的信息。在所有的采访中，渔民都异口同声地说，近年来捕捞量严重下降，他们花费很长时间，在较深的海区才能捕捞到2-3条体重大于500克的个体。对于高商品价值海参，如糙海参（*Holothuria scabra*）的研发始于2000年，目的是培育种苗供放流增殖用。实验室的研究致力于提高幼体的成活率和网箱养殖。关于增殖放流，计划由科研单位和资助人之间建立合作伙伴关系来开展。但是，最近因资金不到位，这方面的研究和开发项目已暂停。

关键词：海参、贸易、资源衰退、糙海参、放流、菲律宾

Introduction

The Philippines, as an archipelago, is naturally blessed with a high diversity of sea cucumber species that inhabit its wide seagrass beds, soft bottom areas, and reefs. Sea cucumber ranks 8th among the major fishery exports of the country. About 100 known species, distributed throughout the country, have been recorded (Schoppe, 2000; Domantay, 1934) and trade currently exists from the north to the south (Formacion, 1979; Trinidad-Roa, 1987). The country has been a major exporter of the processed trepang or beche-de-mer for the last several centuries (Akamine, 2002) and the trade has been responsible for the prosperity of the Sulu Sultanate in southern Philippines during the 18th and 19th centuries (Akamine, 1998). Based on recent records, export production reached a peak of 3 499 tonnes, worth about US$ 3 million, in 1985 and was followed by a drastic drop to almost half of the said volume in the succeeding year. Since then, trepang export has been maintained at ≥1 000 tonnes, perhaps second only to Indonesia (FAO, 2000; Akamine, 2002).

A review of the fishery at the national scale was first published in 1987 (Trinidad-Roa, 1987). The issues raised then were as follows:

1. Localized depletion;
2. Lack of baseline surveys to ascertain extent of depletion; absence of inventory and monitoring of existing stocks in both unexplored and exploited areas;
3. Uncontrolled, non-selective harvesting;
4. Export demand has led fishers to search farther and deeper;
5. Despite the increased catch effort, the catch volume has been decreasing;
6. Absence of guidelines for regulating collection;
7. Absence of management plans about the fishery;
8. Absence of hatchery efforts.

Eighteen years after that review and at the start of the 21st century, has the fishery fared any better? For this updated report, both primary and secondary data were used. Primary data were gathered mainly through interviews (conducted in 2002 as well as accumulated through the last five years) with fishers, traders and consumers (restaurant owners, exporters or food processors). The places where interviews and/or visits were conducted are, namely:

A. Luzon - Batangas, Ilocos, Metro Manila, Pangasinan.

B. Visayas - Bohol, Cebu, Iloilo, Negros Occidental and Oriental, Palawan.

C. Mindanao - Davao del Norte, del Sur and Oriental, Surigao del Norte, Tawi-tawi.

D. Zamboanga.

Secondary data were taken from available related literature as well as from the main offices of the Department of Environment and Natural Resources (DENR), Department of Trade and Industry (DTI), the Bureau of Agricultural Statistics (BAS) and the Bureau of Fisheries and Aquatic Resources (BFAR). Our assessment shows that the issues in 1987 are exactly the same issues, becoming more pronounced, that have yet to be addressed today. While a pilot scale hatchery production was started in 2000, the project suffered a set back when government suspended the funding this year until further notice. In what follows, we will try to echo the same issues by looking at several dynamics of the fishery.

Species composition and abundance

The BFAR considers sea cucumber as a heavily exploited resource and acknowledges that localized depletion exists in many fishing grounds. But the bureau possesses no quantitative census to support this claim. Nevertheless, fishers and middlemen interviewed for this particular report were in agreement to concerns like:

1. *Lessened frequency in fishing and reduced catch volume as compared to the boom years* - In Samal Island, for example, from a year round activity to an average of three to five months per year; from several kilograms to a few individuals;
2. *Longer time to accumulate a certain volume* - In Bolinao, a middleman of dried products who used to leave for Manila every month now goes once every three months; another middleman of chilled products leaves once or twice a month with lesser volume but compensated by higher prices;
3. *Resorting to low value species* - A trader in Manila does not discriminate species in order to meet demand.

Available references on species composition and abundance are limited to local descriptions which vary in space and time (Acosta, 1969 as cited by Tan Tui, 1981; Alcala and Alcazar, 1984; Domantay, 1933, 1934, 1953, 1968; Domantay and Conlu, 1968; Leonardo and Cowan 1984; Metillo *et al.*, in press; Tan Tiu, 1981), thus, could not be compared directly. In 1987, only 15 species were exploited (Trinidad-Roa, 1987). By 2000, the number had grown to 25 (Schoppe, 2000). This is, perhaps, one of the most diverse among the beche-de-mer exporting countries. The Solomon Islands listed 22 species in 1993 (as cited by BAS, 2001, Philippines), while Madagascar has 27 species (Conand, 2001).

During the surveys, difficulty in ranking the exploited species and comparing them with those of Akamine (2002) or Schoppe (2000) were attributed to the following: (a) the use of different local names from place to place; (b) unavailability of fresh species at the time of the survey; and (c) varying prices as quoted by the different fishers and middlemen.

Another concern is the seeming lack of effort, on the side of the Government, in obtaining regional demographic or ecological information on holothurians in the country. Where such information exists, they are incomplete and fragmented and hardly helpful to local beneficiaries, *e.g.* local government units, who may need the information for planning and management purposes. Several regional BFAR offices were randomly checked for local data on standing crop and production. None was collected, as most often sea cucumbers are lumped together under marine products. Thus, this lack of demographic/ecological information is a big knowledge gap hindering the formulation of a management plan for the sustainability of the fishery.

Collection and management

Harvesting methods for sea cucumbers are of two types. One group of fishers targets and gathers sea cucumbers exclusively for direct sale to a local middleman; the other, more common, group collects individuals as by-catch. The first group can be further classified according to the volume of their catch. The more organized, as exemplified by those in Mangsee Palawan (Akamine, 1998), go out to deeper reefs for as long as forty days. The other group, as exemplified by those in Batangas, may consist of individuals who wade on seagrass beds during low tide and dig for or hand pick sea cucumbers. While it is the men who are primarily involved in both types, women and even school children are engaged in the latter type of harvesting, specifically on weekends.

Sea cucumbers as bycatch are gathered by 2-3 people on a boat that do traditional fishing by skin diving or diving with the use of an air compressor. The catch is sold to the nearest middleman who sometimes waits right at the landing site. The cash is equally divided between the fishers. In north western Iligan Bay (Metillo *et al*, in press) and in Samal

Island in Davao Gulf, a boat with 1-3 persons may be launched to collect sea cucumbers which are sold either directly to a middleman or sliced into bite sizes and sold fresh at the nearest wet market. This type of group sets out only when the all the conditions are ideal, namely: low tide, fair weather and new moon.

In all these types of gathering processes, no regulation or monitoring exists at the local level. There is no official size or volume restriction, no closed season, not even tax collection on the landings. The only fee the fishers pay is for the licence to operate a motorized boat. Under the Local Government Code, coastal municipalities are empowered to develop their own coastal development plan, which should include the sustainable use of marine resources. These plans, however, face a tough challenge during the implementation. Among the obstacles are a lack of political will especially in prosecuting the big-time illegal fish operators, a conflict of interests among the implementers, a lack of support from the community and a shortage of funds.

For marginal fishers who have to go farther and deeper, an air compressor is a basic tool. These divers, though fully aware of the danger and local ban on the use of air compressors, insist that it is cheaper and more practical than SCUBA. They would argue further that they are left with little alternative and taking risks (*e.g.* getting paralysed or imprisoned) is part of their hand-to-mouth existence. This attitude of fatalism ("what will be, will be") is common even among urban dwellers. While policing the use of banned gears such as air compressors and trawls is encouraged at the local government level, success stories are few and hardly sustained as the sea police operate on a volunteer basis and their trips depend on the availability of a boat with fuel. Moreover, the violators they apprehend are turned over to the local authorities where prosecution is another complicated, often politician-intervened process.

Traders sometimes complain of the indiscriminate practice of harvesting small individuals by some fishers. One trader said that once he tried imposing a minimum dried length of 7.5 cm and did not buy anything smaller. However, the fishers that he turned away would proceed to the next trader who willingly bought the rejected goods. The other trader would claim that there is market even for small ones. Another trader justified his purchase of all sizes from the fishers by saying it was out of pity. Whether for sustainability or out of pity, it is the traders and not the fishers who live comfortably, judging from the house amenities observed during interviews.

From the point of view of fishers, what is more important is the additional income they derive from catching sea cucumbers. They argue that the small ones they leave behind will be collected by the other fishers so why be selective. Thus, there is a problem of sea cucumbers being overexploited like all other open access fisheries in the country.

Utilization and product flow

Holothurian resources in the Philippines are utilized almost exclusively as an export commodity based on the availability of national data on exports, but an absence of the same for local production and consumption. Locally consumed beche-de-mer is usually an ingredient in preparing mixed seafood and "ho-to-tay" dishes popular in regular Chinese restaurants. Unfortunately, the ingredient is unknown to many. At more expensive dining places, beche-de-mer from the better species are sautéed in a marinade of special sauce and condiments. An appetizer among Boholano divers is fermented entrails (PCAMRD, Philippine Council for Aquatic and Marine Research and Development, 1991). Traditional knowledge on sea cucumber as a medicine also exists, such as the Cuverian tubules as crude plaster for minor wounds and the extracts from the body musculature for tumours, fungal infection, high blood pressure, arthritis and muscular disorders (Trinidad-Roa, 1987). There is a growing volume of literature on the pharmaceutical importance of sea cucumber in international journals. Sadly, very little R&D effort is invested in this area by the Philippine Government.

Figure 1 shows the flow of sea cucumber from the sea to the plate. The fishers could use their harvest for: (a) immediate domestic consumption, (b) selling either directly to a middleman or in wet form at the local market; or (c) post-harvest processing. The third option involves boiling, after which the product is either chilled or smoke-dried. According to traders, the bulk of the processed items go to foreign markets and Manila restaurants. The processed product is allowed to accumulate for a time before the stock is taken to the nearest middleman. The process of storage, either for larger volumes or higher prices, is repeated depending on the distance of the middlemen and traders to Manila where the major exporters are based. How much volume flows through each step is difficult to quantify and would depend on the type of fishers and the storage time.

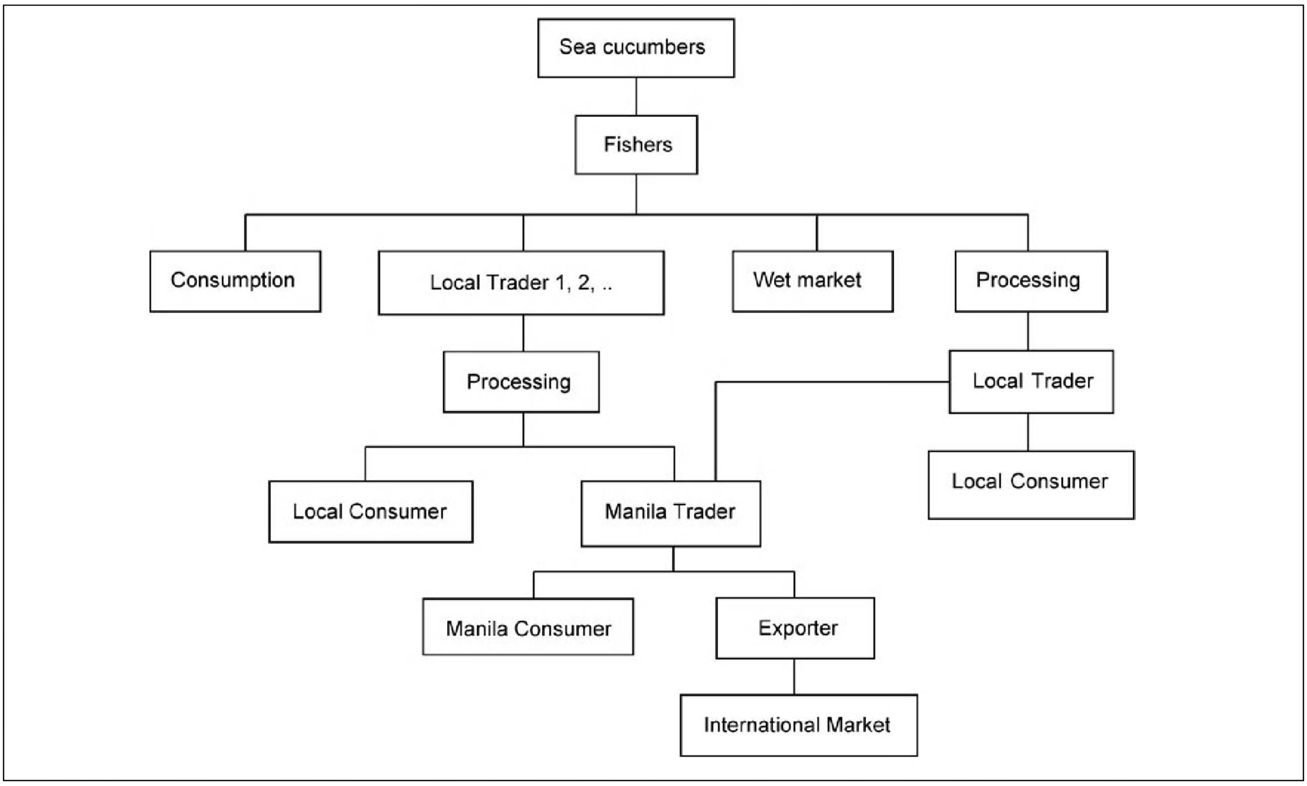

Figure 1. *The flow of Philippine sea cucumbers from fishers to consumers.*

According to Akamine (1998, 2001), there are exporters in Manila who provide capital for some local traders in key cities such as Zamboanga and Puerto Princesa. These locals are forced to sell to their financiers at prices lower than those offered by other traders. Nonetheless, such an arrangement ensures a market for their stock. The Manila traders would come once a month and the local traders would hardly have an idea on where the products will eventually be sold and at what prices.

What volume is retained for restaurants in Manila as well as supermarkets in big cities is unknown. The product on the shelf comes in the form of chilled, ready-to-cook slices in styropacks. Depending on the species and the supply, prices can range from P 200-500 per kg (US$ 1 = P 54). Two supermarkets in Davao City say they get their supply from Manila as local processors provide inferior quality product. In such a case, the flow can be from Mindanao to Manila then back to Mindanao. The processing technology in Mindanao is to be developed to improve local prices.

The product flow further shows the absence of a market support system by which the fishers can derive maximum returns for their catch. The fishers do not have any say at all on the prices for their goods. While a majority of them are contented to receive some cash in exchange, if given the chance, they too would like to have some leverage on price setting. Local traders, on the other hand, point to the Manila exporters as the ones who really control the prices. For their part, the Manila exporters cite the Chinese market as the real price setter. According to Akamine (1998), there are only four of these exporters, all of Chinese descent. No government interventions exist for the control and regulation of exported trepang. Generally, the government's emphasis on export as a dollar earner for the country encourages exploitation and unsustainable use of domestic resources.

Trade and foreign markets

Sea cucumbers are sources of income for marginal fishers in impoverished coastal villages in the country. In some islands like Panay, certain species like *H. scabra* can be the top export earner (del Norte-Campos *et al*, in press). However, the actual contribution to the gross income per family is difficult to determine due to different fishing practices and frequency. Even the middlemen or local traders, who are materially better off than the fishers, are hesitant to give information on their real profit.

Citing Akamine (2002) as the source of the latest available statistics, the five highly priced species and the corresponding prices of large-sized individuals are as follows:

Species	US$/kg (as of 2001)
Holothuria fuscogilva	33.3
Holothuria scabra	29.4
Actinopyga lecanora	21.6
Stichopus hermanni	21.6
Holothuria nobilis	19.6

In Bolinao, where an almost mono-specific fishery of *H. scabra* exists, field collectors are paid by local buyers P 5 (or US$ 0.10/piece) of 250-300 g (unpublished data). Assuming there is 90 % reduction in weight after processing, there should be 33-40 dried pieces to make up a kilogram. The total investment of the direct buyer in this case would be roughly US$ 4/kg while the export price could fetch about US$ 19-33/kg based on the above quoted prices. This is a clear picture of the traders taking the bulk of the profit and the fishers being given a token. It is not surprising, therefore, to see tremendous interest in trepang, especially among the traders.

One factor affecting price at the fisher's level is insufficient drying. Most of the traders would not buy insufficiently dried sea cucumber and would return them to the fishers. Although the rejected goods would eventually end up on the domestic table, still they represent lost cash for the fishers. Teaching the fishers improved ways of processing can be one way to avoid such loss. Among the traders, it is not unusual for them to do further drying themselves. This improves the quality of the products, thus, increasing their profit.

The sources of the authors' export market data (BAS and BFAR) are the same as that of Akamine's (1998) with the addition of years from 1997 to 2001. The total volume and value of trepang export for the last 22 years are presented in Figure 2. The significant volume peak of 3 500 tonnes in 1985 was not matched in value that year and was followed by a significant drop the next year. The drop in both volume and value in 1986 could have been due to excess supply from the previous year or to the rapid devaluation of the national currency (peso) before the downfall of the Marcos dictatorship in the third quarter. The peak has not been repeated since and volume in the years that followed averaged 1 500 tonnes. The last decade saw a surge in the value of trepang despite the continued devaluation of the peso. The sharp drop in value in 1998 could be partly attributed to the Asian crisis during the same period. While the volume may vary, the last two decades generally have been "boom years" for Philippine trepang. In fact, the last decade shows relatively better prices. This persistent export market and better prices exert sustained pressure on the fishery.

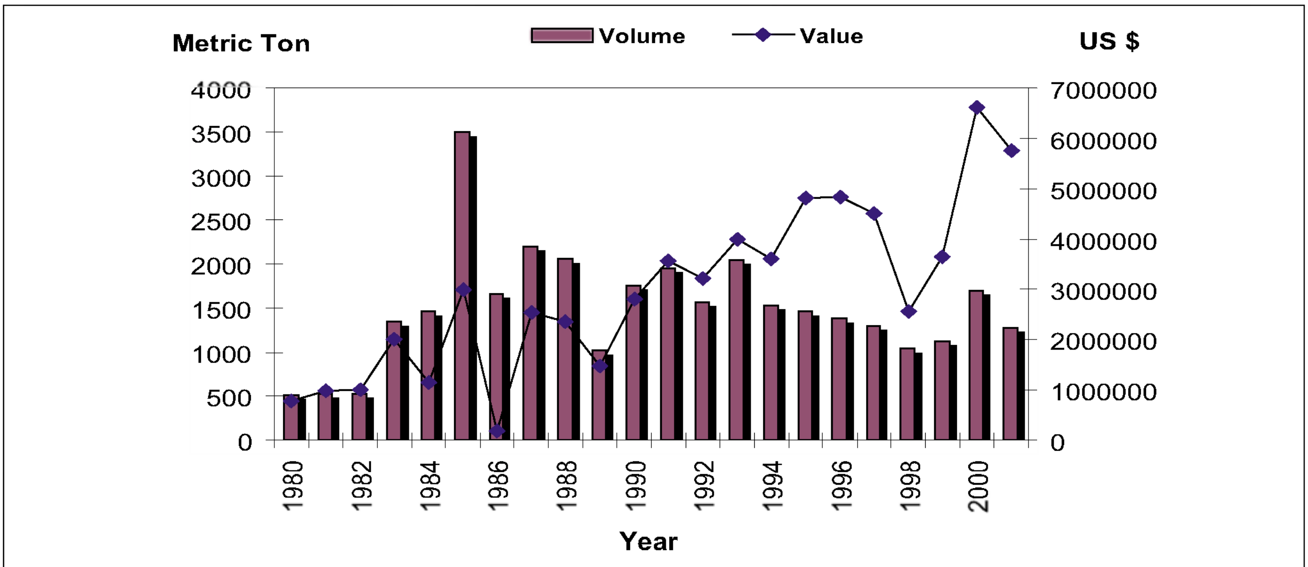

Figure 2. *Total volume(MT) and value (FOB US$) of Philippine trepang export from 1980-2001. (Sources: BAS and BFAR, Philippines).*

The foreign market destinations for Philippine sea cucumbers since the 1980s number around 16, which include Australia, the United States of America, Europe, the Middle East and even Africa. Of these, in chronological order, Hong Kong SAR (China), Singapore, Korea Rep., Taiwan (Province of China) and Japan started as the top five importers, although, Japan intermittently had years with no import. No reason can be given at this point. Figure 3 shows the total volume and value of Philippine sea cucumber exported to the top three foreign markets during the period 1990-2001. Hong Kong SAR (China) has maintained its top position since then absorbing 80 % of the total export. In the last decade, Singapore and Korea Rep. have switched places. The average price paid per kilogram by the three markets is shown in Figure 4. Korea Rep. paid the highest price while Hong Kong SAR (China), the top importer, paid the cheapest. According to Akamine (1998), this discrepancy means that Hong Kong SAR (China) was buying the low-value trepang while Korea Rep. and Singapore prefer the more expensive varieties. It is unlikely for Hong Kong SAR (China), being a small territory, to consume all the sea cucumbers it is importing from the Philippines. Most likely it serves as a transit point for shipping sea cucumbers to other destinations, perhaps, after further processing. While there is no available information to substantiate this claim, a seafood exporter in Davao (Philippines) considers Hong Kong SAR (China) a "middleman" of many export products.

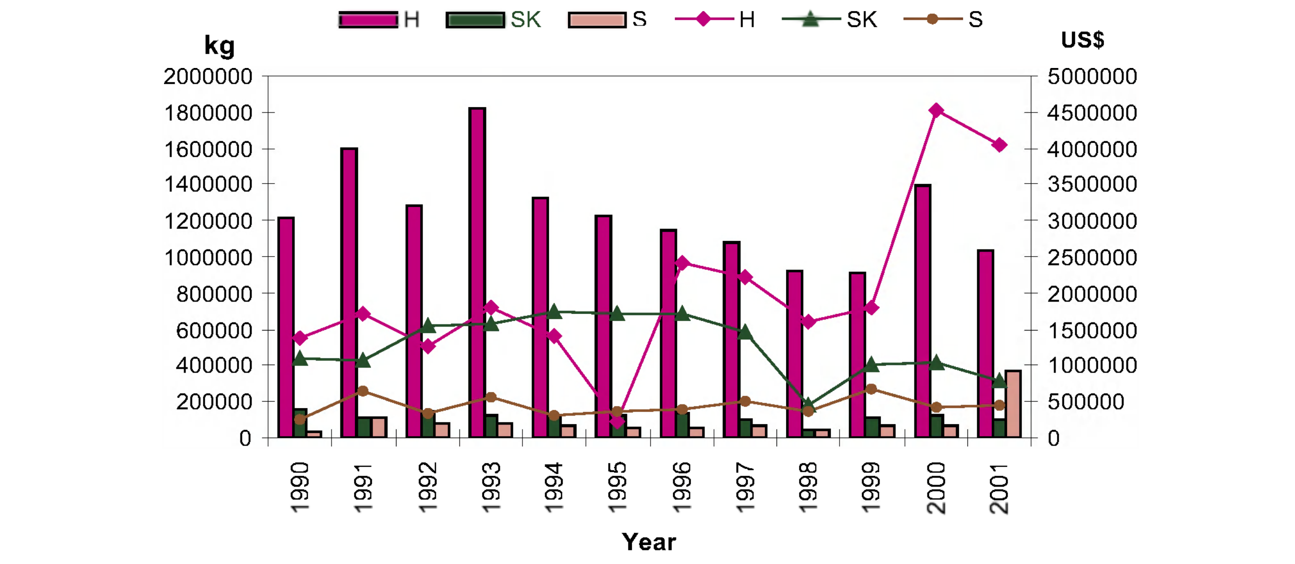

Figure 3. *Total volume (▮) in kg and value (—) in FOB US$ of Philippine trepang exported to the top three markets, namely: Hong Kong SAR (China) (H), Korea Rep. (SK), and Singapore (S). (Source: Bureau of Agricultural Statistics, Philippines).*

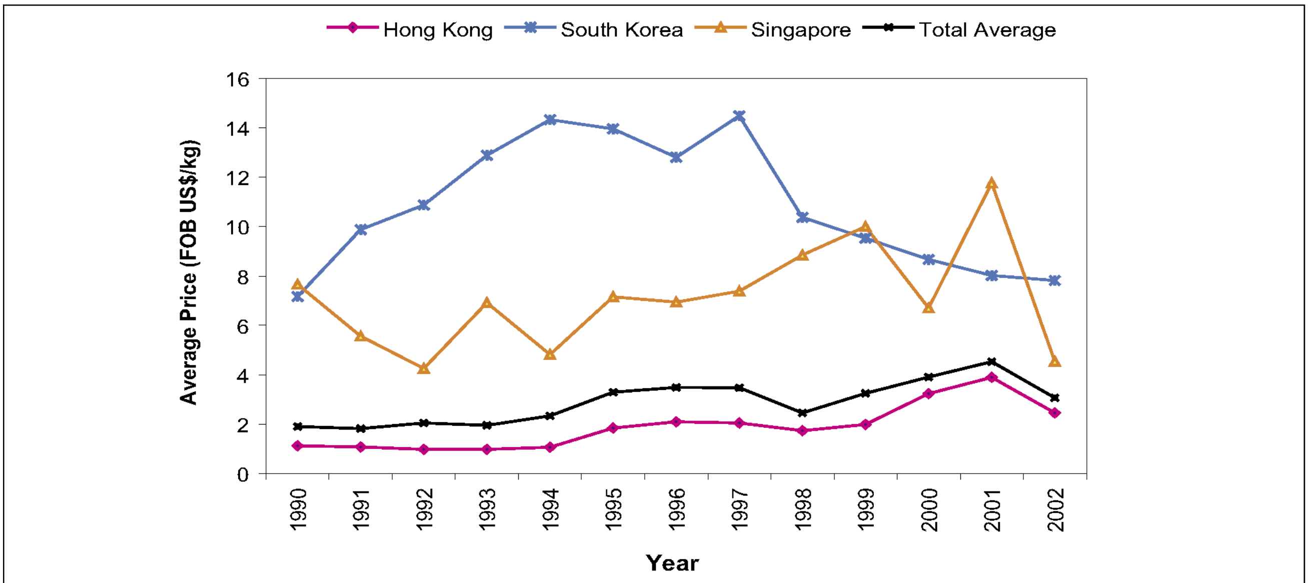

Figure 4. *The average price per kilogram (US$) of the total Philippine trepang export compared with the average prices paid by the top three markets, namely: Hong Kong SAR (China), Korea Rep., and Singapore. (Source: Bureau of Agricultural Statistics, Philippines).*

Mariculture and R&D

In the Philippine experience, marine products for export without a hatchery complement almost always ended up being depleted. The collapse of the sea urchin *Tripneustes gratilla* fishery (Juinio-Meñez *et al.*, 1998) in Bolinao in the 1990s is a good example. With little regulation, difficulty in arresting violators and sometimes a lame judicial system, commercially important marine resources whose fisheries are highly dependent on wild stock are good targets for exploitation.

For sea cucumbers, while a significant effort on resource management will have to be focused on the regulation of harvest, enhancing the natural stock with hatchery-bred individuals has become a feasible option. In 2000, by modifying the technology used in Japan (Ito, 1994) and India (James *et al.*, 1994) and by using the information on local species (Ong Che and Gomez, 1985), the production of *H. scabra* was successfully pilot-tested by Gamboa and Juinio-Meñez (2003) at the Bolinao Marine Laboratory (BML) of the Marine Science Institute of the University of the Philippines, Diliman. With a *trepang* history spanning several centuries, what took the Government so long to go into hatchery interventions? Two practical reasons are: (a) until very recently, resources in the country have been viewed as something to be extracted not managed; and, (b) the lack of technical skills to embark on the project. For the next two years after the pilot test, small scale experiments were conducted to optimise production within the limitations of the facilities and funding. Using the *Isochrysis:Chaetoceros* food regime, survival rates to early juvenile ranged from 15-33 %. Preliminary growout experiments were likewise conducted and results showed that juveniles in field cages had better survival rate when they were brought out at a larger size. Those juveniles showed positive growth in both coral sand and muddy seagrass substrate.

From the sea to the restaurant tables of importing countries, there is a long list of knowledge gaps which R&D should address if the country hopes to have a sustainable fishery. Published and unpublished works on Philippine sea cucumbers reveal that research efforts have been exclusively done by people from academia. The technology in Bolinao is ready for pilot-testing in other parts of the country when willing partners and logistics are ready. The long term goal of the invertebrate team at BML is to set up two hatcheries outside Luzon, one in the Visayas and another in Mindanao. The two hatcheries can start with sea cucumber and later expand to other species whose technology exists at BML, like those for *Tripneustes gratilla* (sea urchin), *Haliotis asinina* (donkey ear abalone) and *Trochus niloticus* (topshell). The presence of a hatchery in each of the three island groups of the country will fast track the reseeding intervention meant to enhance the recovery of depleted stocks and at the same time develop new options for sustainable culture of marine invertebrates. Using the multi sector participatory approach, medium to large scale production can be a possible venture, with the marginal fishers as the major sea farmers/ranchers. The feasibility of large scale growout systems is under pilot testing in Viet Nam (Pitt and Duy, 2003).

Also currently investigated at BML is the potential of sea cucumber to mitigate feed wastage (San-Diego-McGlone *et al.*, 2003). Initial findings show that sea cucumbers placed at the bottom of the tank where milkfish is grown can remove feed and fish wastes like NH_4, PO_4 and NO_2. The potentials of polyculture can be an alternative technology that is not only environment friendly, but also adding value to the investment.

Conclusion and recommendations

Is there no dearth of natural stock in the wild for a country with an export trade spanning several centuries? Both fishers and traders have observed a diminishing return for their catch and business efforts, any increase is attributed to the exploitation of smaller and lower valued species or exploration of new fishing grounds. In the absence of any wild stock assessment, the persistent demand for export coupled by good prices in the last decade is alarming. The indiscriminate harvesting of the cheaper species is another cause for alarm. The issues raised as early as 1987 sadly remain, in fact, the state of the resource is even more serious under an economic system that encourages exploitation of the resource but puts little regard for the environment (Haribon Foundation, 2003). Stock enhancement has become a management option to be pursued and concerted efforts to implement management actions are imperative.

Traders and fishers interviewed for this study agree that the fishery should be managed for sustainability. Their own suggestions are as follows:

- Fishers and traders alike to be convinced of the advantages of observing a size limit in their catch;
- Declare a closed season and provide alternative livelihood during such period;
- Fishers to be educated on how to preserve areas where sea cucumbers are found;
- Fishers and middlemen to be taught improved processing techniques;
- Fishers and middlemen to form an association where the fishers are given equal voice on pricing.

Three additional recommendations from the authors are as follows:

1. Conduct a survey of the present status of the wild stock and the degree of exploitation. This can be undertaken by the respective regional BFAR offices. Given only the statistics for export and nothing for domestic consumption, it is most likely that the annual harvest is underestimated. Thus, the survey can provide a benchmark for local and national governments when they develop management plans for the sustainability of the resource. The plans should include regulation, monitoring and evaluation of all sectors of the fishery from production to trade.
2. Pursue the R&D efforts that have been started. This will bridge knowledge gaps needed to support sound management plans.
3. If the same issues are being experienced by other sea cucumber exporting countries, agree on concrete measures during this workshop (i.e. ASCAM) that can be commonly observed by the affected countries. Two examples are to endorse a standardized size limit for export and encourage research effort at the regional scale.

Acknowledgments

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Status of the sea cucumber fishery in the Red Sea – the Egyptian experience

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Abstract

The beche-de-mer fishery began in Egypt 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 over-exploitation. As a consequence, the Red Sea Governorate initiated a ban on sea cucumber fishing in 2001 so that a baseline survey and stock assessment could be performed. This survey began in 2001 and was undertaken jointly by the Egyptian Environmental Affairs Agency (EEAA) 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 reopen the fishery lead 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 whole 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 the preliminary data collected as part of the stock assessment.

Keywords: Red Sea, stock assessment, area survey, over-exploitation

红海海参渔业状况

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摘要

埃及南部海参渔业始于1998年。最初阶段仅仅是一种由小型拖网渔船作业的低水平渔业。到了2000年，海参渔业迅速扩大。红海有关当局担心出现过度捕捞决定从2001年禁止在该海域进行海参渔业，同时开展基础调查和资源评估。该项调查得到了英国政府主持的达尔文项目的资助，由埃及环境事务管理局、赫尔大学和埃及苏伊士运河大学联合进行。自禁捕海参令颁布后，埃及沿海非法捕捞海参猖獗。此外，在渔业管理当局要求重新开发渔场的压力下，导致红海管理局于2002取消了禁令。然而，由达尔文项目所开展的基础调查资料表明，承受商业开发的渔场资源量明显下降。这一事实促使政府各部门一致认识到，必须立即对海参资源采取保护措施。最终，于2003年3月颁布了一项新禁令，禁止在埃及所有海域从事海参捕捞作业。根据项目所得出的资源评估结果，埃及政府将于2004对海参渔业做出新规定。本文介绍了埃及海参渔业现状以及资源评估的基本资料。

关键词：红海、资源评估、区域调查、过度开发

Introduction

The sea cucumber fishery

The harvesting of sea cucumber has developed throughout the Indo-Pacific and beyond for the preparation and sale of beche-de-mer (MacKnight, 1976; Conand and Tuwo, 1996). China PR is the main market with the trade passing through Hong Kong SAR (China) and Singapore (FAO, 1990; Conand, 1997; Conand and Byrne, 1993; Sommerville, 1993). Final destinations include countries with Chinese communities all over the world and the current high demand for beche-de-mer is likely to continue, and strengthen, due to the high economic growth in China PR. Many countries want to develop this lucrative fishery resulting in many studies on the potential or viability of sea cucumber exploitation (FAO, 1990; Conand and Byrne, 1993; Done and Navin, 1990; Harriot, 1985; Joseph, 1993; Lokani, 1997; James, 1983, 1989).

Unfortunately, the fishery has a history of over-exploitation and collapse (FAO, 1990; Richards *et al.*, 1994). Recently there has been considerable concern over declines in stocks with the closure of the fishery in some areas due to a lack of animals (Conand, 1997; Battaglene and Bell, 1997). The pattern of the fishery is characterized by boom and bust cycles with biological over-exploitation often occurring before economic over-exploitation (Preston, 1993; Conand, 1997). The fishery has collapsed throughout the Indo-Pacific with many species now commercially extinct (Sitwell, 1993; Jenkins and Mulliken, 1999). Over-harvesting can now be considered a worldwide phenomenon (Conand, 2000). Furthermore, the recovery of depleted populations is slow and sporadic (Kinch, 2002). In Torres Strait, for example, the *Holothuria scabra* fishery still has not recovered from heavy depletion in 1996, even though the fishery has been closed since 1998 (Skewes *et al.*, 2000). *Holothuria nobilis* are also a particularly vulnerable species and are considered overexploited in the Great Barrier Reef (Uthicke and Benzie, 2001). Fundamental aspects of the biology and ecology of holothurians make them very vulnerable to over-exploitation - slow moving, easy to see and collect, with recent molecular evidence suggesting that the animals may live up to 100 years (Uthicke *et al.*, 2003). Generally slow growing, holothurians are mostly broadcast spawners and, consequently, need to occur in high densities to ensure fertilization of gametes. The potential for over-exploitation is exacerbated by the fact that most countries are currently exploiting the resource without management plans. As a result whole populations have been depleted in many areas (Uthicke, 1996).

The Egyptian fishery

Fishing grounds throughout the world can be divided into three main groupings, the Western Central Pacific (subdivided into the Central Pacific and the Southern Tropical Pacific), the Indian Ocean (divided into Eastern Africa and Southwest Asia) and the North Eastern Pacific. The Red Sea opens into the Indian Ocean and any fishery developing here will be most clearly linked to the East African sub-zone.

The beche-de-mer fishery started in Egypt in 1998 in the south and on a small scale. It operates at the community level. Villagers collect and process sea cucumber and the products are sold to exporters, mostly bound for markets in Hong Kong SAR (China) and Singapore. Egypt has become one of the most important suppliers of beche-de-mer after the depletion seen other areas. However, little is known about the Egyptian fishery, the species of economic importance or levels of take and impact on the environment.

Aims and objectives

The Darwin Initiative funded project was developed with the principal aim of developing a sustainable fishery along the coast of Egypt under the guidelines of the Convention on Biological Diversity (CBD). The three main objectives of the project are to perform a stock assessment of the current resource, to develop a mariculture system appropriate to the commercial species and conditions experienced in the Red Sea and to explore the biotechnology potential of sea cucumber in the Red Sea.

The objective of this paper is to report on the progress made in the first of these three objectives, to present the data collected on the fishery and to report on the stock status. Assessment of stock status, generally expressed as the level of depletion compared to unexploited levels, is difficult from a single abundance survey. However, an indication of stock status can be provided, first, by comparing standing stock estimates between protected and non-protected sites along the Red Sea, second, by comparing fishing effort trends inferred from available information, third, by comparing standing stock estimates with estimates of the catch which to give a rough indication of the sustainability of the catch, and finally, by comparing density (number/hectare) of each species with the population density of the same species on reefs of other fisheries with variable levels of exploitation.

Methods

Study area

The Red Sea is located between Asia and Africa. At the north it splits to form the Sinai Peninsula and stretches over 1 000 miles south to join the Indian Ocean between Ethiopia and Yemen. In the north and west are desert plains, while in the south is a mountainous region (2 642 meters high), that is part of the mountain range stretching from deep in Saudi Arabia across the Sinai and then into Nubia on the African Continent. The Red Sea forms a part of the Sirian-African rift with its many unique and impressive geographical features. The Sinai Peninsula is bordered by the relatively shallow Gulf of Suez along its west side, and the much deeper Gulf of Aqaba along its east side. To the south, the partly very deep main body of the Red Sea extends down to its shallow and narrow exit to the Indian Ocean, at Bab El-Mandab.

The Egyptian coast of the Red Sea is approximately 1 000 km extending from Suez at the entrance of the Gulf of Suez to Shalatein on the Sudanese border and west into the Gulf of Aqaba. The Red Sea is divided into 2 main sectors. The first sector starts from Taba on the border with Israel, to Sharm El-Sheikh on the Sinai Peninsula. The second sector passes from north Hurgada south to the Sudanese border and includes a number of offshore islands (Figure 1).

***Figure 1.** Map of the Egyptian Red Sea coast running from Taba in the North to Shalatein in the South.*

Survey method

Sampling was carried out from July 2002 to August 2003. The survey employed a modified rapid marine assessment technique applied to beche-de-mer surveys in Torres Strait and Moreton Bay (Long *et al.*, 1996; Skewes *et al.*, 2000). Field work was undertaken with two teams of divers. On the reef flat, a diver snorkelled along a 50 m transect and recorded information 2.5 m either side of the transect line. Holothurians and other echinoderms were counted. When necessary, length and weight measures of the commercial species of holothurian were taken. At each site the substrate was described in terms of percentage of live to dead coral, seagrasses and sand. The survey was designed to ensure that all habitat types (coral reef, seagrass bed, mangrove swamps and sandy lagoons) were surveyed in each Red Sea sector. Walking transects were carried out at extremely low tides when the reef flat was exposed.

At each site on the reef slope, divers also swam transects parallel to the reef edge. These transects were positioned in the approximate depth ranges 5-10 m, 10-15 m and 15-20 m depending on local topography. Two transects were surveyed at each depth, beginning at the deepest stations, with each diver surveying a 2.5 m belt each side of the transect line. Each new species of holothurian encountered was collected for later identification and the divers counted each of the commercial species of interest. In addition, the length of each of the commercial species was measured and habitat information recorded. Each survey site was geo-referenced using a hand-held Global Positioning System (GPS) device.

During each trip, time was taken to talk with a wide variety of people. Much of the fisheries data was gathered from these interviews with local people, mostly fishermen and traders. This is an accepted method in much artisanal fishery research (Johannes, 1993; Castillo and Rivera, 1991) and the most relevant information was gathered in this manner, rather than by use of strict questionnaires.

Results

The sea cucumber fishery in Egypt

First noted in the mid-1990s, the sea cucumber fishery started officially in 1998 in the southern part of Egypt. In the Red Sea the harvesting of sea cucumber involves two processes. In the south and in the Gulf of Suez, trawlers harvest the sea cucumber using a benthic trawl. Initially part of the by-catch, sea cucumber were later specifically targeted and subject to heavy trawling activity. In the central part of the Red Sea and the Gulf of Aqaba, SCUBA diving is used for collecting the animals. In addition, some species are harvested by hand at low tide on the reef flats. In Egypt the processing of sea cucumber is not significantly different from the methods described previously in other fisheries and many descriptions have been given.

The catch and the total income derived from beche-de-mer fishing in the Red Sea is known to have increased significantly between 1998 and 2000, mainly due to the dramatic increase in the value of sea cucumber over that period. In 1999, as the price of beche-de-mer increased, the fishery expanded to cover the rest of the Egyptian coast of the Red Sea. The expansion of the fishery is highlighted by the fact that during the period 2000-2002 the number of boats using either SCUBA or trawling techniques doubled (Figure 2a and 2b). Furthermore, the number of companies involved in the fishery increased significantly during the same period (Figure 2c). However, it has proven very difficult to determine reliable values paid for each species of sea cucumber during the period, making the total value of the fishery difficult to determine.

In April 2000, the Red Sea Governorate banned the fishing of sea cucumber in the Red Sea until the stock assessment supported by the Darwin Initiative could be performed. However, this ban only existed for the area of coastline under the jurisdiction of the Red Sea Governorate. The neighbouring Suez Governorate, for example, continued with an open fishery. This lead to further depletion of stocks in the Red Sea as a whole, and added to the difficulty of policing of Red Sea Governorate coastal areas. For example, fishermen and boats from the Suez region were observed fishing illegally in areas under the protection of the Red Sea Governorate. However, this was impossible to prove once the catch had been landed.

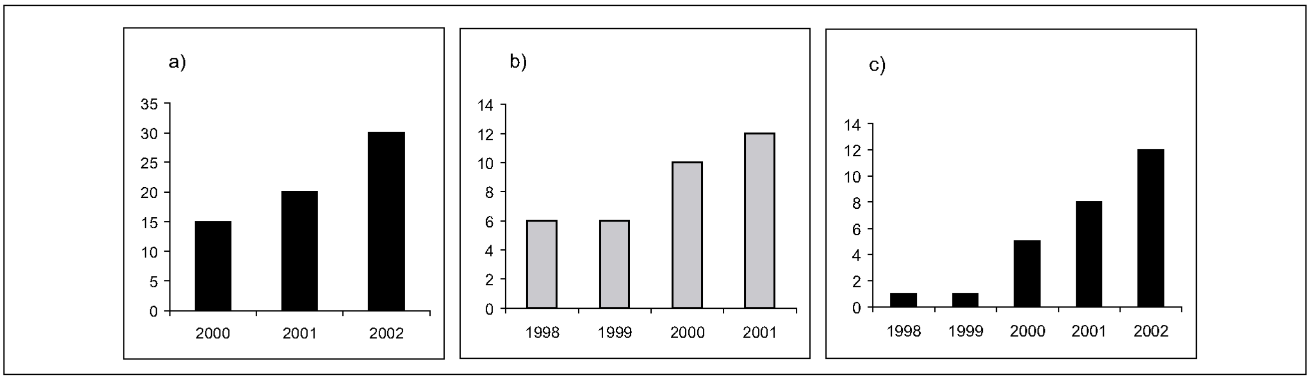

Figure 2. *The growth in the number of boats involved in the sea cucumber fishery in Egypt employing a) SCUBA diving b) Trawling and c) The increase in the number of companies involved in the fishery.*

Furthermore, the ban also resulted in the development of a large illegal fishery in the region under the jurisdiction of the Red Sea Governorate. This illegal fishery continued unabated both as a result of the low level of patrolling (and difficulty of policing such a large area) and the development of a conflict between the Egyptian Environmental

Affairs Agency (EEAA), which wanted to limit the fishery, and the Ministry of Agriculture, Department of Fisheries, which aimed to exploit the resource to its maximum. The impact of the illegal fishery is highlighted by the significant reduction in the total catch landed per trip from 3 million animals in 1998 to 400 000 in 2001 despite the increase in the number of boats fishing during this period (Figure 3).

There was a further social consequence of the illegal fishery. The official number of recorded accidents of fishermen involved in fishing for sea cucumber using SCUBA increased six-fold between 2000-2002 (Figure 4). However, the unofficial estimate of the number of accidents is 10 times this figure (Selim, *Pers. Comm.*). The fishermen do not receive any training in SCUBA and might make up to 6 dives per day to depths of 30 m or more. It is known that due to the fear of prosecution, many boat crews have not reported deaths that have occurred during fishing of holothurians with individuals either dumped or buried on remote beaches. Furthermore, the EEAA has found itself in the difficult position of having to permit and cover the costs of fishermen using decompression chambers to recover from the decompression sickness, a cost the individuals could not cover themselves.

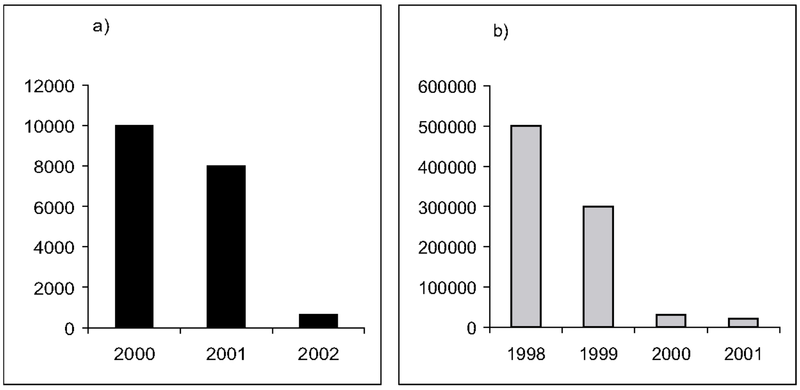

Figure 3. *The total catch of sea cucumber (numbers of individuals) collected per boat per trip using a) SCUBA and b) trawling along the Red Sea coast of Egypt between 1998 and 2002.*

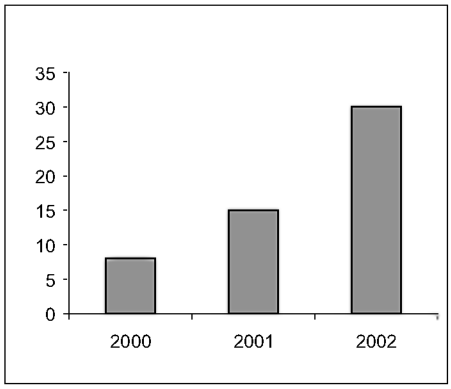

Figure 4. *The official number of diving accidents occurring whilst fishing for sea cucumber in Egypt between 2000 and 2002, reported by Decompression Chambers.*

Further evidence of the likely over-exploitation of the commercial species of sea cucumber in Egypt was illustrated by the fact that during the period 1998-2002 the number of species fished increased from an initial two, to up to 14 in the case of SCUBA (Figure 5). Thus, as the fishery increased, the numbers of the most valued species decreased and fishermen attempted to compensate for this by collecting other, less valuable species.

As a result of the conflict between different government agencies, the sea cucumber fishery was re-opened in 2002 and licenses were given to fishermen to collect sea cucumber. A total number of 52 boat licenses and 100 individual fishermen licenses were issued. Due to the further depletion of commercial holothurians, a meeting was held in the Red Sea Governorate in March 2003 to discuss the problem of sea cucumber fishing in the Red Sea. The meeting included representatives from the EEAA, Ministry of Agriculture and Red Sea Governorate. As a result of this meeting a second complete ban on the fishery was instigated until December 2003. At this time, the initial assessment of the stock, based on the current study will be presented together with preliminary recommendations on future exploitation and management of the fishery.

Whilst the expansion in the number of boats in the industry, catch per trip and increase in numbers of species taken are indicative of over-exploitation, it is currently difficult to assess the overall level of impact. As part of the on-going study, the team are still trying to get reliable estimates for the number of trips each boat takes per year and the value of each individual species. This would allow a better evaluation of the numbers of animals taken and value of the fishery prior to the ban.

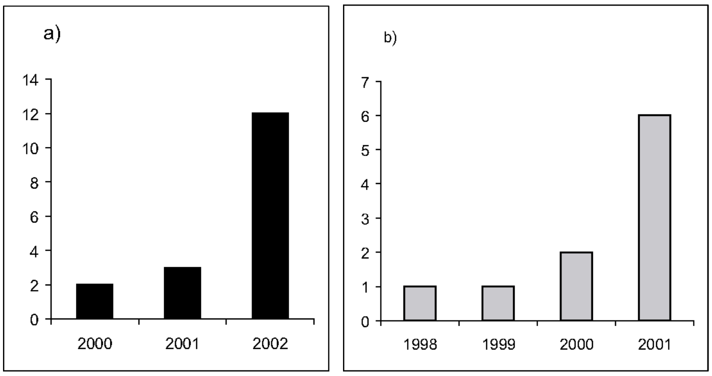

Figure 5. *The number of commercial species of sea cucumber collected by a) SCUBA and b) trawling techniques in Egypt between 1998 and 2002.*

Preliminary Area Survey

To date over 690 transects have been surveyed at 116 sites from Taba, on the border with Israel in the northern Gulf of Aqaba, to Shalatein, on the border with Sudan in the southern region of the Red Sea. In Sharm El-Sheikh area 34 sites have been surveyed covering the whole coast of the Gulf of Aqaba whilst about 82 sites have been surveyed in the northern portion of the Red Sea.

A total of 22 species have so far been identified (Table 1). Of these, seven are described for the first time in Egyptian waters. Whilst none of the species so far identified are unique to the northern coastline of Egypt (Ras Mohammed to Taba), ten species have only been found in the southern region (Hurgada to Shalatein) (Figure 1 and Table 1). In addition, seven species are predominantly collected as the commercial species. These can be divided into three groups based on market value. First class species include *Holothuria scabra* (sandfish), *Holothuria fuscogilva* (white teatfish) and *Holothuria nobilis* (black teatfish). These are fished preferentially. Second class species include *Stichopus hermanni* and *Stichopus horrens*. Third class species include: *Actinopyga mauritiana, Holothuria atra,* and *Pearsonothuria graeffi.*

Table 1. *Species of sea cucumber identified through an Area Survey along the Red Sea coast and offshore islands of Egypt. Species described for the first time in Egyptian waters or important commercially are highlighted together with their value category and broad geographic range.*

Species	First record in Egypt	Commercially important and Grade	Range of Species (North & South Sectors)
Actinopyga crassa	-	-	N&S
Actinopyga mauritiana	-	3rd Class	N&S
Pearsonothuria graeffei	Yes	3rd Class	South only
Bohadschia cousteaui	-	-	N&S
Bohadschia tenuissima	-	-	N&S
Bohadschia vitensis	-	-	N&S
Holothuria hilla	-	-	N&S
Holothuria edulis	-	-	N&S
Holothuria atra	-	3rd Class	N&S
Holothuria pardalis	-	-	N&S
Holothuria leucospilota	-	-	N&S
Holothuria scabra	-	1st Class	N&S
Holothuria fuscogilva	Yes	1st Class	South only
Holothuria nobilis	Yes	1st Class	South only
Holothuria impatiens	-	-	N&S
Holothuria rigida	Yes	-	South only
Holothuria coluber	Yes	-	South only
Holothuria sp.	Yes	-	South only
Stichopus hermanni	-	2nd Class	N&S
Stichopus horrens	-	2nd Class	N&S
Synapta maculata	-	-	N&S
Synaptula sp.	Yes	-	South only

The distribution of each species has also been examined in relation to depth and habitat type. Results from this are shown in Figures 6 and 7. Figure 6 highlights the fundamental importance of seagrass beds to most of the main commercial species from each class. The two exceptions being *H. nobilis* and *P. graeffei* which have only been found on coral substrate. In addition, each of the commercial species have been mostly found in the depth range of 5-10 m (Figure 7). The main exception to this is *H. fuscogilva* which was predominantly found beyond 30 m depth and *H. nobilis* and *H. atra* which was mostly found on the reef flat.

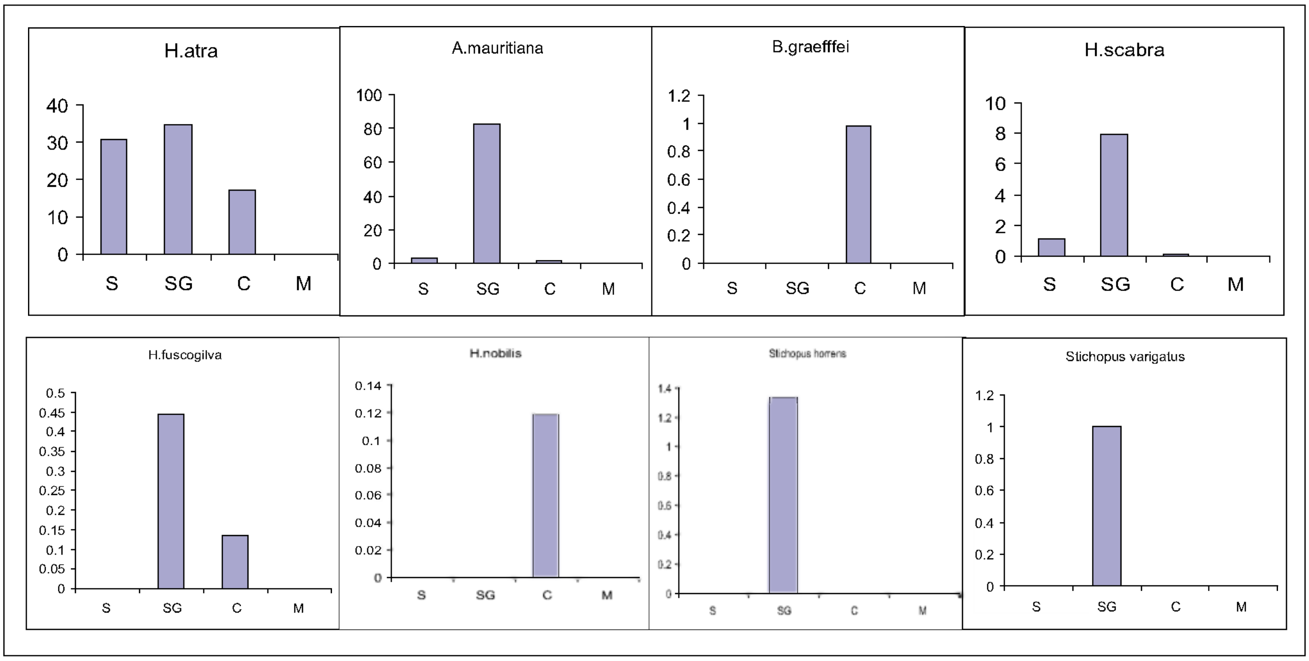

Figure 6. *The habitat distribution of the main commercial species of sea cucumber along the Egyptian Red Sea coast expressed as mean number per transect (**S** = sand, **SG** = Seagrass, **C** = coral and **M** = mangrove).*

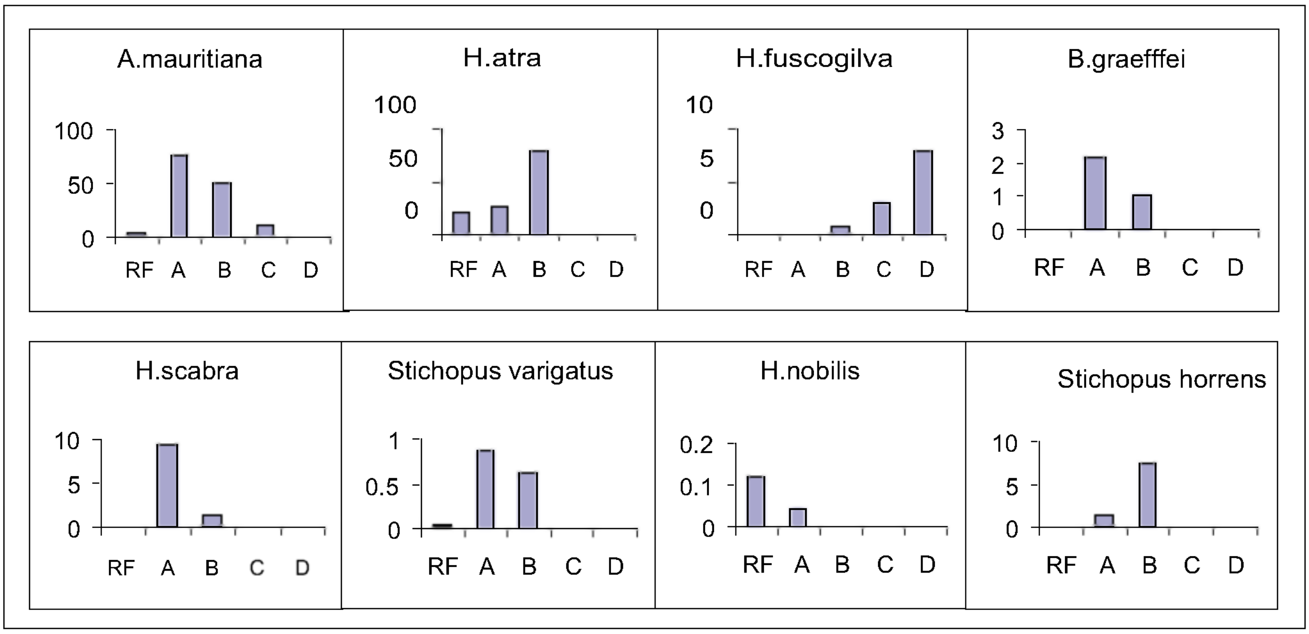

Figure 7. *The depth distribution of the main commercial species of sea cucumber in the Egyptian Red Sea expressed as mean number per transect (**RF** = Reef Flat, **A** = 5-10 m, **B** = 10-20 m, **C** = 20-30 m and D = >30m).*

Clear differences have been found in the abundance of the main commercial species when fished and non-fished areas are compared (Figure 8). However, it should be noted that it is almost impossible to find non-fished sites along the coast of Egypt. In this instance, therefore, non-fished refers to sites that are mostly unexploited. These sites benefit from some form of protection, being either too remote, difficult to approach, near to army installations or forming part of the private beach to hotel complexes. Figure 8 highlights the almost complete loss of the most valuable species *H. scabra* and *H. nobilis*, as well as the removal of most commercial species from most fished areas. Whilst both seagrass and coral sites have been targeted by fishermen, their impact on seagrass areas appears to have been more severe.

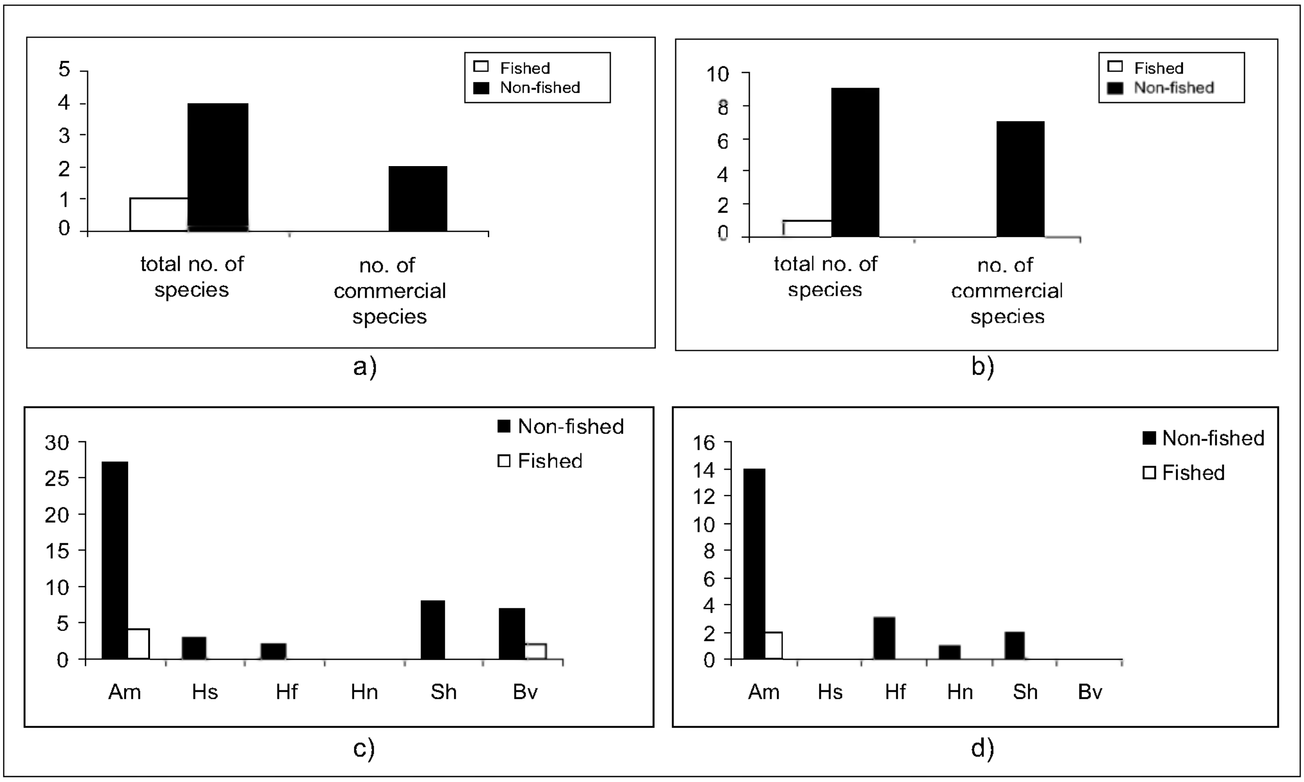

Figure 8. *The impact of fishing on the total number of species of sea cucumber, number of commercial species and their composition on seagrass (a & c) and coral (b & d) habitats. Data is expressed as mean number per transect (**Am** = Actinopyga mauritiana, **Hs** = Holothuria scabra, **Hf** = Holothuria fuscogilva, **Hn** = Holothuria nobilis, **Sh** = stichopus hermanni, **Bv** = Bohadichia vitensis).*

Based on the numbers of animals counted on each of the transects, the mean density of the main commercial species per hectare has been calculated for sand and seagrass areas (Table 2). For each of the species the density is higher in the southern sector than in the northern sector. Also apparent is the low density of most valuable species (Class 1) compared with the less valuable. Generally, the highest density species is *A. mauritiana*, one of the lower valued species. It should be noted that the value calculated for *H. scabra* is the result of a high density of animals found at one specific site. The project is currently liaising with the EEAA Remote Sensing Group based in Hurgada to estimate the overall area of sand and seagrass along the coast of Egypt and to a depth of 30 m. From this the project will be able to estimate the current standing stock of each commercial species.

Table 2. *The density of animals per hectare of the main commercial species of sea cucumber in Egypt, compared with the highest and lowest estimated densities found in the literature.*

Species	Gulf of Aqaba Sector	Hurgada Sector	Highest density from literature	Lowest density from literature
H. scabra	0.0	158.0	> 600 (1) 2 900 (2)	0.00 (3)
H. fuscogilva	4.0	8.0	> 18 (1)	0.42 (3)
H. nobilis	2.2	6.4	> 13 (1)	0.18 (3)
S. hermanni	28.0	46.0	450 (1)	0.09 (3)
S. horrens	4.0	19.6	-	-
P. graeffi	0.0	26.0	-	0.37 (3)
A. mauritiana	70.0	204.0	300 (1)	0.12 (3)
H. atra	950.0	1002.4	> 500 (1)	9.8 (3)

1- Preston, 1993, 2- Shelley, 1981; 3- Kinch, 2002.

Discussion

Stock size and indications of stock status are two useful parameters on which to base robust management strategies. In the absence of detailed, reliable fisheries data, stock size can only be estimated by abundance surveys. Using a combination of outputs from the abundance survey and limited fisheries dependant data, stock status can be estimated with some confidence. These parameters can then be used to indicate future catch levels that allow for sustainable development of the fishery.

It is apparent from the data gathered during the stock assessment that the sea cucumber fishery in Egypt has followed the pattern seen elsewhere with a boom in the fishery being followed by the collapse of most stocks. It is currently impossible to find any site in Egypt that has not been fished. However, comparison between sites afforded some protection with those heavily exploited shows a significant difference between the two, with the most valuable species completely absent at the fished sites. This was reflected in the area survey in which the same high value species were absent from almost all sites. Thus it appears that overfishing has lead to the extirpation of several of the most commercial species from many sites. These local extinctions might have continued to be masked by the lack of any detailed collection of fishery statistics, particularly at the species level. This problem has been highlighted in other fisheries (Dulvy *et al.*, 2000) and will be a continuing problem with sea cucumber given their difficult taxonomy and changed shape and form following processing. However, the collection of species specific fisheries data is imperative given the potential consequences of these extirpations both to the meta-population and to the habitat (Thorpe *et al.*, 2000; Uthicke, 2001).

Clearly the use of trawling methods in the southern part of Egypt is not sustainable as is evidenced by the complete collapse of populations in this region. The use of benthic trawls has the added problem that it significantly impacts on the habitat and has been compared to forest clear cutting in this capacity (Wattling and Norse, 1998). Impacts include the reduction of habitat complexity (Engel and Kvitek, 1998), changes to sediment structure (Schwinghammer, 1998) and reduction in species diversity (Engel and Kvitek, 1998). Furthermore, models have shown that these impacts are highest for sensitive, complex and stable areas (Auster, 1998; Kaiser *et al.*, 2000). As such, coral reefs and seagrass beds are likely to be particularly sensitive to trawling, the impacts of which are not only unsustainable, but likely to reduce the quality of the habitat and, therefore, recovery times for depleted stocks.

Whilst there are no pre-fishery baseline data for sea cucumber populations in Egypt, species densities are almost all higher in the southern sector. Comparison of the densities in this region with other studies indicate that the populations are not as depleted as has been reported in the Torres Strait, Great Barrier Reef or Warrior Reef (Long *et al.*, 1996; Skewes *et al.*, 2000; Uthicke and Benzie, 2001; Kinch, 2002). However, they are much lower than the densities reported by Shelley (1981) and Preston (1993). This, together with the comparison of densities between fished and un-fished sites, provides further evidence to suggest that overfishing has occurred in Egypt and that all species have been over-exploited with the exception of *H. atra* and possibly *A. mauritiana*. However, this assumes that the populations in the Red Sea mirror those seen elsewhere throughout the Indo-Pacific and ignores the possible effects of this unique environment on each species.

The fact that densities are not as low as reported in some parts of the Indo-Pacific may suggest some hope for the fishery in Egypt. The current ban should be extended for at least two years to assess whether any populations show signs of recovery. Given the density-dependent nature of the reproductive process, and the failure of populations described elsewhere to show recovery after 6 years, this is fundamental to any future sustainable fishery development. In addition, during this two-year moratorium, a management plan for the whole of the Egyptian coastline should be developed and approved by all stakeholders. This should include relevant government agencies, the Fishermen Society and recognized traders. A sense of ownership of the fishery by the stakeholders has proven successful in the past in other invertebrate fisheries, aiding the collection of biomass estimates and self-policing of the fishery (Young, 2001; Castilla and Defeo, 2001).

The plan should include the adoption of no-take zones in important areas and a permanent ban on benthic trawling. Additional management regimes are likely to include the continuance of the permit system but with permit holders having to submit fishing logs/catch statistics, the introduction of closed seasons and a Total Allowable Catch (TAC) based on a precautionary approach, size restrictions and gear restrictions. In addition, the allocation of permits should be given only to those boats using qualified divers following dive regulations, to reduce the human losses currently occurring in the fishery.

Sea cucumber catch data collected from fishing logs should be species based as highlighted earlier. This would have the added advantage that it might encourage policy-makers to further consider the listing of sea cucumber under CITES Appendix II. Ultimately, it requires a concerted international effort under a mechanism such as CITES to ensure the recovery, future protection and sustainable use of sea cucumber both in Egypt and worldwide.

As a signatory to the Convention on Biological Diversity and the Jakarta Mandate, Egypt is committed to the conservation and sustainable use of species and coastal resources. In the case of its sea cucumber resource this will require the continuance of the current ban alongside the area and seasonal survey programme and further development of its embryonic mariculture facilities. It will also require the full participation and agreement of all stakeholders in the future management decisions related to the fishery. It is only this approach that will ultimately allow Egypt to develop a sustainable fishery under the guidelines of the CBD.

Acknowledgements

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Population density and fishery impacts on the sea cucumber (*Isostichopus fuscus*) in the Galapagos marine reserve

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Abstract

Over the last decade, the sea cucumber *Isostichopus 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 program to assess the status of the resource. From 1999 until 2003, density surveys of *I. 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 *I. 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, which 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 *I. fuscus* populations in the Galapagos Islands are severely depleted and unless there is another recruitment pulse, along with a complete ban on fishing activities these populations are in serious risk.

Keywords: Population dynamics, surveys, recruitment, participatory monitoring

加拉帕戈斯等刺参（*Isostichopus fuscus*）的种群密度和捕捞的影响

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摘要

在过去的10多年内，加拉帕戈斯群岛的等刺参是当地的重要渔业对象。不断扩大的渔业活动和它的潜在影响促使海洋公园当局启动了一项共同参与管理计划来评估该种的资源状况。从1999年起到现在，由渔民、导游、经理和科学家共同组成的小组对等刺参捕捞前后的密度状况做了调查。用一个100平方米的取样环在Fernandina, Isabela, Española, Floreana, Santa Cruz 和 San Cristóbal捕捞区随机地对每地做了平均900平方米的取样调查。结果显示，在捕捞季节前后无论是等刺参的密度，还是个体大小的组成均发生了明显的变化。在Isabela 和 Fernandina, 2000年4月首次观察到补充资源，其后，高峰出现在2001年的3-4月间，这一现象可能有助于这些岛屿周围水域海参资源的恢复。 而其它岛屿周围尚未发现新资源的补充。尽管如此，加拉帕戈斯群岛的等刺参资源已经严重衰竭；除非有新的补充资源，再加上全面禁止捕捞，也许会出现生机，否则，这些种群将受到严重威胁。

关键词：种群动力学、调查、资源补充、全方位参与的监管

Introduction

Sea cucumbers have been harvested for years in the coastal zones of temperate and tropical regions of the world, mainly throughout the Indo-Pacific, with temperate fisheries in the North Pacific and tropical fisheries in the Indian and Western Pacific islands (Conand and Sloan, 1989). The rapid decline of sea cucumber populations worldwide

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to support the beche-de-mer market (Conand, 2001) induced the beginning of this fishing activity in continental Ecuador in 1989 focusing on *Isostichopus fuscus* Ludwig 1875 (Carranza and Andrade, 1996). A few years later, after economical depletion of this species in mainland Ecuador (Camhi, 1995) this activity began in the Galapagos Islands in 1991 (Camhi, 1995;, De Paco *et al*., 1993; Powell and Gibbs, 1996). Although this fishery was expected to be mainly local (Powell and Gibbs, 1996), it brought a wake of illegal mainland fishers into the local community and caused a series of conflicts which led to the ban of this fishery in 1992 (De Paco *et al*., 1993). During the first legal fishery in 1994, the fishing activity focused in the Canal Bolívar (between the islands of Isabela and Fernandina) (Figure 1) due to greater abundance of *I. fuscus* in this region. However, after the reopening of the fishery in 1999, the fishing grounds extended to Isabela, Fernandina, Floreana, Española, San Cristóbal and Santa Cruz with the potential for expansion to the rest of the archipelago (Figure 1).

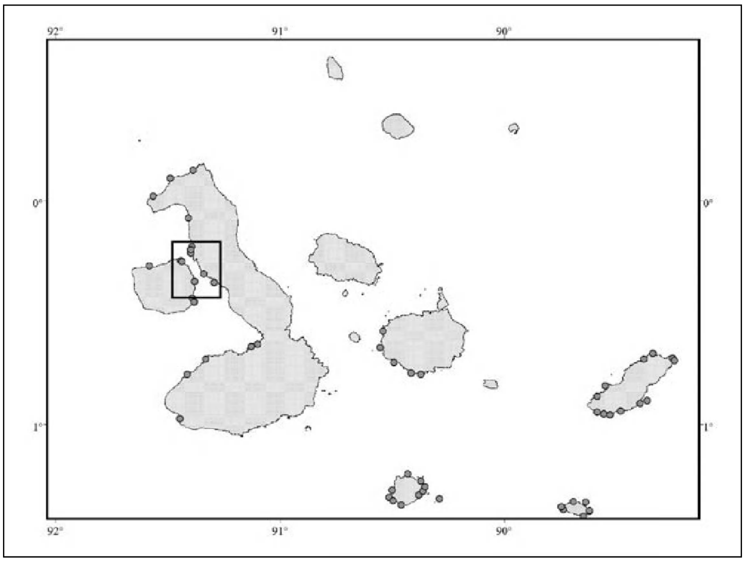

Figure 1. *Participatory monitoring sites in the Galapagos Marine Reserve since 1999. Only islands with dark circles (sites) have been monitored. The section in the frame is known as the Bolívar Channel.*

This species (*Isostichopus fuscus)* is the most common commercial species found in the Eastern Pacific (Maluf, 1988) and was once known as the most conspicuous invertebrate of the shallow littoral zone in the Galapagos Islands (Wellington, 1974). Its distribution includes Baja California, México to mainland Ecuador, including Galapagos, Socorro, Cocos and Revillagigedos islands (Deichmann, 1958; Maluf, 1991). It can be found from the coastal zone to 28-39 m depth (Deichmann, 1958; Maluf, 1991). However, this species was declared in risk of extinction in Mexico (Secretaria de Medio Ambiente, Recursos Naturales y Pesca, 2000) and has very low populations in mainland Ecuador.

Isostichopus fuscus is collected from the sea bottom by hand by hookah divers at depths between 1 and 35 m. The Galapagos National Park Service (GNPS) is the entity in charge of managing the fishery. This fishery has a Total Allowable Catch (TAC) which varies year to year (Murillo *et al*., 2003), minimum landing size of 20 cm for fresh individuals and 6 cm for dried individuals and no-take zones distributed in different islands. Although the sea cucumber fishery is the most important fishing activity in the Galapagos Islands (Murillo *et al*., 2002) there are still some areas of scientific interest that need to be covered in order to sustain the fishery. Most of the information available is on population density (Martínez, 1999; Toral-Granda *et al*., 2003), reproductive biology (Toral-Granda, 1996), growth and basic ecology, fishery information (Bustamante *et al*., 1999; Toral-Granda *et al*., 2000; Murillo *et al*., 2003). The fishery shows evidence of overexploitation (Murillo *et al*., 2002, 2003) with average catch per unit effort values decreasing with time [(i.e. from an average of 109 individuals diver^{-1} day^{-1} in 1999 to 82 individuals diver^{-1} day^{-1} in 2003 (Murillo *et al*., 2003)], increased claims of fishers for the opening of other islands to this activity and decrease in size of landed individuals.

Since the establishment of the Galapagos Marine Reserve (GMR) in 1998 through a participatory process, all major stakeholders, i.e. tourism, fishing, naturalist guides, science & conservation (Charles Darwin Research Station) and management (GNPS), have taken active part in the population monitoring of *I. fuscus*. Twice a year since 1999, participatory monitoring trips have taken place prior to and after the fishing season, aiming to determine the impacts of the fishing activity and potential recovery of this species during bans and closed zones.

This paper focuses on the results of the participatory monitoring censuses in Española, Fernandina, Floreana, Isabela, San Cristóbal and Santa Cruz from 1999, giving an up to date overview of *I. fuscus* in the GMR after five fishing seasons, with special focus on the impact of fisheries on this species, its recovery during fishing bans and closed zones and the implication of the current fishing practices on the well-being of this species.

Participatory management of the Galapagos Marine Reserve

In 1998, the Ecuadorian Government in response to both national and international pressure for a better management of the Galapagos Islands passed on the Special Law of Galapagos, which led to the creation of the GMR. The GMR management consists of a three-pole arrangement with the Participatory Management Board (PMB), the Interinstitutional Management Board (IMA) and the GNPS. The PMB members are based in the Archipelago and represent the direct users where any decisions concerning the management of the GMR is taken on a consensus based system. The IMA is on a ministerial level where all decisions taken in the PMB are approved by a voting system. The GNPS is the entity in charge of putting into effect all resolutions taken by both the PMB and the IMA (Altamirano *et al*., 2004).

The PMB comprises the participation of all direct stakeholders: artisanal fishing sector, naturalist guides, tourism sector, science, conservation & education (Charles Darwin Foundation) and the management authority (GNPS). Hence, when the Ecuadorian Government approved a sea cucumber fishing season in 1999, the need was recognised to integrate all stakeholders in the gathering and analysis of the scientific information in the GMR.

Twice a year, before (between January and April) and after (between June and August) each fishing season a team, comprised of fishers, managers, naturalist guides and scientists, have visited permanent monitoring sites located in Española, Fernandina, Floreana, Isabela, San Cristóbal and Santa Cruz islands (Figure 1) over an average of 10 working days. At each site (Figure 1) a minimum of 900 m^2 were surveyed using a circular sweep transect specially developed for holothurians and in use in Galapagos since 1993 (Richmond and Martínez, 1993). Surveys were performed by a team of two divers using a rope of 5.64 m length, weighted at one end, which is used as a rotation point. While one diver holds the end of the rope and swims in circles, a second diver counts and collects all individuals found within the circle. The total area covered once the circle is completed is 100 m^2 (Figure 2). At the surface, all collected individuals were measured to the nearest centimetre and then returned to the collection point. All scientific information was analysed and then presented to the PMB and IMA for further decisions on the status of *I. fuscus* in the GMR.

From 2001 onwards, a threshold value was set to determine whether a fishing season will take place on the GMR. The threshold value was set on 0.4 ind. m^{-2} of individuals $\geq$ 22 cm total length based on the information gathered in 2000. For the 2001 fishing season, a population survey was carried out at all sites and despite that only one of the sites met the threshold value, the fishery was opened (Martínez *et al*., 2001). However, as from then, rotation of islands has been promoted in order to protect, to a certain extent, the well-being of *I. fuscus*. For further details on the management scheme on *I. fuscus* see Altamirano *et al*. (2004).

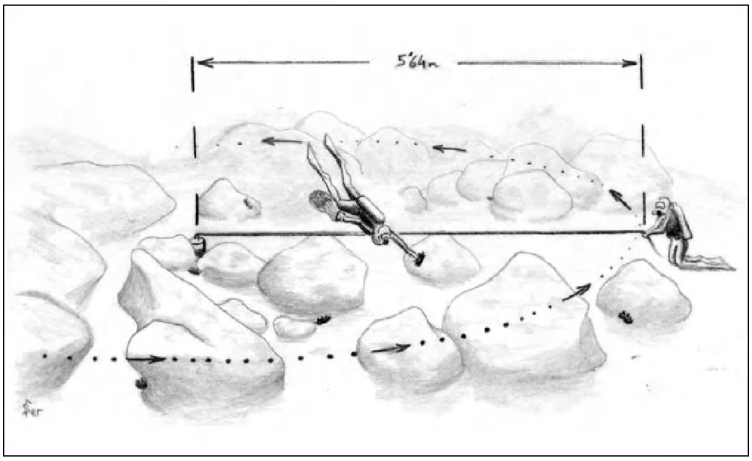

Figure 2. *Circular transect used to gather population density and size structure of* I. fuscus *in Galapagos. Drawing: Fernando Pinillo.*

In order to evaluate the effect of the GMR coastal zoning (approved in 2000) and permanent monitoring on the population of *I. fuscus*, a subset of 17 sites that have been monitored 8 out of 10 times was used (Table 1). These sites belong to the three subzones of protection: subzone of Comparison and Protection (2.1), subzone of Conservation and Non-Extractive Uses (2.2) and subzone of Conservation, Extractive and Non-Extractive Uses (2.3).

Table 1. *Sites analysed to evaluate the impact of No-Take Zones (NTZs) in the Galapagos Marine Reserve.*

Subzone 2.1[2]	Subzone 2.2[3]	Subzone 2.3[4]
Punta Cevallos (Española)	Bahía Elizabeth (Isabela)	Chorros de Agua Dulce (San Cristóbal)
	Las Cuevas (Floreana)	Veinte Varas (San Cristóbal)
	Punta Mangle Sur (Fernandina)	Puerto Bravo (Isabela)
	Punta Espinosa Sur (Fernandina)	Punta Mangle Norte (Fernandina)
	Punta Espinosa Norte (Fernandina)	Bahía Urbina-Poza de los Chinos (Isabela)
		La Montura (Floreana)
		Manzanillo (Española)
		Botella Grande (Floreana)
		Patrullera (Isabela)
		Las Negritas (San Cristóbal)
		Las Palmas (Santa Cruz)

Results

Between 1999 and 2003, a total of 69 sites have been monitored throughout the islands with over 325 000 m^2 surveyed in five years. The number of sites has varied between years, with a subset of 17 sites having 80 % of the visits. As from 2000, there was a drastic impact of the fishing seasons on populations of *I. fuscus* around the archipelago, with a recovery during the ban (Figure 3). Current density values are 39 % lower than those found in the survey before the 1999 fishing season and 85 % lower than those registered after the highest peak registered in the pre-fishery survey in 2001. Due to financial constraints, in 2001 there was no post-fishery population survey in the southern islands (Española, Floreana and San Cristóbal) which explains the low variation between the pre- and post-fishery surveys.

In addition to the great fluctuation in the abundance of *I. fuscus*, the total abundance of individuals $\geq$ 20 cm has also changed during the study period, with the lowest values mostly in the post fishery surveys (Figure 4). However, the biggest decrease in the abundance of such individuals was found in the survey after the 2002 fishing season and with a further decrease in the 2003 post-fishery survey. The highest density value was recorded in the pre-fishery survey of 2001 (Figure 4). The abundance of *I. fuscus* < 20 cm was low in 1999, with a sudden increase in the pre-fishery survey in 2000 followed by a drastic drop after the fishing season and a recovery in 2001, which remained relatively constant until the pre-fishery survey in 2002. After this period, there is a notable decline in the population for both, larger and smaller individuals, and in 2003 density values were lower than in any previous surveys (Figure 4).

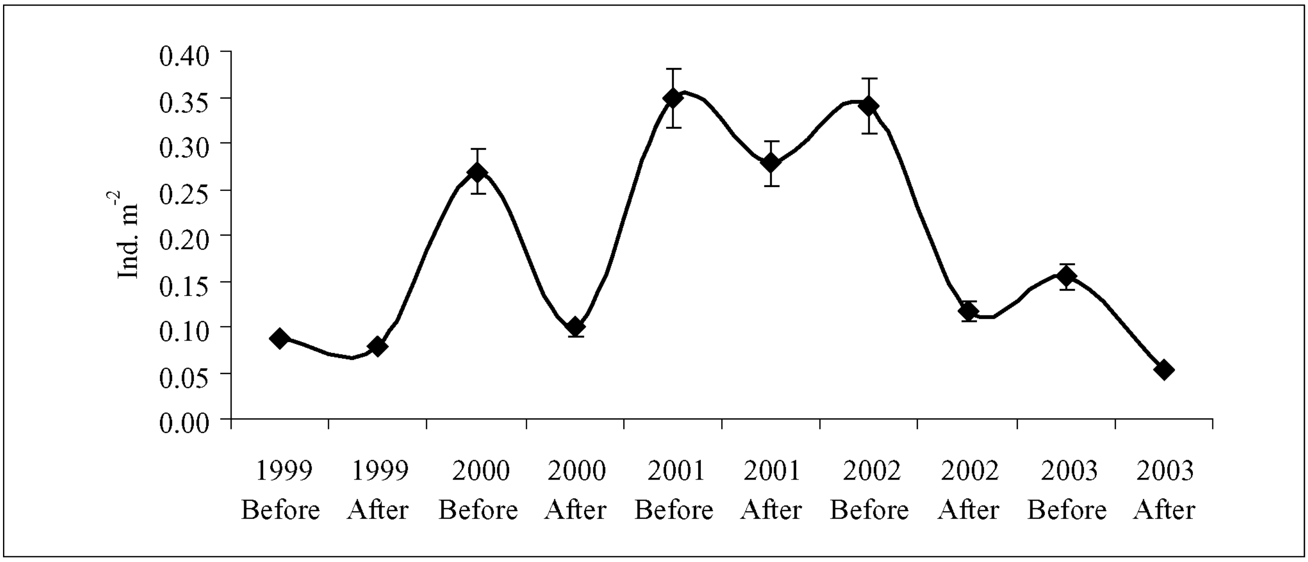

Figure 3. *Average density (ind. m^{-2}) of* I. fuscus *at all sites monitored in the before and after fishery surveys between 1999 and 2003.*

[2] *Only scientific use allowed.*

[3] *Only scientific and tourist use allowed.*

[4] *Fishing activities allowed in this subzone, as well as scientific and tourist use.*

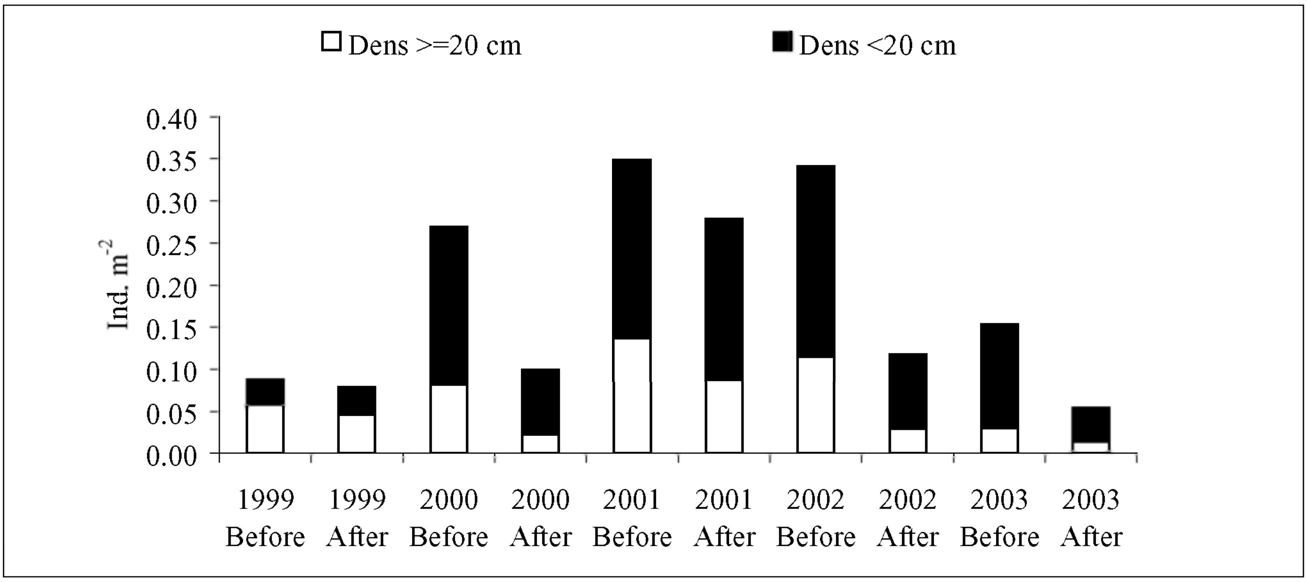

Figure 4. *Density of* I. fuscus *below and above 20 cm TL (Total Length) in all sites monitored since 1999.*

The greatest variation of total average density was observed in Fernandina and Isabela, where the values were almost an order of magnitude different than those observed elsewhere (Figure 5). The drastic recovery in the 2000 and 2001 seasons may be due to a recruitment pulse that was observed then, which lasted until the beginning of 2002 when it started to diminish. This figure also shows the lack of recruitment pulses in the other islands, where in most cases the average density is very low and does not show any sign of recovery (Figure 5).

From 1993 to date, five sites in the western part of the archipelago (between Western Isabela and Fernandina) have been monitored - Punta Espinosa Norte, Punta Espinosa Sur, Punta Mangle Norte and Punta Mangle Sur in Fernandina and Bahía Elizabeth in Isabela. It is as a result of this monitoring effort that the only recruitment event ever observed in the GMR could be detected (Figure 6). From April 1993 until November 1999, juvenile density (≤ 16 cm)[5] is almost non-existent (Figure 6), however, as from April 2000 the value for this size class increases drastically, remaining fairly high in the pre-fishery surveys of 2000, 2001 and 2002 (April and December 2000, April 2001 and March 2002). Despite the minimum landing size (20 cm fresh length) it can be observed the substantial decrease of juvenile individuals after each fishing season (Figure 6).

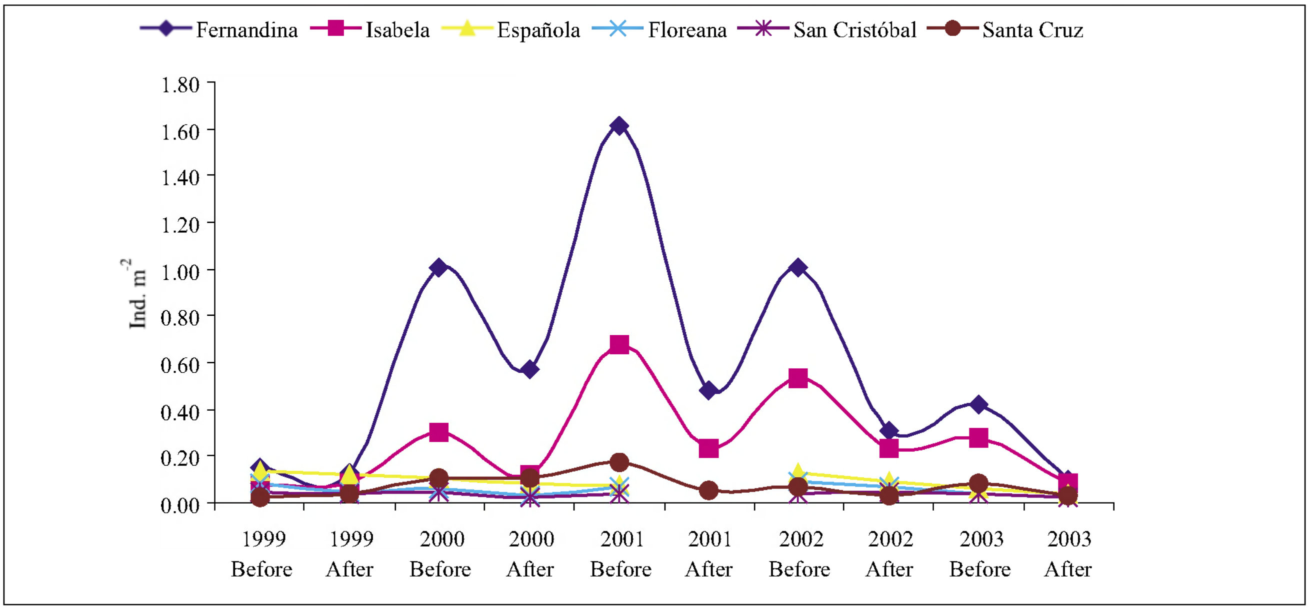

Figure 5. *Average density of* I. fuscus *in the six islands surveyed since 1999.*

[5] *According to Toral (1996) size at first maturity is 16 cm total length.*

Total numbers of adults (≥ 16 cm TL - Total Length) have also fluctuated throughout the study period in these five sites. Despite the ban on fishing on this species in Galapagos from 1994 until 1999, the population density of *I. fuscus* in the Bolívar Channel has decreased throughout time, achieving very low values just before the observed recruitment event (Figure 6).

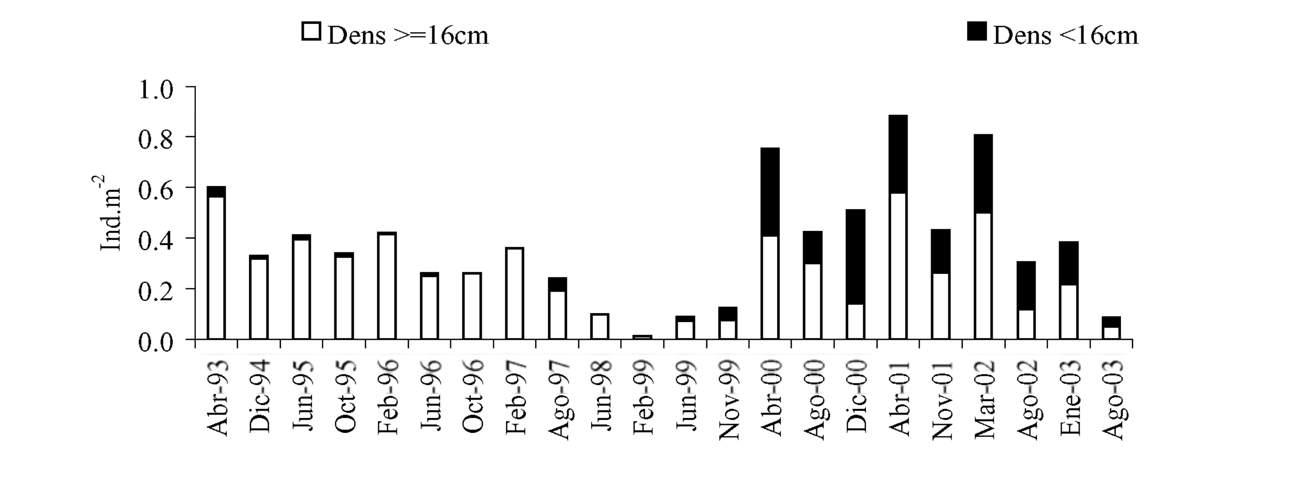

Figure 6. *Population density of juveniles (< 16 cm Total Length) in five permanent monitoring sites located in the Bolívar Channel (between western Isabela and Fernandina): Punta Espinoza Norte, Punta Espinoza Sur, Punta Mangle Norte, Punta Mangle Sur in Fernandina and Bahía Elizabeth en Isabela (De Paco et al., 1993; Richmond and Martínez, 1993; Martínez, 1999).*

The coastal zoning in the GMR is yet to prove its benefits. Populations of *I. fuscus* within No-Take Zones (2.1 and 2.2 - see Table 1) still present a dwindling pattern (Figure 7). The impacts of the fishing seasons can be easily observed especially in subzone 2.2 and subzone 2.3 where the values decrease drastically after the fishing season. However, in Punta Cevallos (subzone 2.1) the population density tends to decrease with time (Figure 7).

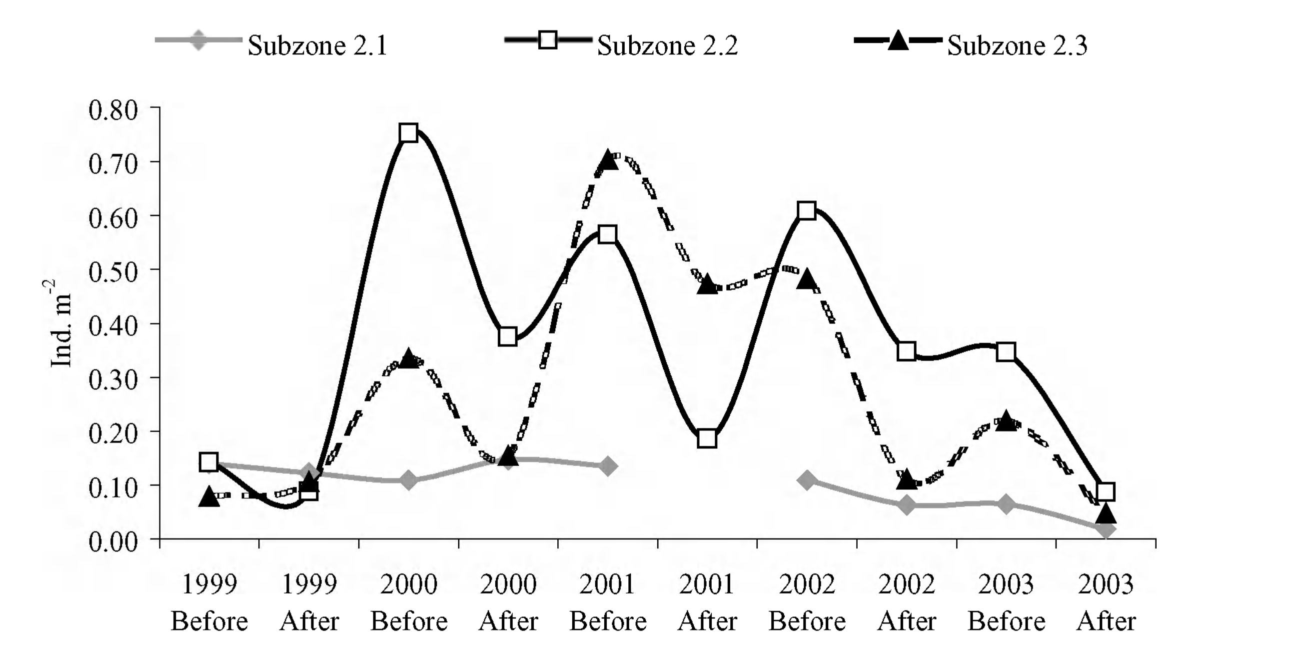

Figure 7. *Average density of I. fuscus in No-Take Zones (Punta Cevallos-2.1 and 2.2) and in fishing zones (subzone 2.3).*

[6] *Data gathered independently of the fishing season for this species. It normally implies information from the before and after fishing season.*

Discussion

Since the start of the sea cucumber fishery in 1991 a considerable amount of sea cucumbers have been harvested both legally (De Miras *et al.*, 1996; Murillo *et al.*, 2003) and illegally (De Miras *et al.*, 1996; Martínez, 1999; Piu, 1998, 2000) which has yielded fluctuating populations. The constant reduction of *I. fuscus* in the GMR has lead to the fact that this species can no longer be considered the most conspicuous of the subtidal zone (Wellington, 1974) and its removal can yield changes in the ecosystem functioning due to its important role as a nutrient recycler and bioturbation agent (Bakus, 1973; Conand, 1993).

Sea cucumber fisheries worldwide have presented cycles in which the total catch decreases despite an increase in the fishing effort, which in turn leads to the overexploitation of the species and low economic returns (Aguilar-Ibarra and Ramírez-Soberón, 2002). This trend of exploitation has been recorded in various places, including México (Aguilar-Ibarra and Ramírez-Soberón, 2002), mainland Ecuador (Carranza and Andrade, 1996) and now in the Galapagos Islands, showing once more that this group of organisms is easy to collect and prone to overexploitation.

Legal fishing activity in the Galapagos Islands has led to the extraction of approximately 31 million individuals (De Miras *et al.*, 1996, Murillo *et al.*, 2003), with most of the catches from Western Isabela and Fernandina (Murillo *et al.*, 2003). Catch values from other islands have decreased with time, with certain islands (i.e. Española) with very low values (Murillo *et al.*, 2003), which prompted the closure of that island for the 2003 fishing season. From the fishery independent data[6], only those populations in western Isabela and Fernandina are still able to sustain fishing activities, however, it is only in this region that recruitment has been observed.

The total density of *I. fuscus* (≥ 20 cm TL) found during the post-fishing survey in 2003 are the lowest ever recorded in the GMR. *Isostichopus fuscus* is a broadcast spawner whose successful reproduction relies on the proximity of its conspecifics. Studies done elsewhere show that there is a 75 % reproductive success when the density of mature animals is between 5 and 8 ind. m^{-2} (Hamel and Mercier, 1996) but when the nearest neighbour is metres away, successful reproduction may go down to zero (Levitan *et al.*, 1991). Fifty percent of the *I. fuscus* population reaches sexual maturity between 21 and 23 cm TL (Toral-Granda, 1996; Martínez, 1999), however, with less than 10 % of the population within this size range the whole survival of this species may seem to be in peril. Current adult densities of *I. fuscus* in the south and central islands are quite low, which may mean that the 'Allee Effect' is likely reducing recruitment levels below those necessary to sustain both the fishery and the population (Shepherd *et al.*, in revision). Additionally, according to Shepherd *et al.* (in revision) a minimun of 1.2 ind.m^{-2} is required for a 50 % fertilization success in *I. fuscus.* Tegner and Dayton (1977) in studies of other species of echinoderms have proved that when there is not a high enough density of adults, recruitment may not be sufficient to compensate fishing mortality.

The recruitment pulse that was observed in 2000 and 2001 is coming to an end, showing the vulnerability of this population to overexploitation when there is not a known cycle of reproduction happening in the GMR. If an *I. fuscus* population relies on external factors (i.e. El Niño and La Niña) to favour the successful reproduction and settlement (Murillo *et al.*, 2002) of this species, then extra care must be taken in its management so as to avoid the collapse of this species and even its possible commercial extinction in the Ecuadorian territory.

Although the information on the importance of NTZs for the benefit of *I. fuscus* populations in the GMR is not clearly evident this could be attributed to the relatively short period of time of the NTZ's existence, thus it is too early to see recovery of the populations. Additionally, the limited patrolling activities due to financial constraints can mask the results. But another fact is that there is a certain level of ignorance among fishermen about the new zoning scheme of the GMR and poaching continues. However, it is important to continue this area of research as the benefits of NTZs for populations of both marine vertebrates and invertebrates have been proved elsewhere (Edgar and Barrett, 1996; Allison *et al.*, 1998; Nowlis and Roberts, 1999; Ward *et al.*, 2000). Despite the great efforts from the Galapagos National Park Service (GNPS) to control and enforce the NTZ, there is still a substantial amount of illegal fishery within the GMR (Altamirano and Aguiñaga, 2002). This lack of adherence to the existing legal framework of the GMR makes it difficult to obtain reliable data on of the effect of the NTZs. Yet, only the continuation of this type of study along with an increased enforcement by the GNPS will prove the possible benefits of all NTZs in the GMR.

The sea cucumber (*I. fuscus*) populations in the GMR are seriously endangered due to commercial exploitation. Only a comprehensive management plan that will involve the best available scientific information, together with a serious commitment of the fishing sector to follow the rules imposed in the plan and the continues control of the GMR authorities, may allow any commercial activities to be sustained over time. Further research is needed to clarify the role of density dependent factors, the 'Allee Effect', oceanographic parameters, amongst other topics, that could lead to a better understanding of the *Isostichopus fuscus* population dynamics and would improve our assessment and management of this important resource.

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World markets and trade flows of sea cucumber/beche-de-mer

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Abstract

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 international trade. Nearly 90 % of this trade takes place in the Asian Far East where China Hong Kong SAR and Singapore dominate the business and China PR remains the main consuming country. The niche markets located outside Asia are strongly linked with trading houses in these two markets. Regular supply of this seafood these days 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 China.

Keywords: Beche-de-mer, trade, demand, supply, price, Southeast Asia, Far East

海参的世界市场和贸易流向

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《INFOFISH》市场促进处主任

摘要

海参的国际贸易结构不同于一般的水产贸易。而对海参的需求也仅仅局限于华人和华裔的亚洲人，海参贸易也为他们所控制。

海参主要以干品形式出口，鲜品和冻品仅占国际贸易的一小部分。贸易量的90%是在地处远东地区的香港和新加坡进行的，而中国内地是海参的主要消费市场。在亚洲以外的市场也与上述两地区的从事海参贸易的家族紧密相关。

海参贸易时至今日依然存在问题，价格一直在上升。然而，这类典型的传统产品在中国以外的消费方式正在发生着微妙的变化。

关键词：价格、香港、新加坡、海参、中国

Introduction

Sea cucumbers are fascinating aquatic invertebrates rather popular among the Mongoloid races who mostly reside in the eastern part of Asia. Hence nearly 90 % of sea cucumber harvested globally is consumed in Southeast Asia and the Far East. The international trade of these species is also dominated by this region. However, with increasing migration and relocation of Oriental people to outside Asia, some exports are taking place to North American and Western European markets with sizeable Oriental populations.

In Asia, the main markets for sea cucumber are China PR, Hong Kong SAR, Taiwan PC, Singapore, Korea Rep. and Malaysia. Imports into Japan, the largest seafood market in the world, are rather limited. China Hong Kong SAR, the largest direct importer of sea cucumber, re-exports half of its imports to mainland China. Re-exports also take place to European and North American markets. Singapore meets its domestic demand through imports. This trading nation also re-exports to the regional markets namely China Hong Kong SAR, Malaysia, Taiwan PC, Thailand, Myanmar and to some western countries.

In international trading, sea cucumbers are marketed in fresh/chilled, frozen, dried and canned forms. More than 90 % of these are dried products.

International trade

Due to lack of available trade data on sea cucumber from both exporting and importing countries, it is difficult to quantify the international trade of these species accurately in volume or in value terms (Ferdhouse, 1996). Re-exports and subsequent double reporting of trade figures also make the authenticity of available data doubtful in some cases, particularly in quantitative calculation (FAO, 1990). The fact is, few exporting countries classify sea cucumber trade separately in their national statistics. Hence the problems of under reporting and double reporting exist.

World imports

According to FAO (2003), the global imports of *fresh, frozen* and *dried* sea cucumber (including salted in brine, but excluding canned products) totalled 7 299 tonnes in quantity and US$ 56.7 million in value in 2001 (Table 1). However, the same source also reports other trade data under the heading '*imports of fresh, frozen, dried and canned sea cucumber and other invertebrates*'. Under this heading the global imports of these categories of products totalled 34 000 tonnes at a value of US$ 130 million. Presumably, the figures differ because of the inclusion of the "*other invertebrates"* in this category (Table 2). It is noteworthy that imports of sea cucumber into Singapore in any forms were not reported in these trade figures.

Table 1. *World imports of sea cucumber, fresh/frozen/dried/salted/ in brine, 1995-2001 (Q=tonnes; V=US$'000).*

Country		1995	1996	1997	1998	1999	2000	2001
China PR	Q	-	49	1	9	139	186	2 059
	V	-	49	3	30	265	793	1 229
Hong Kong (China)	Q	5 789	5 020	4 523	3 975	2 922	4 759	4 382
	V	40 898	43 376	38 147	39 565	33 571	55 533	50 430
Japan	Q	25	10	5	5	4	3	3
	V	799	350	134	163	121	141	81
Korea, Rep.	Q	7	36	16	2	10	29	51
	V	128	154	302	23	68	127	400
Malaysia	Q	521	358	-	18	21	32	2
	V	755	564	4	8	34	24	16
Singapore	Q	-	-	-	-	-	-	-
	V	-	-	-	-	-	-	-
Taiwan PC	Q	1 273	1 079	1 014	859	899	887	676
	V	5 792	5 327	5 291	4 549	4 735	4 514	3 979
Thailand	Q	32	32	71	78	75	133	115
	V	102	90	446	282	417	528	504
World total	Q	**7 653**	**6 597**	**5 630**	**4 946**	**4 079**	**6 040**	**7 299**
(incl. others)	V	**48 507**	**49 987**	**44 327**	**44 620**	**39 331**	**61 691**	**56 722**

Source: FAO FISHDAB, 2003.

Nonetheless, referring to the national statistics of major importing countries, Table 1 seems to be more realistic and this reflects the trade of the main product forms namely *fresh/chilled*, *frozen* and most of all *dried.* The international trading of canned sea cucumber is rather small compared to the other product forms.

Table 2. World imports of sea cucumber & other invertebrates, fresh/chilled/frozen/dried/salted/canned, 1995-2001 (Q=tonnes; V=US$'000).

Country		1995	1996	1997	1998	1999	2000	2001
Belgium	Q	608	766	733	586	765	906	951
	V	3 168	3 644	3 209	2 709	3 320	3 456	3 269
China PR	Q	-	49	1	9	139	186	2 059
	V	-	49	3	30	265	793	1 229
France	Q	7 257	6 825	8 384	7 744	7 739	7 561	8 966
	V	17 282	15 739	19 606	20 550	20 094	21 091	26 862
Germany	Q	768	1 024	1 014	1 076	1 814	2 221	2 108
	V	3 520	4 788	4 195	4 332	6 126	6 137	6 114
Hong Kong (China)	Q	5 789	5 020	4 523	3 975	2 922	4 759	4 382
	V	40 898	43 376	38 147	39 565	33 571	55 533	50 430
Japan	Q	25	10	5	5	4	3	3
	V	799	350	134	163	121	141	81
Korea, Rep.	Q	6 947	7 423	8 436	3 196	4 504	5 460	6 474
	V	26 915	27 943	30 090	9 161	13 591	13 968	16 790
Malaysia	Q	1 479	770	74	259	236	218	52
	V	2 474	1 195	64	136	162	126	57
Spain	Q	2 034	2 503	2 929	3 649	3 024	3 761	4 301
	V	7 363	6 377	6 796	9 078	6 404	8 413	10 653
Taiwan PC	Q	2 620	3 056	2 700	2 322	2 512	2 360	1 649
	V	7 940	8 666	8 103	6 425	7 330	6 794	5 690
Thailand	Q	32	32	71	78	75	133	115
	V	102	90	446	282	417	528	504
Singapore	Q	-	-	-	-	-	-	-
	V	-	-	-	-	-	-	-
World total	**Q**	**29 570**	**29 882**	**30 667**	**25 646**	**26 187**	**29 718**	**34 116**
(incl. others)	**V**	**119 893**	**124 263**	**120 102**	**100 342**	**101 493**	**124 737**	**130 508**

Source: FAO FISHDAB, 2003.

World Exports

The latest trade figures published by FAO on global exports are much lower than the import figures due to lack of published data from exporting countries (Table 3). For example, according to official statistics of China Hong Kong SAR, the territory itself imported over 4 000 tonnes of dried sea cucumber against the available global figure of 1 450 tonnes in the year 2001.

Nonetheless, the Asia/Pacific region is the main source of sea cucumber with the leading exporters being Indonesia, the Philippines, Singapore, Malaysia, Papua New Guinea, Solomon Islands, Fiji and Australia in order of ranking. More recently, supplies from the Middle East, namely the United Arab Emirates, Yemen and some African countries (Mozambique, Kenya, Madagascar and South Africa) are also entering the markets, mostly being sent to Asian markets. More than 98 % of these exports consist of dried products.

Although China PR remains the major market and consuming country for sea cucumber, China Hong Kong SAR is the main trading outlet for most of the producing countries. Lately, some direct exports are taking place to China PR, but these mostly consist of lower value species. The expensive varieties, namely the sandfish, white teatfish, etc., are exported through China Hong Kong SAR and Singapore.

In 2000, Indonesia, the largest producer, exported over 2 500 tonnes of sea cucumber to the global market. Nearly 50 % of these went to China Hong Kong SAR, followed by Singapore, China PR, Taiwan PC, Korea Rep. and Malaysia; a small quantity went to Japan. France is the main outlet for Indonesian sea cucumber in Europe, importing

Table 3. World exports of sea cucumber, fresh/frozen/dried/salted in brine, 1995-2001 (Q=tonnes; V=US$'000).

Country		1995	1996	1997	1998	1999	2000	2001
China PR	Q	-	16	11	21	88	298	653
	V	-	296	98	99	209	612	845
Hong Kong (China)	Q	31	116	-	-	-	53	-
	V	88	200	-	19	-	108	-
Cuba	Q	-	-	-	-	-	21	14
	V	-	-	-	-	-	452	351
Fiji Islands	Q	454	666	862	127	141	-	1
	V	3 978	4 071	2 781	1 171	1 379	-	32
French Polynesia	Q	-	-	-	2	1	-	-
	V	1	-	-	14	13	-	7
India	Q	-	-	-	-	-	-	-
	V	-	-	-	-	-	-	-
Indonesia	Q	-	-	-	-	-	-	-
	V	-	-	-	-	-	-	-
Kiribati	Q	40	74	39	3	4	9	14
	V	281	602	199	31	61	79	116
Korea, Rep.	Q	3	15	12	12	12	20	10
	V	21	60	47	59	116	165	92
Madagascar	Q	317	279	162	-	-	-	-
	V	1 254	751	452	-	-	-	-
Malaysia	Q	32	17	25	1	5	1	22
	V	142	49	136	1	11	5	84
Maldives	Q	94	145	318	85	54	-	-
	V	707	646	728	346	407	-	-
Marshall Islands	Q	-	55	29	-	-	-	-
	V	-	432	312	-	-	-	-
Mozambique	Q	-	43	-	25	3	-	2
	V	-	116	-	24	20	5	34
New Caledonia	Q	53	49	-	-	49	62	-
	V	1 300	930	-	-	593	1 170	-
Nigeria	Q	-	-	-	-	-	-	1
	V	-	-	-	-	-	-	6
Papua New Guinea	Q	-	-	453	-	379	-	-
	V	-	-	3 861	-	3 332	-	-
Philippines	Q	1 459	1 469	1 297	-	1 125	-	-
	V	4 803	4 827	4 505	-	3 653	-	-
Saint Helena	Q	-	6	-	-	-	-	-
	V	-	58	-	-	-	-	-
Samoa	Q	29	32	9	3	-	-	-
	V	80	70	34	5	-	-	-
Seychelles	Q	-	-	-	-	-	-	16
	V	-	-	-	-	-	-	247
Singapore	Q	-	-	-	-	-	-	-
	V	-	-	-	-	-	-	-
Solomon Islands	Q	219	113	203	253	376	48	269
	V	509	354	664	853	393	253	1 749
Sri Lanka	Q	188	176	307	213	104	-	96
	V	2 028	2 936	6 352	4 260	2 547	-	1 936
Taiwan PC	Q	34	160	71	267	258	179	146
	V	562	863	828	1 025	1,150	1 503	1 704
Tanzania	Q	263	296	254	873	93	-	-
	V	359	438	685	201	262	-	-
Thailand	Q	12	8	40	87	225	242	121
	V	48	56	129	160	320	857	432
Tonga	Q	109	86	-	-	-	-	1
	V	911	719	-	-	-	-	7
United Arab Emirates	Q	-	3	22	-	-	11	-
	V	-	19	70	-	3	161	1
Vanuatu	Q	-	20	35	25	8	-	16
	V	-	123	121	130	33	-	102
Yemen	Q	-	6	-	-	-	-	77
	V	-	138	-	-	-	-	374
World total	Q	**3 337**	**3 890**	**4 149**	**1 999**	**2,925**	**944**	**1 459**
	V	**17 072**	**18 908**	**22 002**	**8 498**	**14,505**	**5 370**	**8 122**

Source: FAO FISHDAB, 2003.

83 tonnes from Indonesia in 2000. The other markets were the UK (6 tonnes), Belgium, Germany, the Netherlands, etc. Imports into Belgium and Germany were about 8 tonnes each. In North America, the USA was the main outlet, importing 50 tonnes of dried sea cucumber in 2000.

From South Asia, Sri Lanka, the Maldives and India are the main producing/exporting countries. Compared to Southeast Asia and the Pacific, supplies from these countries are relatively small. The published data from India indicated that exports of dried sea cucumber declined from 32 tonnes in 1997 to 13 tonnes in 2001. Singapore was the main market for Indian dried sea cucumber followed by China Hong Kong SAR. Some exports also took place through Sri Lanka and to Canada. The Maldives exports less than 300 tonnes annually.

From the Pacific region, Papua New Guinea (PNG), the Solomon Islands, Fiji and Australia are the leading suppliers of dried sea cucumber to the Oriental markets. A review on the Hong Kong market indicated that supplies from Australia and the Solomon Islands increased during 2000-2002, but declined from PNG and Fiji. Sea cucumbers from the Pacific are the most popular in China Hong Kong SAR, China PR, Malaysia and Singapore.

Consumption

In general, consumption of sea cucumber is associated with high quality dried and prepared/preserved seafood such as shark fins, abalone and other shellfish which are popular among the people of Chinese origin worldwide. Hence, in most of the producing countries, domestic consumption of sea cucumber is almost zero, with the exception of China.

China is the largest market and consumer of sea cucumber. Unfortunately, the level of total annual supply in this market (including foreign supplies) is not yet known. Most of the imported sea cucumber in China PR comes through China Hong Kong SAR. The other major consuming countries and territories in the region are China Hong Kong SAR, Taiwan PC, Singapore and Malaysia.

In the minor markets in North America (USA and Canada) and Western Europe, consumption of sea cucumber is rather occasional compared to other seafood preferred by the Oriental people residing in those countries.

Review of major markets

China PR

China PR is the largest market for sea cucumber. However, the actual trend in the market is not reflected on the published data. The official trade statistics from China Hong Kong SAR indicated that re-exports to mainland varied between 2 000 and 3 500 tonnes annually during 2000-2002 (Table 5). In 2001, re-exports to China PR from China Hong Kong SAR were 3 543 tonnes.

The 2001 official statistics from China reported annual imports of 2 059 tonnes according to which only 13.50 tonnes came from Hong Kong (Table 4). Imports from Indonesia in that year were 1 146 tonnes - 50% of the total official imports in that year. The other major suppliers were the Philippines (791 tonnes), Korea Rep. (21 tonnes) and Thailand (56 tonnes). Minor supplies came from Canada (17 tonnes) and Russia (1.2 tonnes).

Taking into consideration the exports from China Hong Kong SAR to this market, the annual import into China PR could be around 5 500 tonnes. This shows the importance and supremacy of China PR in the international market for sea cucumber.

It is important to note that the market is capable of absorbing all kinds and qualities of sea cucumber due to the varied degrees of purchasing power. Per capita income of the population in southern provinces is much higher than the average national per capita income of the country. Hence both high and low valued species and different qualities of sea cucumbers are imported into China for domestic consumption.

Table 4. *China: Imports of sea cucumber, frozen/dried/salted/in brine, 1999-2001 (Q=tonnes; V=US$'000).*

Country	1999		2000		2001	
	Q	V	Q	V	Q	V
Russia	0.5	7 500	0.85	8 500	1.20	6 000
Ecuador	0.09	525	-	-	1.16	11 258
Philippines	28.8	23 599	45.02	348 241	791.48	489 250
Korea, Rep.	0.06	1 300	12.34	76 766	21.10	107 840
Papua New Guinea	-	-	-	-	0.62	4 992
Canada	14.63	22 107	-	-	17.54	41 385
Madagascar	7.19	13 793	10.58	24 031	0.94	2 560
USA	9.47	10 293	27.17	65 397	6.41	40 276
South Africa	-	-	-	-	1.08	1 642
Japan	14.28	19 795	-	-	0.02	1 023
Thailand	-	-	-	-	55.91	18 780
Hong Kong (China)	50.19	154 001	13.76	54 509	13.50	11 369
Indonesia	9.12	4 766	44.06	84 846	1 146.41	488 502
Chile	-	-	-	-	1.20	720
Total	**139.15**	**265 306**	**186.24**	**793 045**	**2 059.05**	**1 229 799**

Source: Bureau of Fisheries, China PR.

China Hong Kong SAR

This Special Administrative Region of China is regarded as the largest importer of sea cucumber in the international market. The market is dominated by imports of dried tropical sea cucumber of all varieties. However, a small quantity of air-freight chilled, skinless sea cucumbers are also imported from New Zealand for specialty restaurants in China Hong Kong SAR and the southern provinces of China PR. The cold water species are imported from the USA and Canada in gutted frozen form for the up markets in the mainland.

Imports of sea cucumbers declined by almost 50 % in 2000 compared to the mid 1990s. The import market has stabilized at a volume of about 4 000 tonnes per annum during the last 6 years. However, supplies declined in 1998 and 1999 due to the economic recession that engulfed Southeast Asia and the Far East in the late 1990s.

In 2002, imports recovered to 4 417 tonnes at a value of HK$ 440 million (US$ 56 million) (Table 5A).

The main suppliers were Indonesia, the Philippines, Singapore, PNG, the Solomon Islands, Madagascar and Australia. For the last few years, supplies have been dwindling from regular sources except from Indonesia. New supplies from Africa and the Middle East have entered the market. However, the quantity is not sufficient to offset the lower exports from the other sources.

A survey indicated that the domestic market in China Hong Kong SAR absorbs about 500-700 tonnes of dried sea cucumber annually. While the population growth in the territory has remained static over the years, there have not been many changes in local consumption patterns. In general, sea cucumber is perceived as an expensive product. Day to day consumption is limited to the middle-aged group, festival celebration (Chinese New Year), wedding dinners, banquets, etc. Hence, demand fluctuates according to the age group and most of all by disposable income. The market preference is similar to the mainland. Consumers in China Hong Kong SAR prefer large and medium sized dried skin-on calcium coated *sandfish* and *teatfish*, which are the high value species.

However, for China Hong Kong SAR traders the main attraction is the expanding mainland market. In 2002, China Hong Kong SAR re-exported nearly 3 000 tonnes of sea cucumber, which was 67 % of the total imports in that year.

Table 5A. China Hong Kong SAR: Imports of beche-de-mer (dried, salted or in brine), 1997 – June 2003 (Q=tonnes; V=HK$ '000).

Countries		1997	1998	1999	2000	2001	2002	Jan-Jun 2003
USA	Q	41	44	114	182	90	155	88
	V	3 307	3 242	6 032	10 473	5 439	10 318	5 790
Canada	Q	18	20	5	3	59	18	13
	V	2 337	2 911	660	80	3 332	1 373	630
United Arab Emirates	Q	21	-	-	11	0.2	21	1
	V	600	-	-	1 393	13	1 585	0
Yemen	Q	-	-	3	-	3	113	71
	V	-	-	256	-	332	11 497	3 831
Taiwan	Q	22	71	41	40	57	119	34
	V	2 024	5 300	6 255	7 695	17 705	29 485	9 447
Indonesia	Q	1 097	961	757	1 007	1 060	1 008	429
	V	484 424	42 073	31 207	40 907	34 084	31 986	13 467
Philippines	Q	165	467	591	1 070	737	775	268
	V	18 931	18 855	31 608	63 751	39 400	39 004	15 109
Korea, Rep.	Q	2	2	-	3	-	1	12
	V	232	369	-	273	-	211	782
Japan	Q	29	53	55	75	103	127	94
	V	23 321	41 386	53 593	81 230	90 771	131 763	121 827
China PR	Q	27	77	30	13	12	27	22
	V	1 314	214	1 830	2 074	778	1 218	837
Viet Nam	Q	56	47	34	1	3	1	4
	V	2 516	2 904	957	215	950	142	448
Maldives	Q	117	23	4	39	29	38	25
	V	6 085	1 296	229	2 345	1 626	1 080	1 080
Sri Lanka	Q	76	52	19	65	33	50	49
	V	8 982	4 616	1 838	3 732	1 894	2 918	2 441
India	Q	-	1	2	1	4	2	-
	V	-	396	523	114	807	356	-
Malaysia	Q	22	60	19	59	66	124	69
	V	1 452	3 090	1 382	3 939	3 677	8 982	5 267
Singapore	Q	479	349	212	345	335	364	149
	V	33 471	22 834	15 872	24 005	24 925	28 305	7 969
Mozambique	Q	82	25	1	0	1	37	33
	V	1 932	204	76	40	220	3 307	2 558
Madagascar	Q	204	216	154	178	179	169	122
	V	28 400	22 080	18 084	17 745	15 497	9 946	4 837
South Africa	Q	47	49	21	28	29	53	34
	V	2 303	4 151	1 085	2 188	969	1 035	584
Kenya	Q	-	-	2	52	39	20	9
	V	-	-	148	3 377	1 407	1 873	2 447
Mauritius	Q	-	-	-	3	-	6	1 716
	V	-	-	-	271	-	1 408	339
Tanzania	Q	182	72	31	115	56	92	40
	V	10 853	4 781	5 237	8 708	4 676	5 462	1 613
US Oceania	Q	29	20	12	18	41	-	-
	V	2 680	2 463	1 789	1 935	-	-	-
Australia & Oceania	Q	70	39	32	14	22	17	12
	V	11 776	6 769	5 737	2 735	3 703	3 383	2 539
Kiribati	Q	4	3	4	9	14	9	1
	V	104	264	522	683	1 005	883	192
Tonga	Q	12	-	-	-	-	-	-
	V	1 705	-	-	-	-	-	-
Western Samoa	Q	11	4	6	-	-	-	-
	V	1 045	833	533	-	-	-	-
Australia	Q	63	73	118	139	187	139	59
	V	13 008	16 870	23 615	42 061	40 910	32 792	19 154
Solomon Islands	Q	122	252	50	144	260	249	141
	V	6 897	12 779	2 641	7 325	14 896	12 027	4 846
Fiji	Q	528	291	166	364	276	162	86
	V	26 232	23 956	14 523	28 149	21 770	12 659	4 973
New Zealand	Q	15	8	1	11	31	16	3
	V	1 333	469	186	2 227	3 998	1 241	192
Vanuatu	Q	35	25	8	28	16	8	1
	V	1 038	1 116	286	1 315	888	401	44
Papua New Guinea	Q	453	613	336	532	493	368	212
	V	33 215	52 684	27 201	45 655	37 405	38 097	23 711
Total	Q	**4 523**	**3 975**	**2 922**	**4 759**	**4 382**	**4 417**	**2 222**
(incl. minor exporters)	V	**295 341**	**306 442**	**260 425**	**432 665**	**393 297**	**439 628**	**270 499**

Source: Agriculture, Fisheries and Conservation Dept., China Hong Kong SAR.

China was the largest outlet (72 %); all types of sea cucumber are exported to the China PR market mainly by road and also by sea depending on the destination. The other markets are Taiwan PC, the USA and some other niche markets (Table 5B).

Table 5B. *Hong Kong: Re-export of beche-de-mer (dried/salted/in brine), 1997 – June 2003 (Q=tonnes; V=HK$'000).*

Country		1998	1999	2000	2001	2002	Jan-Jun 2003
USA	Q	21	17	23	38	106	48
	V	2 938	2 544	2 880	2 750	6 409	3 657
Canada	Q	27	16	13	27	14	8
	V	3 779	2 722	2 717	3 395	3 906	1 232
France	Q	-	0.001	-	0.001	-	-
	V	-	-	-	28	-	-
United Kingdom	Q	-	-	-	-	-	-
	V	-	-	-	-	-	-
Taiwan PC	Q	224	158	209	117	152	39
	V	20 797	15 479	25 164	9 927	16 662	4 488
Indonesia	Q	-	10	0.1	-	-	-
	V	-	236	13	-	-	-
Korea Rep	Q	50	50	82	62	36	10
	V	4 616	4 780	7 102	4 294	2 703	644
Thailand	Q	-	31	30	40	40	8
	V	-	5 265	6 005	6 555	7 656	2 000
Japan	Q	1	0.1	1	1	1	0.2
	V	302	46	711	325	213	92
China PR	Q	2 780	2 268	3 771	3 543	2 127	938
	V	97 438	78 159	176 034	141 171	73 903	25 544
Malaysia	Q	9	22	21	6	6	1
	V	714	2 550	2 866	667	1 046	78
Singapore	Q	37	81	70	28	19	10
	V	5 769	12 293	9 854	6 122	4 253	2 664
Australia	Q	1	3	1	2	2	2
	V	277	288	79	359	203	129
Total	**Q**	**3 174**	**2 658**	**4 221**	**3 867**	**2 944**	**1 305**
	V	**139 691**	**125 099**	**233 885**	**176 792**	**130 575**	**49 288**

Source: Agriculture, Fisheries and Conservation Dept., China Hong Kong SAR.

As direct imports to China PR are subject to high import duty and rather complicated procedures, exporters from other countries prefer to supply to China Hong Kong SAR traders. The territory still retains the status of a duty free port for imported products.

Taiwan PC

Demand for high value fish and fishery products is relatively high in Taiwan PC. This is related to high per capita income and the traditional influence of the Fijian and Teochew provinces - the origins of the Taiwanese. Household consumption of processed sea cucumber is high in Taiwan PC although the species are not popular with highlanders.

Traditionally the Taiwanese market has a preference for various kinds of spiky sea cucumber which are both tropical and coldwater species. The coldwater prickly redfish are imported from Alaska (USA) and Canada in frozen form. Taiwan PC also imports frozen sea cucumber from Peru which are processed into dried products for the domestic market. Demand for high value *sandfish* is rather limited, but is increasing slowly through supplies from China Hong Kong SAR.

Consumption of sea cucumber was low during the economic recession in 1998-2000. However, imports have recovered since 2001 and totalled 1 015 tonnes in 2002 against 624 tonnes in 2001. Nearly 28 % of these were frozen products imported from coldwater sources (Table 6). Imports of tropical species are from India, Indonesia, the Philippines and from mainland China PR.

Table 6. *Taiwan: Imports of beche-de-mer, 1997-2002 (Q=tonnes; V=NT$'000).*

Year	Products	Spiky species		Other species		Total	
		Q	V	Q	V	Q	V
1997	Frozen	-	-	348	47 762	348	47 762
	Dried	39	19 675	658	90 039	697	109 714
	Salted/in brine	-	-	14	1 562	14	1 562
	Total	**39**	**19 675**	**1 020**	**139 449**	**1 059**	**159 124**
1998	Frozen	-	-	274	42 812	274	42 812
	Dried	41	25 763	530	81 581	371	107 344
	Salted/in brine	-	-	1	163	1	163
	Total	**41**	**23 763**	**805**	**124 572**	**846**	**150 335**
1999	Frozen	-	-	299	43 343	299	43 343
	Dried	37	25 033	508	75 592	545	100 625
	Salted/in brine	-	-	54	4 535	54	4 535
	Total	**37**	**25 033**	**862**	**123 489**	**899**	**148 522**
2000	Frozen	-	-	295	44 594	295	44 594
	Dried	32	23 126	517	68 406	549	91 532
	Salted/in brine	-	-	44	4 507	44	4 507
	Total	**32**	**23 126**	**855**	**117 507**	**887**	**140 633**
2001	Frozen	-	-	198	35 483	198	35 483
	Dried	20	16 089	426	62 237	446	78 326
	Salted/in brine	-	-	-	-	32	3 736
	Total	**20**	**16 089**	**624**	**97 720**	**676**	**117 545**
2002	Frozen	-	-	208	38 429	208	38 429
	Dried	12	10 468	733	89 047	745	99 515
	Salted/in brine	-	-	62	9 599	62	9 599
	Total	**12**	**10 468**	**1 002**	**137 075**	**1 015**	**147 543**

Source: Fisheries Statistical Year Book, Taiwan PC.

Import duty on sea cucumber is high in Taiwan PC. The tariffs also differ according to the species, ranging from 20-40 % on the invoice value. The spiky varieties enjoy lower tariffs compared to the other species. Import duty on frozen products is also lower than that of dried/salted products.

Unlike China Hong Kong SAR, the market in Taiwan PC is dominated by a few importers. The market also demands high quality products.

Singapore

In this trading nation where production of sea cucumber is nil, it is a preferred seafood delicacy of the highest order, a positioned shared with dried shark fins. However, sea cucumber is an expensive seafood thus follows the demand pattern dictated by the consumer`s disposable income.

A large share of imports is re-exported to other destinations from Singapore. Imports fluctuated from 820 tonnes in 1997 to 629 tonnes in 2000 due to the economic recession in the region. China Hong Kong SAR was the main supplier. The other exporters to this market were India, Yemen, the USA and South Pacific island countries. During the late 1990s, imports increased from Madagascar and Tanzania consisting of cheaper quality *sandfish* and some white *teatfish*. The best quality products come from Australia and the other Pacific sources. Imports also take place from Indonesia, but these are not reflected in the official statistics (Tables 7A and 7B).

Table 7A. *Singapore: Imports of beche-de-mer (dried/salted/in brine), 1997-2000 (Q=tonnes; V=S$'000).*

	1997		1998		1999		2000	
Country	**Q**	**V**	**Q**	**V**	**Q**	**V**	**Q**	**V**
Australia	12	NA	7	585	14	1 185	4	337
New Zealand	5	NA	13	820	12	1 428	19	1 047
China PR	13	NA	21	1 437	4	385	5	853
Taiwan	86	NA	75	3 852	16	865	27	1 340
Hong Kong (China)	201	NA	73	7 374	93	9 972	104	12 964
India	97	NA	58	3 332	43	2 837	82	6 732
Sri Lanka	36	NA	30	2 282	18	1 203	15	2 388
Malaysia	2	NA	5	111	5	317	3	296
Myanmar	1	NA	1	83	-	-	-	-
Viet Nam	-	-	-	-	3	317	1	162
Fiji	-	-	-	-	20	890	-	-
Maldives	23	NA	18	2 139	11	974	10	1 644
Papua New Guinea	-	-	2	80	1	70	1	129
Solomon Islands	4	NA	-	-	-	82	-	-
Mauritius	5	NA	4	224	4	170	-	-
Kenya	7	NA	6	275	2	76	-	-
Madagascar	-	-	-	-	10	137	5	349
United Arab Emirates	9	NA	1	71	5	288	7	369
Yemen	2	NA	9	430	23	506	21	382
USA	-	-	3	82	57	2 255	49	2 751
Oceania	-	-	12	443	101	3 840	122	6 218
Total (incl. others)	**820**	**-**	**538**	**32 448**	**692**	**37 221**	**629**	**48 145**

Source: National Statistics, Singapore.

Table 7B. *Singapore: Exports of beche-de-mer (dried/salted/in brine), 1997-2000 (Q=tonnes; V=S$'000).*

	1997		1998		1999		2000	
Country	**Q**	**V**	**Q**	**V**	**Q**	**V**	**Q**	**V**
Hong Kong (China)	502	-	236	3 543	161	3 111	295	4 351
Malaysia	255	-	146	3 943	238	6 247	214	7 143
Taiwan PC	116	-	81	3 359	132	6 146	138	5 236
Thailand	19	-	20	586	8	177	17	345
USA	-	-	2	139	1	87	2	111
Brunei	1	-	-	-	-	-	-	-
Total (incl. others)	**895**	**-**	**542**	**12 251**	**586**	**16 530**	**723**	**18 356**

Source: National Statistics, Singapore.

Although the market demands high value products, the small population in Singapore (2.3 million) is not able to support the total import. Thus the lion's share gets re-exported to China Hong Kong SAR, Malaysia, Taiwan PC and Thailand. The ASEAN Free Trade Agreement also allows re-exports to the ASEAN member countries (Malaysia, Thailand, Myanmar). While exports to Malaysia consist of medium grade sandfish of different sizes and a small quantity of teatfish, high quality products are exported to Taiwan PC.

Domestic consumption of sea cucumber in Singapore has been low during the last few years. The economic recession since 1998 coupled with the SARS (Severe Acute Respiratory Syndrome) problem in 2002-2003 have affected the domestic consumption of seafood in general.

Table 8A. *Malaysia: Imports of dried beche-de-mer, 1997 - June 2003 (Q=tonnes; V=RM).*

	1997		1998		1999		2000	
Country	**Q**	**V**	**Q**	**V**	**Q**	**V**	**Q**	**V**
Australia	-	-	0.24	5331	4	56 261	1	21 488
China PR	376	665 489	242	494 162	209	440 737	13	35 082
Hong Kong (China)	3	23 598	11	88 189	15	113 760	21	313 115
India	2	18 446	1	6 000	1	16 340	0.4	19 165
Indonesia	221	1 377 552	129	988 992	110	767 585	114	1 068 041
Japan	-	-	-	-	2	21 904	-	-
Papua New Guinea	0.25	24 860	2	53 601	-	-	4	25 587
Philippines	3	40 758	5	57 094	9	100 377	33	344 436
Singapore	-	-	8	26 132	13	76 575	14	119 611
Sri Lanka	2	10 608	4	24 734	0.46	5 993	-	-
Others								
Total	**959**	**2 800 628**	**548**	**2 131 873**	**523**	**2 072 666**	**246**	**2 470 515**

	2001		2002		Jan-Jun 2003	
Country	**Q**	**V**	**Q**	**V**	**Q**	**V**
Australia	-	-	-	-	-	-
China PR	0.2	20 562	13	41 329	-	-
Hong Kong (China)	7	98 198	15	119 014	19	24 946
India	2	12 891	2	14 292	2	31 789
Indonesia	53	515 665	42	329 897	20	204 606
Japan	-	-	-	-	-	-
Papua New Guinea	10	120 397	4	143 183	4	43 023
Philippines	24	228 948	58	526 272	27	289 997
Singapore	15	413 052	2	47 320	2	15 000
Sri Lanka	5	38 568	2	11 777	9	49 356
Others						
Total	**158**	**1 934 753**	**160**	**1 447 853**	**92**	**765 233**

Source: MATRADE, Ministry of Trade and Industry, Malaysia

Malaysia

The Malaysian population is multi-racial with the Chinese as the second largest group. As of 1994 about 35 % (6.65 million) of the 19 million Malaysians were ethnic Chinese. The country's population has increased since then to 23 million in 2003, but the ratio has declined as the average family size of the people of Chinese origin has reduced. Hence the market for sea cucumber in Malaysia has shrunk. The other races, namely Malays and Indians, do not have a liking for sea cucumber.

Consumption of sea cucumber among the ethnic Chinese in Malaysia is not as high as Singapore or China Hong Kong SAR. The market imports a small volume of fresh/chilled and frozen sea cucumber from neighbouring Indonesia, but dried products are the predominant type. Nearly half of the imported sea cucumber is re-exported to other markets. Imports in 2002 were low at 160 tonnes compared to over 500 tonnes in 1998 (Table 8A). The major share of supplies came from Indonesia followed by China Hong Kong SAR and China PR. Dried sea cucumbers were re-exported from Malaysia to China Hong Kong SAR, Taiwan PC, Singapore and Thailand (Table 8B).

Table 8B*. Malaysia: Imports of beche-de-mer (live/fresh/chilled/frozen), 1997 - June 2003 (Q=tonnes; V=RM).*

	1997		1998		1999		2000	
Country	**Q**	**V**	**Q**	**V**	**Q**	**V**	**Q**	**V**
Hong Kong (China)	-	-	-	-	1	5 663	-	-
Indonesia	-	-	13	24 676	17	52 693	23	66 841
Japan	-	-	-	-	-	-	-	-
Philippines	0.04	40	-	-	-	-	-	-
Singapore	-	-	-	-	-	-		
China PR	-	-	-	-	4	6441	9	23 707
Others	0.16	11 433	-	-	-	-		
Total	**0.20**	**11 473**	**18**	**30 727**	**26**	**127 260**	**32**	**90 548**

	2001		2002		Jan-Jun 2003	
Country	**Q**	**V**	**Q**	**V**	**Q**	**V**
Hong Kong (China)	-	-	-	-	-	-
Indonesia	1	17 566	0.2	5 376	1	11 595
Japan	-	-	-	-	-	-
Philippines	-	-	-	-	16	57 563
Singapore						
China PR	-	-	-	-	-	-
Others						
Total	**1**	**17 566**	**0.2**	**5 376**	**17**	**69 158**

Source: MATRADE, Ministry of Trade and Industry, Malaysia.

Table 8C. Malaysia: Exports of beche-de-mer (live/fresh/chilled/frozen), 1997 – Jan-June 2003 (Q=tonnes; V=RM).

	1997		1998		1999		2000	
Country	**Q**	**V**	**Q**	**V**	**Q**	**V**	**Q**	**V**
Brunei	-	-	-	-	-	-	-	-
Singapore	-	-	0.3	1 400	4	30 366	3	38 625
Hong Kong (China)							1	19 500
Total	**-**	**-**	**0.3**	**11 400**	**11**	**72 969**	**4**	**58 125**

	2001		2002		Jan-June 2003	
Country	**Q**	**V**	**Q**	**V**	**Q**	**V**
Brunei	-	-	-	-	-	-
Singapore	-	-	-	-	-	-
Hong Kong (China)	8	154 208	12	221 503	-	-
Total	**8**	**154 208**	**12**	**221 503**	**-**	**-**

Source: MATRADE, Ministry of Trade and Industry, Malaysia.

Table 8D. Malaysia: Exports of dried beche-de-mer, 1997 – Jan-June 2003 (Q=tonnes; V=RM).

	1997		1998		1999		2000	
Country	**Q**	**V**	**Q**	**V**	**Q**	**V**	**Q**	**V**
Brunei	0.48	28 050	-	-	-	-	0.05	9 000
Hong Kong (China)	7	134 200	15	268 280	13	234 872	82	1 378 602
Singapore	14	189 838	39	343 120	34	227 774	71	654 521
Taiwan PC	1	5 100	32	238 161	79	670 557	1	16 208
Thailand	-	-	-	-	3	20 384	-	-
Others			49	338 070	131	1 461 342		
Total	**25**	**376 499**	**136**	**1 190 931**	**260**	**2 614 929**	**181**	**2 361 856**

	2001		2002		Jan-June 2003	
	Q	**V**	**Q**	**V**	**Q**	**V**
Brunei	-	-	0.3	30 882	-	258
Hong Kong (China)	100	1 900 286	74	1 386 411	3	311
Singapore	47	745 184	36	454 261	16	226 798
Taiwan PC	18	175 647	67	511 562	46	320 309
Thailand	-	-	11	71 220	-	-
Others						
Total	**403**	**4 874 554**	**312**	**3 496 130**	**178**	**2 546 178**

Source: MATRADE, Ministry of Trade and Industry, Malaysia.

Local consumption is related to the festive season and occasions (weddings, birthdays, etc.) due to the price factor. Households buy processed/soaked products particularly during the Chinese New Year for the family dinner. These are sold at traditional wet markets, some supermarkets and also at Chinese wholesale shops which sell other dried fishery products and Chinese herbs.

In Malaysia the import and domestic markets are dominated by Chinese traders.

Other Markets

Sea cucumber is relatively less popular in Japan, Korea Rep. and other Southeast Asian countries. In Japan, sea cucumber is not a preferred species. Thus the annual import is limited to 3-4 tonnes of frozen and dried products.

Korea Rep. imports 15-20 tonnes of dried sea cucumber annually and the preferred species are *curryfish* imported from Singapore, China Hong Kong SAR and Taiwan PC. However, the market demands premium quality products.

In Thailand, preference for sea cucumber again is limited to the tourism industry. The Thai people seldom like this species.

In the western markets, namely the USA, Canada, the United Kingdom, France, Belgium, etc., sea cucumber is imported for the ethnic Chinese population living in these countries. However, it is popular or used mostly by the elderly and middle aged people. Sea cucumber does not have much appeal to the younger Chinese generation living in these countries. Thus consumption in general is declining.

Product preference and price trends

In terms of market preference and commercial value, sea cucumber species are classified into four categories:

- High value: Sandfish, white teatfish, black teatfish, prickly red teatfish (coldwater).
- Medium value: Stonefish, Surf redfish (good quality), greenfish (good quality), curryfish.
- Lower medium value: Deep water redfish, surf redfish, blackfish, greenfish.
- Low value: Brown sandfish, lollyfish, pinkfish, elephant trunkfish, amberfish, tigerfish.

Due to the large market size and varied purchasing power, China PR imports a wide variety of sea cucumber. However, the mainland Chinese market is increasingly demanding good quality products irrespective of the species and consumers are willing to pay better prices for quality products.

Consumers in China Hong Kong SAR have preference for good quality sea cucumber as for those in the southern provinces of mainland. China Hong Kong SAR imports all sizes and species, but the local market generally takes large and medium sizes products. The remaining is re-exported, mostly to China PR. High value best quality species are sold through retail specialty shops in consumer packs. During the Chinese New Year, expensive gift packs of sea cucumber are exchanged by the rich class and large Chinese companies.

For the Taiwanese, the coldwater species are the most preferred, as market preference is more for large size spiky sea cucumber. Taiwanese consumers are extremely quality conscious, hence the market demands high quality products.

Singaporeans' preference for sea cucumber is slightly different to those in other Chinese markets. Good quality smoked, cleaned, dried sandfish is the preferred species; retailers are the main outlets for this product and households are the main user of this product type. Consumers in Singapore do not like calcium coated sea cucumber. Reprocessed wet products are sold to local markets in insulated boxes using medium quality and low quality products.

The Malaysian market imports medium quality and medium size sandfish and teatfish for local Chinese consumers. Relatively good quality processed products are available in Chinese specialty shops; local supermarkets sell smaller size wet (processed) products, whereas the traditional wet market sells low grade products.

Price trends

Prices of dried sea cucumber in the international (Table 11) as well as domestic markets vary according to the species (high, medium and low value), sizes and quality of the species. While *sandfish* fetches the highest prices, the lowest are offered for *lollyfish.*

Over the decade the ranking of the species has also changed. Some medium value species have moved to the category of high value species as supplies of *sandfish*, the traditional high value species, are getting scarce due to low supplies.

Table 11. *Prices of sea cucumber in the international market, October 2003.*

Products	US$/kg	Market	Origin
White teatfish, skin-on, 3-5 pc/kg			
Holothuria fuscogilva			
- Grade-A	23.00	c&f South East Asian Ports	South Pacific
- Grade-B	13.00	c&f South East Asian Ports	South Pacific
Prickly Redfish, 6-15 pc/kg			
Thelenota ananas	15.00	c&f South East Asian Ports	South Pacific
Black teatfish, 3-5 pc/kg			
- Grade-A	18.00	c&f South East Asian Ports	Australia
- Grade-B	10.00	c&f South East Asian Ports	Australia
Stonefish	18.00	c&f Singapore	Indonesia
Sandfish, Grade A	48.00	c&f Singapore	Indonesia
10-30 pc/kg	56.00	c&f Singapore	South Pacific
15-40 pc/kg	40.00	c&f Singapore	South Pacific
Greenfish 50-120 pc/kg	25.00	c&f Singapore	South Pacific
Stichopus chloronotus			
Surf Redfish, 15-35 pc/kg	11.00	c&f Singapore	South Pacific
Actinopyga mauritiana			
Tigerfish, 25-55 pc/kg	3.00	c&f Singapore	South Pacific
Brown Sandfish, 25-110 pc/kg	5.00	c&f Singapore	South Pacific
Bohadschia marmorata			
Curryfish	19.00	c&f Singapore	South Pacific
Stichopus hermanni			
Elephant Trunkfish, 3-8 pc/kg	5.00	c&f Singapore	South Pacific
Lollyfish	1.50	c&f Singapore	South Pacific

Source: INFOFISH Trade News, 1 October 2003.

In the China Hong Kong SAR market (Table 12), the average import prices of Australian origin sea cucumber have been the highest in recent years due to the species and quality factor. A similar trend is also observed for the sea cucumber originating from Pacific countries.

The China Hong Kong SAR market also controls international market prices of sea cucumber. However, quality is the main factor that determines prices of sea cucumber in general.

Outside China PR the difference between the import and retail prices varies widely for all categories of sea cucumber. For example, in the Malaysian market the retail price of quality dried sandfish is around US$ 110/kg. The retail price of processed frozen wet sea cucumber is US$ 23-24/kg.

A similar trend is also noticed in the other markets in Asia.

Table 12. Hong Kong: Average import prices of sea cucumber, 2001-January/June 2003 (US$/kg).

Country	2001	2002	January-June 2003
Australia	28.05	30.25	41.62
Indonesia	4.12	4.07	4.02
Papua New Guinea	9.73	13.27	14.34
Philippines	6.85	6.45	7.23
Singapore	9.54	9.97	6.86
Sri Lanka	7.36	7.48	6.39
Madagascar	11.10	7.55	5.08
South Africa	4.28	2.50	2.20
Mozambique	28.21	11.46	9.94
Tanzania	10.71	7.61	5.17
Fiji	10.11	10.02	7.41
Solomon Islands	7.35	6.19	4.41
India	25.86	22.82	-
Maldives	7.19	3.64	5.54

Source: Agriculture, Fisheries and Conservation Dept., China Hong Kong SAR.

Conclusion

- In the international trade for seafood, sea cucumber is regarded as a specialty product. While supplies of these species are coming from many parts of the world, the market is dominated by China PR and China Hong Kong SAR on the trading side.
- Global supplies of sea cucumber have declined over the years mostly due to the over exploitation of resources in many countries. On the other hand, the opening of the largest market, China PR, has contributed to an increasing demand for these species. New supplies are showing up from Africa and the Middle East, but the quality and quantity of these supplies are not able to match the demand which is steadily growing in China PR.
- Consumers in China PR nowadays demand an increasing volume of quality products. However, currently the availability of a wide variety of seafood on the Chinese market has taken away the focus on sea cucumber. Therefore, sea cucumber is not in the list of top choices for seafood. Nonetheless, demand for these species has increased in medium and lower income groups in the recent years. Cheaper restaurants in China PR nowadays prepare sea cucumber based dishes. These dishes used to be reserved for the expert chefs in high priced restaurants.
- Demand for sea cucumber in other traditional Asian markets is shrinking as the average Chinese family size is becoming smaller. Being an expensive product, consumption of sea cucumber is linked with the socio-economic situation and consumer`s disposable income.
- Consumption of sea cucumber in western countries, where the niche markets exist, is also showing a declining trend as the younger generation has less interest in this seafood product.
- In the international trading for sea cucumber, China Hong Kong SAR will continue to play an important role. Most of the low volume exporters find it difficult to sell these products directly to China PR as consignments are usually small.

- Moreover, if the proposed free trade arrangement between China Hong Kong SAR and the mainland takes place, more seafood including sea cucumber will be imported into China PR through China Hong Kong SAR.
- Strong ethnic linkage in Asia will continue to support the intra-regional trade for sea cucumber in the coming years. Free flow of trade between the ASEAN nations will allow more trading between Indonesia (a producing country), Singapore, Malaysia, Thailand and Myanmar, irrespective of the market size.
- Product quality is the factor that needs urgent attention in sea cucumber producing countries. A major share of sea cucumber exports from many developing producing countries consist of low quality, under sized products. As a result, the products fail to fetch higher prices in the international market. On the other hand, resources are becoming depleted which also affects the livelihood of fishermen in producing countries.
- Improved post harvest handling and processing and creation of awareness on market requirements for good quality sea cucumber will alleviate the problem of resource depletion to a great extent. It will also increase fishermen's income generated from these species.

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From the sea to the market place: an examination of the issues, problems and opportunities in unravelling the complexities of sea cucumber fisheries and trade

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Abstract

This paper, using available published information and an exploratory questionnaire, presents the difficulties associated with the collation of official statistics on sea cucumber catch, effort and trade. It 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.

Keywords: Holothurians, beche-de-mer, marine resource management, conservation

从海洋到市场：对解决海参捕捞业和贸易复杂性的争论、问题和选择的审查

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摘要

本文利用已公开出版的资料和问卷调查相结合的方法，将所得到的海参捕捞、加工和贸易相关的数据与官方统计数据进行核对，结果发现不少困难。其主要难点有：渔获物渔场的确定、渔获物非法上岸和交易、跨国影响、分类问题、混淆不清的海参类别，监测的不力，国际、国内对此未于重视和资金不足等。本文对这些问题一一予以清晰的描述，并对解决这些问题的可能的方法进行了分析。

关键词：海参、海洋资源管理、资源保护

Introduction

More and more in recent years, concern is being expressed at the health of worldwide sea cucumber populations and their management and trade (e.g. Bruckner *et al*., 2003). In this report, the author explores the problems and issues that have contributed to the current situation. Information was compiled from relevant, available literature, and is supported by the results of an international questionnaire exercise. The questionnaire sought the views and opinions of members of the Beche-de-mer Special Interest Group, co-ordinated through the Secretariat of the Pacific Community, on the following main questions related to their country's sea cucumber fisheries:

- Do official statistics, in your opinion, accurately reflect the level of catch and effort that is taking place in this country/island?
- Are you aware of illegal sea cucumber fisheries and trade activities?
- Are you confident that sea cucumber landings originated from this country's waters? (Name the possible origin of sea cucumbers landed in this country/island but not caught in its waters).
- How is beche-de-mer categorised in official fisheries and trade statistics?

- Are sea cucumber landings monitored regularly?
- Is a high level of priority placed on sea cucumber fisheries by government, in terms of manpower and funds (for monitoring, research and industry development)?
- What do you consider to be the main problems facing this country/island in terms of sea cucumber fisheries management?

The author stresses that this was not a thorough questionnaire exercise, but merely sought to provide information on specific aspects of sea cucumber fisheries in different countries. Of the representatives contacted for 35 islands and countries (or internal states), 20 (57 %) replied. Each representative had a recorded interest in sea cucumbers. These included representatives from Argentina, American Samoa, Brazil, the Cook Islands, China, Northern Mariana Islands, Malaysia, Marshall Islands, Nauru, Viet Nam, Papua New Guinea, Philippines, Solomon Islands, Indonesia, New Caledonia, Ecuador, Kiribati, Cuba and Western and Northern Australia. The Cook Islands, Northern Mariana and Marshall Islands' groups reported no organised fishery but only some evidence of subsistence fishing, as did American Samoa and Brazil. Argentina and Nauru reported no subsistence or commercial fishing activities. Representatives from other countries did not respond, one possible explanation being that contact details for the Special Interest Group require updating.

The holothurian resource

The Class Holothuroidea consists of around 1 200 species in total (FAO, 1990). Of these, the number of species thought to be subject to exploitation has risen over the past 10 years from 12 (Conand and Byrne, 1993) to over 30 (Bruckner *et al*., 2003; Conand, 1999), the latter identified as belonging to 3 families and 8 genera in total from the orders Dendrochirotida and Aspidochirotida. The highest diversity of holothurians occurs in the tropics where multi-species fisheries exist. Table 1 provides a snapshot of known target species, based on responses from the questionnaire exercise. This is not a definitive list.

Table 1. *Target species, by country, identified by respondents to the questionnaire exercise.*

Country	Holothuria scabra	H. scabra (var. versicolor)	H. edulis	H. nobilis	H. coluber	H. atra	H. leucospilota	H. fuscopunctata	H. fuscogilva	H. grisea	Actinopyga miliaris	A. echinites	A. lecanora	A. mauritiana	Thelenota ananas	T. anax	Stichopus chloronotus	S. hermanni	S. horrens	S. fuscus	A. japonicus	Bohadschia vitensis	B. argus	B. graeffei	B. marmorata	Isostichopus badiomotus
Australia																										
- Western	x			x																						
- Northern	x																									
China PR																					x					
Cook Islands						x	x							x			x		x							
Cuba																										x
Ecuador (Galapagos)																				x						
Indonesia	x		x	x	x	x	x	x	x						x	x	x					x				
Kiribati	x			x				x	x		x			x	x	x	x		x			x	x			
Malaysia (Sabah)	x			x		x									x	x	x		x							
Marshall Islands															x	x										
New Caledonia (NP)	x			x				x			x			x	x		x									
N Mariana Islands				x										x												
Papua New Guinea	x		x	x		x	x	x	x		x	x	x	x	x	x	x	x				x	x	x		
Philippines	x		x	x		x	x	x	x			x		x		x	x	x	x				x	x		
Solomon Islands	x	x	x	x	x			x	x	x	x	x	x	x	x	x	x	x	x			x	x	x	x	
Viet Nam	x																									

Despite this increase in economic importance and growing concern about their overexploitation in many countries (Baine and Choo, 1999; Conand *et al.*, 1998; Ibarra and Soberon, 2002; Moore, 1998; Schoppe, 2000; Trianni, 2002), the population biology and ecology of many holothurian species remains unclear. Conand (1999) notes the need for research to focus on biology and ecology, and economics and management. Samyn (2000) calls for the following improvements in our basic scientific understanding of holothurians, based on experience in Kenya, in order to fully optimise conservation and management plans:

- correct nomenclature and taxonomy;
- systematics, including the relationships between lineages and biogeographical distributions, and thus ecological roles;
- holothurian biodiversity in narrow political areas and broader zoogeographical provinces; and
- ecological interactions.

Bruckner (2003) notes the inadequacy of existing biological information on exploited species in most fisheries. Even in those countries with regulated fisheries, information on growth, recruitment and mortality is scant, except perhaps for high value species. The lack of such information seriously impedes the determination of sustainable yields. Furthermore, the lack of any detailed biological data, including biomass estimates and distribution, undermines the ability to measure the effectiveness of voluntary or imposed management measures, and in the absence of scientific justification, may also breed mistrust and contempt among fishers.

Capture, processing and trade

Holothurians are consumed in a variety of ways, however, the most significant product is the dried body wall, commonly known as beche-de-mer. This form is particularly favoured by Chinese consumers. Species can be regarded as high, medium or low value with respect to their market demand and processed condition. High value species presently include the sandfish (*Holothuria scabra*), the black teatfish (*H. nobilis*) and the white teatfish (*H. fuscogilva*).

A variety of fishing techniques exist, including hand collection at low tide, scuba and hookah in deeper waters and trawling and spearing. Processing methods are well documented (e.g. SPC, 1994) and can vary for different species and in different regions. Processing may be carried out by the fishers themselves or by dedicated processors who may also export to international markets such as Hong Kong SAR (China), Singapore and Taiwan (Province of China). Fishers may also sell to processors who then sell to exporters. Beche-de-mer is then exported to consumer countries. This valued product may also be sold within the country of origin, depending on consumer demand. Conand and Byrne (1993) and Conand (2001) describe the complexity of routes between fisher and consumer as consisting of at least 5 levels, with numerous interactions occurring between each level. These levels are identified as:

(1) the natural resource and its environment;

(2) capture by fisherman;

(3) processor/exporter/customs;

(4) international trader; and

(5) consumer.

It is not uncommon for a country to simultaneously have a fishery, and also be exporting, importing and consuming beche-de-mer, e.g. Malaysia (Baine and Choo, 1999).

It is this complexity and array of possible interactions that makes it difficult to assess the status of a fishery. Conand and Byrne (1993) and Conand (2001) for each of their identified levels of interaction, offer potential sources of statistics. These are:

(1) scientific surveys;

(2) sampling of the catch;

(3) sampling of processed products and/or national export statistics;

(4) international trade statistics; and

(5) national import statistics.

Unfortunately, the presence of accurate and reliable statistics is a problem for most holothurian fisheries, a problem magnified by the previously mentioned inadequacy of biological studies. Where statistics do exist, they may also be erratic, confusing or have a dubious origin, such as the contrast within national and between national and international statistics for Malaysia (Baine and Choo, 1999). Tuwo and Conand (1992) note discrepancies in international statistics for Indonesia. Kinch (2002) recognises differences between production and export data in export figures for Papua New Guinea. Possible reasons cited in this instance include incomplete datasets, point of export not always equating to harvest point, and the lack of recordings of wastage. Abdulla (1998) notes the unreliability of statistics in Mozambique, while Holland (1994) highlights the lack of official data in the Solomon Islands. These are only some examples.

Table 2 shows information recorded from the questionnaire exercise, related to official statistics. Multiple entries against a country/island represent responses from different sources within that country/island. As can be seen there is a division of opinion on the accuracy of official statistics in the Philippines. Problems highlighted include non-declaration of fishing activities, lack of regulation, small operational fisheries, unrecorded catches and lack of statistics for domestic distribution of catch. Overall, official statistics are reported as representing between 50-100 % of total catch, depending on location.

Table 2. *Comments on official statistics provided by respondents to the questionnaire exercise.*

Country	Do official statistics accurately reflect the level of catch and effort?		Estimated percentage of overall catch
Australia (Northern)	Y		
China PR	N	No fisheries statistics. Landings data collected for aquaculture.	50%
Cook Islands	N	No statistics. Unregulated fishery.	N/A
Cuba	Y		
Ecuador (Galapagos)	Y	Isolated cases of illegal harvest.	95%
Indonesia*	N		50%
	N		<50%
	N		-
Kiribati	Y	Fishermen's data cross-checked with customs.	80%
Malaysia	N	Substantial catch goes unrecorded.	Unknown
N. Caledonia (NP)	N	Do not declare their activities. Not registered as professionals.	N/A
N Mariana Islands	Y	Export permit conditions.	100%
Papua New Guinea	Y	All exporters are licensed with provision of monthly buying summaries. Difficult to estimate fishing effort.	99%
Philippines	Y		
	N	Statistics mainly based on export volume. None for domestic.	60%
Solomon Islands	Y		95-100%
Viet Nam	N	No statistics. Small production.	Unknown

* *Multiple entries against a country/island represent responses from different sources within that country/island.*

A particular problem highlighted by Baine and Choo (1999) for Malaysia is the categorisation of sea cucumber products. National statistics show 2 categories, firstly "live, fresh, chilled or frozen" and secondly "dried, salted, in brine, smoked or boiled" against which tonnage is recorded. There is no separation, for example, between dried and salted, nor is there division into species. Such statistics cannot be used to influence management decisions as there is no way to accurately predict catch quantity or weight for individual species. Similar problems in terms of categorisation have been reported in the Northern Mariana Islands (Trianni, 2002), New Zealand, where sea cucumbers have been grouped together with sea urchins (Morgan and Archer, 1999), and Vanuatu (Jimmy, 1996). Table 3 indicates the different categories that are used to classify beche-de-mer in the countries of respondents to the questionnaire exercise. Caution is advised when interpreting this table as respondents from within the Philippines and Indonesia have provided different answers to the question posed. The author also notes that the question is not precise enough, with the definition of "official" open for interpretation.

A further problem within Malaysia is the inability to confidently identify the origin of catch. It is commonly known that exports from Sabah may include holothurians harvested in the waters of the Philippines (Baine and Choo, 1999). Another serious issue is the transboundary effects of a demand for sea cucumber products on Pulau Langkawi, Malaysia. Overfishing in the waters of this island has led to demand being met by fishermen from the neighbouring island of Adang in Thailand. Unfortunately, this supply of sea cucumber has meant illegal encroachment of Thai fishermen on internal marine reserve waters (Bussarawit and Thongtham, 1999).

The questionnaire exercise, however, indicates that this may not be a widespread problem. When asked about their confidence in the origin of sea cucumber catches, respondents from Viet Nam, Kiribati, Northern Mariana Islands, Ecuador, Philippines, Indonesia, Cuba, Solomon Islands and Australia all answered that landings originated from within their country's waters. Some possible exceptions include landings in Indonesia of sea cucumbers from Australia, Papua New Guinea and the Philippines. The Philippines representative also reported the possibility of Malaysian holothurians being landed in the Philippines. The only outright negative response to the question concerned New Caledonia where the respondent had no confidence in catches occurring solely within its waters, although other possible countries of origin were not suggested.

Table 3. *Beche-de-mer classifications provided by respondents to the questionnaire exercise.*

Country	How is beche-de-mer categorised in official statistics?
Australia (Northern)	Just a total catch figure.
China PR	*Apostichopus japonicus*
Cook Islands	N/A
Cuba	Other resources.
Indonesia	Other (volume and value).
	Trepang (tonnes).
	Trepang.
Kiribati	Other dried products (under their own name).
Malaysia (Sabah)	Dry, processed body covering.
N. Caledonia (NP)	Beche-de-mer (invertebrates).
N. Mariana Islands	Sea cucumber.
Philippines	Trepang, frozen, dried, salted/in brine.
	"Exported seafood products" or "sea cucumber".
Solomon Islands	Sometimes to the species level.
Viet Nam	N/A

Illegal Fishing

Illegal sea cucumber fishing is not a prolific problem in countries with this resource. However, being such a lucrative market, it has caused major problems in certain areas. Historically, the Galapagos Marine Reserve in Ecuador has suffered high levels of illegal fishing, coinciding with increased migration to the islands. Fishers have been provided with boats and motors financed by mainland and foreign traders (Martinez, 2001; Noble, 2001). The impetus to fish has been high and violent clashes with the Galapagos National Park Service have occurred in the past. Illegal fishing has also been recorded in Madagascar (Irwing, 1994), Malaysia (Baine and Choo, 1999), Mexico (Ibarra and Soberon, 2002), Papua New Guinea (Kinch, 2002) and Venezuela (Rodriguez and Marques Pauls, 1996). The questionnaire exercise (Table 4) additionally identifies illegal activities in New Caledonia, Viet Nam, the Philippines, Indonesia, the Marshall Islands and Brazil as well as confirming such activities in Malaysia and Papua New Guinea. Equally, illegal fishing is not thought to occur in the Cook Islands, Kiribati, China PR, Ecuador (at present), and the Northern Territory of Australia.

Table 4. *Information on illegal fishing supplied by respondents to the questionnaire exercise.*

Country	Are you aware of illegal sea-cucumber fisheries and trade activities?	
Australia (Northern)	N	
Brazil	Y	Some private collection and consumption (Japanese).
China PR	N	
Cook Islands	N	Suspicion that an opportunistic fishery may exist from transient fishermen.
Cuba	N	
Ecuador (Galapagos)	N	Not at present.
Indonesia	Y	Indonesian fishermen fish in Australian waters.
	Y	Fishing in foreign waters, smuggling pout of the country, deliberate under reporting.
Kiribati	N	Amount exported is not high.
Malaysia	Y	Especially not sparing spawning and immature individuals.
Marshall Islands	Y	Occurs on some atolls although species remain abundant.
N. Caledonia (NP)	Y	Fishermen do not declare their activities. No regulation of trade.
N. Mariana Islands	Y	Some personal use despite moratorium.
Papua New Guinea	Y	Mainly through one vessel in a remote area of the country.
Philippines	N	No clear regulations so no illegal fishing. Fishers do illegally fish Malaysian waters.
	Y	Illegal fishing by trawl and some probable illegal exports.
Solomon Islands	N	All exporters are licensed – no limit on tonnes exported.
Viet Nam	Y	Regulation needed.

Management, Monitoring and Prioritisation

Adams (1993) presents South Pacific Commission (SPC) recommendations regarding the management of individual South Pacific holothurian fisheries. These recommendations are suggested by Adams (1993) as a basis for possible general principles for beche-de-mer fisheries management. The following list takes these recommendations and presents them in general terms:

- Undertake baseline surveys, where possible; establish permanent population survey sites; establish monitoring programmes to collect data on fisheries and exports;
- Encourage communities in the regulation of their fisheries; provide exclusive rights to local fishers;
- Limit entry to fisheries; reduce fishing effort on overfished areas; suspend fishing and export activities to allow recovery of resources; suspend harvesting during breeding seasons; rotational harvesting; provide closed seasons; establish marine reserves for the provision of broodstock; discourage, and possibly prohibit, night fishing for nocturnal species;
- Prohibit SCUBA diving and hookah to alleviate pressure on deeper water spawning stocks; implement minimum size limits (MSLs) to prevent early removal of potential spawning stock; consider quotas as a management measure to encourage selective harvesting of larger, more valuable specimens;

- Restriction of number of export businesses and introduction of export quotas;
- Education and instruction in improved processing techniques; and
- Establishment of sea ranching programmes.

Table 5 summarises the types of management tools that have been employed in some sea cucumber fisheries. This list does not represent current management regimes but merely gives an indication of the range of options that have been historically applied in different countries. More common measures relate to closures, quotas and export restrictions. As can be seen, a variety of management options have been employed in different combinations, or at different times. This is a common in many fisheries. In Papua New Guinea, for example, under the National beche-de-mer Fishery Management Plan, there is a combination of access restrictions, closures, Total Allowable Catches (TACs), Minimum Size Limits (MSLs) for 17 species, and storage and export licences (Desurmont, 2003). On the other hand, the only regulations reported for New Caledonia are self imposed by fishers and include harvesting seasons and size limits (Anon, 1993). It should also be noted that 30 % of the countries in Table 5 have reported no regulations.

When reviewing available information on holothurian fisheries, however, there are a number of readily identifiable general issues that should concern us:

- There are many countries that have no regulations in place or if they do, a lack of funds and manpower for monitoring and enforcement is seen as a common problem (Adams, 1992; Baine and Choo, 1999; Jimmy, 1996, Martinez, 2001; Trianni, 2002);
- There is little in the literature that provides information on the success or failure of management initiatives, mainly as a result of relatively recent imposition of regulations and management measures and the lack of any baseline data for comparison;
- Many of the problems discussed earlier, such as the lack of basic ecological information, lack of education and awareness programmes, combined records of species caught and uncertainty as to the origin of catch (Baine and Choo, 1999; Rasolofonirina and Conand, 1998; Samyn, 2000), all impede the adoption of effective management tools;
- The growing economic importance of this resource and resulting community dependencies will affect acceptance and adherence to regulations and lead to internal disputes e.g. over territory (Kinch, 2002; Martinez, 2001); and
- Each fishery has different characteristics and there is potentially little to learn from monitoring the imposition of regulations in another fishery.

In more direct terms the following are offered as main causes for concern in many holothurian fisheries:

1. Information on holothurian biology and ecology is lacking, as are basic stock assessments;
2. Holothurian products are in high demand, with holothurian fisheries potentially quite lucrative to fishers, particularly in the provision of stable livelihoods;
3. Holothurian fisheries and trade routes are complex and existing statistics do not inspire confidence when trying to estimate catches;
4. Management in most instances has been reactive to dwindling stocks presumably because of overfishing, with associated difficulties in measuring the effectiveness of management measures;
5. Enforcement of regulations and monitoring is a problem particularly in areas which are geographically isolated and in countries lacking financial and human resources; and
6. There is a lack of education and awareness programmes.

There have perhaps been two major consequences in the past decade as a result of these main problems and the slow progress in addressing them. Firstly, there has been increased interest in holothurian rearing and restocking, in an attempt to perhaps deflect effort away from wild resources in the future and/or to mediate for the social impact of dwindling wild resources. Secondly, CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) has become involved.

Table 5. *Management tools employed in sea cucumber fisheries, by country (and source).*

Country	Closure, area limitation	Gear limitation	Quota or TAC	Limited access, permits	Export permits	Size limits	Export restrictions	Closed seasons	Storage licences	Voluntary	No management	Source
Australia	x	x	x	x								Beumer 1992; Uthicke and Benzie 2000
Ecuador	x		x					x				Martinez 2001
Fiji						x	x					Adams 1992
Indonesia											x	Bruckner et al. 2002
Kenya											x	Samyn 2000
Madagascar											x	Irwing 1994
Malaysia											x	Baine and Choo 1999;
Mexico	x					x		x				Castro 1995
Mozambique	x											Abdulla 1998
N. Caledonia										x		Anon 1993
N. Zealand			x									Morgan and Archer 1999
N. Mariana Is.	x				x		x					Trianni 2002
PN Guinea	x	x	x	x	x	x	x	x	x			Desurmont 2003; Kinch 2002
Solomon Is.										x		Holland 1994
Thailand											x	Bussarawit and Thongtham 1999
Tonga		x				x	x	x				Anon 1996
Tuvalu											x	Belhadjali 1997
USA			x									Bradbury 1997; Woodby and Larson 1996
Vanuatu			x				x					Jimmy 1996
Venezuela				x								Rodriguez and Marques Pauls 1996

Table 6 summarises the main problems facing holothurian fisheries, as identified by questionnaire respondents for their respective countries. These are many and varied, ranging from a lack of basic information, limited funds and lack of education to illegal fishing, overexploitation and political bureaucracy.

Tables 7 and 8 provide details from the questionnaire exercise on monitoring and prioritisation of holothurian fisheries within respondents' countries. As can be seen, no monitoring exists in new Caledonia, the Cook Islands, Viet Nam, Kiribati, the Philippines, Indonesia and the Northern Territory of Australia. Where monitoring does occur it relates to administration in the Solomon Islands, purchase and export in Papua New Guinea, catch rates in Western Australia and conservation zones in China PR. It is only in the Galapagos where a comprehensive "from sea to the market place" monitoring regime exists. In terms of prioritisation of holothurian fisheries within these countries, a high level of support is only provided in the Galapagos Islands, Papua New Guinea, Kiribati, Cuba and China PR. In China PR this relates mainly to aquaculture and sea ranching. It is worth noting that in Northern Australia, industry funds stock assessment and monitoring.

Table 6. Management problems identified by respondents to the questionnaire exercise.

Country	What do you consider to be the main problems facing the country/island in terms of sea cucumber fisheries management?
Australia (Northern)	Are current levels sustainable? -Are other fishing methods available? -Aspirations of the local indigenous people to be involved in the fishery.
China PR	Lack of education on farming and ranching techniques.
Cook Islands	Not recovered from historical overfishing. Unlikely in the future.
Cuba	Logistical support for the development of a stable fishery.
Ecuador (Galapagos)	Diminished resource, fishermen used to a lucrative, quick profit industry. Economic problems in Ecuador.
Indonesia	Overfishing.
	Lack of regulations and reliable data, Poor safety record and unscrupulous exploitation of fishermen, Overfishing, lack of awareness and access to knowledge, Illegal practices.
	Poverty, limited knowledge and trading system trap.
Kiribati	Hard to locate releases into the wild after reseeding.
Malaysia (Sabah)	Catch regulations and enforcement. Failure to recognise importance of stock enhancement and sea ranching.
N. Caledonia (NP)	Lack of information on landings, effort, catch origin, CPUE, density and biomass.
N. Mariana Islands	Lure of money and politics.
Papua New Guinea	Buying mainly by non-licensees (middlemen) who in most cases do not provide catch data.
Philippines	Cross border activities e.g. Philippines and Malaysia.
	Overexploitation, resource management politics, R&D only began in 2000.
Solomon Islands	Lack of financial and technical input.
Viet Nam	Overexploitation. Limited funds.

Table 7. Information on monitoring supplied by respondents to the questionnaire exercise.

Country	Are sea cucumber landings monitored regularly?	
Australia (Northern)	N	
Australia (Western)	Y	Catch rates monitored but no attention to removals from particular locations.
China PR	Y	In conservation zones.
Cook Islands	N	No commercial landings.
Cuba	Y	
Ecuador (Galapagos)	Y	Onboard vessels, daily at docks, processed product to traders, and airport control.
Indonesia*	N	Annual estimates.
	N	Mostly based on guestimates and extrapolations. Under-reporting?
	N	Middlemen move faster than officials.
Kiribati	N	Only at the point of export.
Malaysia (Sabah)		Unsure.
N. Caledonia (NP)	N	Only once a year based on voluntary declarations.
N. Mariana Islands	Y	
Papua New Guinea	Y	Through the monthly buying summary as well as export documentation.
Philippines	N	
	N	People who should monitor are not there.
Solomon Islands	Y	Only at the time of export for paperwork purposes, not for stock management.
Viet Nam	N	No regulation.

** Multiple entries against a country/island represent responses from different sources within that country/island.*

Table 8. Information on prioritisation supplied by respondents to the questionnaire exercise.

Country	Is a high level of priority placed on sea cucumber fisheries by government in terms of manpower and funds?	
Australia (Northern)	N	Industry funds stock assessment and monitoring.
China PR	Y	Encouraged aquaculture and sea ranching, benefits wild resources.
Cook Islands	N	Occasional surveys on fishery feasibility. Recent proposals declined.
Cuba	Y	
Ecuador (Galapagos)	Y	Sea cucumber fishery control plan.
Indonesia*	N	No priority.
	N	
	N	
Kiribati	Y	Important income generating activity.
Malaysia (Sabah)	N	
N. Caledonia (NP)	N	Only funding of a repopulation programme.
N. Mariana Islands	N	Resource isn't that extensive.
Papua New Guinea	Y	Involves a high number of fishermen.
Philippines	N	Relative to other marine exports.
Solomon Islands	N	No management plan in place.
Viet Nam	N	

** Multiple entries against a country/island represent responses from different sources within that country/island.*

Discussion

As has been discussed throughout this paper there are many problems with the current status and management of holothurian fishery resources. These problems include a lack of information on the population dynamics of exploited species (including taxonomic difficulties), a lack of reliable fishery and trade statistics, illegal activities, a lack of effective regulations, and low state level prioritisation of this resource with associated knock-on effects on monitoring and enforcement. This final problem is one to take particular note of, as many countries do not view holothurians as a high priority resource, despite their ecological role and economic importance to small communities. One must also take into consideration any possible lack of interest from fishers and traders, with considerable evidence of widespread "boom and bust" fishing activities in reaction to current high market demands. This, however, can also be linked to a lack of educational awareness programmes. It is difficult to identify general approaches to the problems facing holothurian fisheries, as each fishery is unique and very dependent upon political factors within specific states.

Over the last two decades, the global exploitation of sea cucumbers has reached such high levels and raised such concern that a United States of America call, with multi-party support, has been made to consider the listing of the families Holothuridae and Stichopodidae in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Bruckner *et al.*, 2003). Following the CITES Conference of Parties (COP12) in November 2002 in Chile, a draft decision was agreed which would look towards bringing experts together in workshops to discuss conservation and biological and trade information. The Animals Committee of CITES would examine the outcomes of these as well as additional material and would develop recommendations and a discussion paper to provide guidance on actions required to secure conservation status (Bruckner, 2003). However one views the input of CITES, be it positively or negatively, be it through the eyes of a conservationist, producer, importer, exporter, consumer, processor or fisher, as a reality and reflects some international concerns at the current status of sea cucumber populations and approaches to their management and trade.

The involvement of CITES is one new approach to the problems facing holothurian resources. It has a true international dimension, and is an approach that needs consideration. An Appendix II classification refers to species that are not necessarily threatened with extinction now, but that may become so unless trade is closely controlled. International trade in Appendix II species may be authorised by the granting of an export permit or re-export certificate. No import permit is necessary. Permits or certificates should only be granted if the relevant authorities are satisfied that certain conditions are met, and that trade will not be detrimental to the survival of the species in the wild.

Such a measure does have its positive aspects, particularly in the provision of an international face to future management and trade in these species. It offers a watchful eye and would promote more international co-operation on sea cucumber fisheries management as well as more effective country, and even fisheries specific, monitoring and control.

There is a need, however, for countries to be willing and able to implement such a listing. There will always be the problem of illegal fishing and trade, but this could also be exacerbated by any CITES classification when viewed suspiciously by members of the beche-de-mer industry. This problem would be exacerbated even further with a lack of state resources to enforce management measures, coupled with political and other socio-economic issues that may be unique to any given state. It is also difficult to see where CITES can help in unravelling the complexities of fisheries and trade in these species.

There is much to be addressed in taking this route. Bruckner *et al.* (2003) identifies a number of general areas that need to be examined when considering the appropriateness of CITES, namely taxonomic uncertainties within the families, the ability to distinguish taxa in the form they are traded, the adequacy of biological information for making non-detriment findings, the ability to make legal acquisition findings and research needs. Each of these has its own extensive array of issues. To follow this route is a considerable undertaking and will require extensive international discussions and co-operation. It may well provide the necessary impetus for stronger action from the scientific community on many of the basic issues underlying holothurian resource management. On the other hand the potential impact on local communities and economies must be thoroughly understood. It will be interesting and informative to observe the progress and impact of the Appendix II listing of *Hippocampus* spp. (seahorses), which comes into effect on 15 May 2004.

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

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Abstract

The sea cucumber fishery 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 exports were recorded in Madagascar in 1920 with about 40 tonnes of trepang from 3 species. Exports varied then annually from 50 to 140 tonnes. Since 1990, harvesting of sea cucumbers greatly increased and resulted in the overexploitation of the resource. The maximum intensity of the export was recorded in 1994 with 540 tonnes of trepang, and then it declined. The number of species collected shifted from eight in 1990 to twenty-eight in 1996. Currently, more than twenty-five species are exploited. The harvested species, however, vary according to the market price, the international demand and their availability. *Holothuria scabra, Holothuria nobilis, Holothuria fuscogilva*, *Thelenota ananas* are the main collected species. Declining exports and strong competition between collectors indicate over-exploitation of the resources and this affects the local economy and the environment. The situation of some fishermen villages in the Toliara province (south-west of Madagascar) is presented. A survey of the production of the main harvested species over one year was performed and the changes in techniques concerning the processing of sea cucumber during the last seven years are exposed. Aquaculture is considered as a solution to solve the problem of sea cucumber over-exploitation. A hatchery has been built in Toliara in 1999/2000 thanks to funds obtained 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 being considered that aims to master the growth process of post-metamorphic sea cucumbers.

Keywords: Sea cucumber, fishery, Madagascar, beche-de-mer processing, mariculture

马达加斯加的海参渔业：马达加斯加西南沿海图莱亚拉的实地调查

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摘要

海参渔业在马达加斯加沿海地区由来已久，尤其在珊瑚礁水域。马达加斯加的海参捕捞渔业主要以家庭渔业或小型渔业为主，产品完全出口到亚洲国家。出口的首次记载是1920年，出口了40吨，有3个海参种类。出口量的年度变化在50-140吨之间。自从1990年开始，海参捕捞量迅速上升，造成了过度捕捞。最高的年产量发生在1994年，达到了540吨，之后，再未达到这一历史记录。捕捞的种类由1990年的8种上升到了1996年的28种。实际的捕捞种类以国际市场的价格、需求量和捕捞量而变。糙海参（*Holothuria scabra*），黑乳参（*Holothuria nobilis*），黄乳参（*Holothuria fuscogilva*），和梅花参（*Thelenota ananas*）是主要捕捞对象。出口量的下降和渔民之间的强烈竞争表明，资源的过度开发已经影响到当地的社会经济和生态环境。本文还介绍了马达加斯加西南沿海的图莱亚拉省（Toliara）某些渔村的状况。对主要渔业对象进行了一年多的生产调查，并介绍了过去7年间海参加工技术的变化。海参养殖的目的是为了解决资源过度开发的问题。于1999/2000年度得到了比利时政府的资助在图莱亚拉建设了第一座海参育苗场。糙海参的幼虫和变态研究已经取得成功，下一步的工作主要是掌握变态后的海参幼体的生长过程。

关键词：海参、渔业、马达加斯加、海参加工、海水养殖

Introduction

Sea urchins and sea cucumbers are echinoderms exploited in Madagascar. Sea urchins are fished for local consumption and sea cucumbers for the preparation of 'trepang' that is exported mostly to Asian markets. Sea cucumber harvesting is a traditional activity in Madagascar (Conand *et al.*, 1997). Since 1920, Hindu people exploited and exported sea cucumbers to Asian countries (Petit, 1930). This activity developed progressively from early nineties. After reaching significant tonnage (nearly 600 tonnes, which represents more than 6 000 tonnes fresh weight) in 1991 and 1994, official trepang exports showed a significant decline (Rafalimanana, 1997). Exports increased again more recently with about 980 tonnes being exported in 2002. The available data, however, are insufficient to diagnose and analyse current over-exploitation. Indeed the fishing sector is quite complex and analysis is needed at different levels (Conand, 1997a, 1997b).

As in other countries, five main levels should be considered in Madagascar (Conand, 1997a): (1) the abundance and diversity of the resource; (2) the harvesting by fishermen; (3) the processing into trepang (which may be carried out by fishermen or other villagers); (4) the number of intermediate levels in the commercial and administrative chain (collectors, operators, exporters, national and regional Governments - Fisheries Departments, Customs, etc.); and (5) the exports of the product to international markets.

In the Toliara region (south-west of Madagascar), the fishery is a traditional activity. Fishermen collect various resources on the reef flat during the low tide, such as shellfish, urchins, octopus and sea cucumbers (Rosa, 1997; Salimo, 1997; Rakotonirina, 2000). The sea cucumber fishery is very intense in the Toliara region and on the west coast of Madagascar. Current signs of over-exploitation are a declining quality, a decrease in product size, the use of illegal material for harvesting (216 diving tanks were seized in 2002 - L'express de Mada, N° 2 379), the strong competition between collectors (Conand *et al.*, 1998), and the exploitation of fishing areas out of Malagasy waters. In May 2001, 110 fishermen were arrested in Seychelles for illegal exploitation of sea cucumbers (Madagascar Magazine, 3 May 2003).

In that context various actions have been undertaken since 1990 by scientists, professional organisations and the government to monitor fishing, fishery organisation, catches and marketing in many coastal villages both in the Toliara province and in the rest of the country. Conand (1998, 2001) reviewed the status of world sea cucumber fisheries in the entire world and gave perspectives for mariculture. Sea cucumber hatchery and culture are practised in some countries, such as Japan, China and India (James, 1994; James *et al.*, 1995).

Material and methods

Studies sites

Madagascar is a large island in the South Indian Ocean region. It is located east of the African Continent (FAO Area 51). The coastal area is 5 603 km long and the exclusive marine economic zone is 1 140 000 km².

Most of the people in the coastal regions are dependent on fishery resources and many regions in the west are surrounded by coral reef where traditional fishing is still very active. Figure 1 shows the main sea cucumber fishing areas.

Identification of the species

Specimens of sea cucumbers from the fishermen or from natural habitats were transported to the Toliara Fisheries and Marine Sciences Institute ('Institut Halieutique et des Sciences Marines') for current identification.

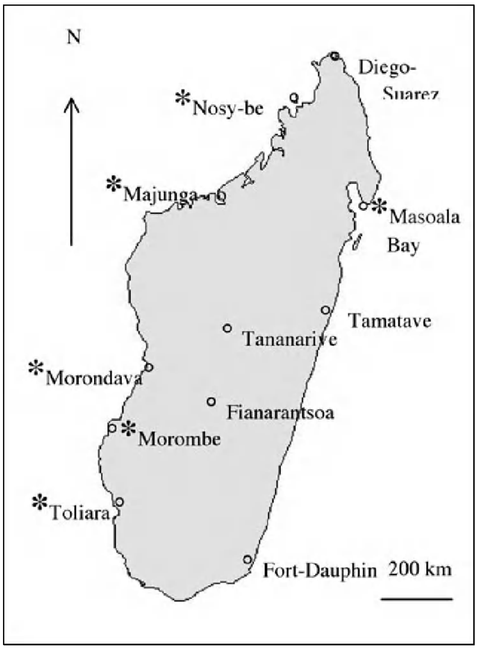

Figure 1. *Sea cucumber fishing areas (*).*

Village survey

The Ankilibe village, near Toliara, was selected for comprehensive monitoring over an eight month period in 1996 and over one year in 2001 (October 2000 to September 2001).

Sea cucumber harvesters were asked daily by an investigator to get information on the total fishing time, the number of working individuals, the fishing sites, etc. Catches were examined before processing, in order to determine the exact species, the number of specimens for each species and the corresponding weights. From these data, average catch sizes and fishing effort on monthly basis, and catch per unit effort (CPUE) could be calculated. These data were also collected by observers appointed in the selected villages.

Investigation to operators and exporters

After harvesting, the products are gathered by collectors in various villages and operators or exporters in the towns. The marketing channel was determined through surveys carried out in various villages and in the city of Toliara. It concerns the different marketable species: their price, the monthly or annual quantity harvested, their origin and destination. It was very difficult to obtain information concerning quantity and price of trepang from exporters because of distrust.

Investigation to administration services

Statistical information concerning the production of trepang was obtained from the Provincial Service of Marines Resources (SPRH) of Toliara, the INSTAT (National Institute of Statistics) and the Statistic Service in Fishing and Marines Resources Office.

Exploitation system and its recent change

Four levels have been taken into account that are: (1) the fisherman (he catches the sea-cucumbers and sells them to the collector); (2) the collector (he buys the sea cucumbers from various fishermen, process them as trepang and sell them to operator); (3) the operator (he buys batches of trepang from various collectors, gathers them together and sell them to the exporter; (4) the exporter (he sends the trepang to overseas markets).

The first exploitation system for sea cucumber in Madagascar was the traditional or familial fishery. Since 1990, the system has changed to an artisanal or semi-industrial fishery. The increase of international demand for trepang, the scarcity of sea cucumbers in shallow waters and the competition between collectors drive the fishermen (and some collectors) to use specialised underwater equipment to explore deeper sea areas off the coastal villages.

Traditional or familial fishery system

It is the only system practised in the Toliara Province. Harvesting is done by a few individuals from a single family. It does not require any particular fishing material or a significant investment. Most of the time, fishermen use a canoe propelled by sail or paddles. For collecting sea cucumbers, they use a jut bag or a bucket and sometimes a diving mask. In some villages located near a fringing reef, fishermen walk on the reef flat at low tide.

In the Toliara region, fishing is mainly performed by foot at low tide on the reef flats. Snorkelling is rather infrequent and occurs only at neap tides. Fishing with diving gear or trawling is not performed in the area, although these techniques are used elsewhere (Rasolofonirina and Conand, 1997). Some family members (or the whole family) go fishing in the morning and come back in the afternoon. They fish in the nearest part of the reef, rather close to their village. In some villages of Toliara, fishermen also practise fishing at night. They go to the reef flat during the spring low tide at full moon and use a torch to find the sea cucumber.

The work is divided up among the members of the family. Usually, the father prepares and sails the boat while all other members take part in the harvesting. The time needed to reach the main reef is comparable for all villages, from 30 to 60 minutes depending on weather conditions. At the fishing site and particularly in the seagrass beds, the families work in groups of two or three and harvest sea cucumbers as well as other reef resources (e.g. octopus, shellfish, crabs). Women are in charge of processing and selling the catch. They sell either the fresh product to a collector from the same village or the processed products to an operator or exporter in town.

Artisanal fishery

The artisanal fishery is performed by using motorised canoes or boats, which have to be registered. This requires some investment. Motorised canoes or boats are equipped with an out- or in-board engine, an autonomous compressor and diving material (diving tank and accessories). Larger boats may be used as floating camp sites, or the fishermen have camping material for land-based camp sites.

Groups of salaried peoples are formed. The number of persons in one exploitation group varies from 3 to 200 depending on the financial power of the manager. He provides material and food, and buys the product (sea cucumbers) by piece from the divers. Harvesting is done by SCUBA diving even though it is illegal - SCUBA diving is very difficult to control. The use of diving tanks has rapidly developed since 1992.

Each fishing boat carries three to eight divers. One man stays onboard both for security reasons and to receive the catch. Each fisher dives two to ten times per day, which represents from four to six hours diving time. After a given period of time (from a few days to several weeks), the groups move towards another site. The divers usually remain onboard or in the camp during the exploitation period.

In short fishing expeditions, the products are immediately processed after fishing when the conditions are adequate (weather, availability of wood for cooking, water and space). Otherwise, sea cucumbers are salted and processed after returning to the village. After processing, the trepang is sent to the nearest port or to Antananarivo, and exported to the international market.

In Toliara, some changes were observed recently in the collection system. A single exporter located in town monopolises the local trepang market. He pays the collectors in advance, the latter consequently not being allowed to sell their products to other operators or exporters. Yet, most of the time, the fishermen of a given village sell their sea cucumber to a village collector. The collector processes the sea cucumbers and sells them to an operator located in town. Collectors often pay the fishermen in advance. This creates strong economic links.

Species exploited and production

Species exploited

About thirty species of commercial sea cucumbers exist in the Toliara region (Table1). While all these species are not collected in the region, the number of harvested species has increased.

About twelve high and medium value species are traditionally harvested, but with the increase in international demand and the dwindling of the resource, fishermen are now collecting other less valuable species (Conand *et al.*, 1997c). More than twenty species are presently collected in the country. From 1920 to 1930, three species only were exported to the Asian market (Petit, 1920). This number increased to eight in 1990 (Rasoarinoro, 1990), and to eighteen in 1995 (Mara *et al.*, 1996). Now, in Toliara, all edible species are being harvested. The actual catches differ according to the price, and their occurrence in the field.

For instance, *Holothuria maculosa* was not exploited before 1996. At that time its price was low (1 500 to 3 000 Fmg/kg) and its abundance very high (60 000 holothurians/ha) (Mara *et al.*, 1997). In 2000, other less valuable species were exploited and the price of *H. maculosa* increased to 6 000 Fmg/kg. Now, that species is intensively exploited and the price reaches as much as 15 000 Fmg/kg. The main species exploited in Toliara are listed in the Table 1 (exploitation at family level).

Table 1. Species of holothurians exploited in the Toliara region.

		Exploitation over the years			
N°	Species identified	1920 (1)	1990 (2)	1996 (3)	2002
	HOLOTHURIIDAE				
1	*Actinopyga echinites* (Jaeger, 1833)		+?	+	+
2	*Actinopyga lecanora* (Jaeger, 1833)			+	+
3	*Actinopyga mauritiana* (Quoy and Gaimard, 1833)		+?	+	+
4	*Actinopyga miliaris* (Quoy and Gaimard, 1833)			+	+
5	*Actinopyga* sp.			+	+
6	*Bohadschia marmorata* (Jaeger, 1833)			+	+
7	*Bohadschia subrubra* (Quoy and Gaimard, 1833)			++	+
8	*Bohadschia tenuissima* (Semper, 1868)			+	+
9	*Bohadschia vitiensis* (Semper, 1867)			+	+
10	*Holothuria scabra* (Jaeger, 1833)		+	+++	+++
11	*Holothuria scabra versicolor* (Conand, 1986)		+	++	++
12	*Holothuria atra* (Jaeger, 1833)			+	+
13	*Holothuria maculosa* (Pearson, 1913)				+++
14	*Holothuria excellens* (Ludwig,1875)			+	+
15	*Holothuria fuscogilva* (Cherbonnier, 1980)		+	++	++
16	*Holothuria nobilis* (Selenka, 1867)		+	++	+
17	*Holothuria edulis* (Lesson, 1830)			+	
18	*Holothuria leucospilota* (Brandt, 1835)			+	
19	*Holothuria cinerascens* (Brandt, 1835)			+	
20	*Holothuria rigida* (Selenka, 1867)				+
21	*Holothuria arenicola* (Semper, 1868)				
22	*Holothuria impatiens* (Forskal, 1775)				+
23	*Pearsonothuria graeffei* (Semper, 1868)			+	+
	STICHOPODIDAE				
24	*Thelenota ananas* (Jaeger, 1833)		+	+	+
25	*Stichopus chloronotus* (Brandt, 1835)			+	+
26	*Stichopus horrens* (Selenka, 1867)			++	++
27	*Stichopus hermanni* (Semper, 1868)	+	+?	++	+
28	*Stichopus* sp.			+	++

Source: (1): Petit, 1920; (2): Rasoarinoro, 1990; (3): Mara et al., 1997 and Rasolofonirina, 1997.

+: *limit harvest;* ++: *harvested;* +++: *highly harvested;* ?: *uncertain level of harvesting.*

For artisanal or semi-industrial fishing, a few species are intensively harvested. These are *Holothuria fuscogilva*, *Holothuria nobilis*, *Thelenota ananas* and *Actinopyga miliaris*.

Fishing Effort

In 1996, the number of fishermen in the region of Toliara was 3 702 with 153 originating from the village of Ankilibe (there were 10 collectors in that village in 1996 and 9 in 2002).

Table 2 indicates the fishing effort in the different investigated villages. In 1996, the highest daily fishing effort was observed in Morombe and Andrevo (117 and 108 fishermen hour/day, respectively). The minimum effort was observed in Androka a place where lobsters fishing is quite active (Mara *et al.*, 1997). In Ankilibe, the monthly effort was estimated to 1 944 fishermen hour/month in 1996; it has increased to 4 382 in 2002, which clearly indicates the intensification of the exploitation.

Table 2. *Mean Fishing Effort at some villages in the Province of Toliara in 1996. (Modified from Mara et al., 1997).*

Villages in Toliara Province	Mean number of harvesting /period (number/month)	Mean number of fishermen (number/day)	Mean harvesting time (hours/day)	Mean Fishing Effort (fishermen hours)	
				per day	per month
Morombe	20	39	3	117	585
Andavadoake	16	9	2	18	288
Lamboara	11	30	2	60	660
Salary Nord	26	10	2	20	520
Andrevo	24	27	4	108	2 592
Ifaty	27	18	2	36	972
Besakoa	13	17	3	51	663
Ankiembe	14	10	3	30	420
Ankilibe (1996)	27	18	4	72	1 944
Ankilibe (2001)	29	38	4	152	4 382
Anakao	13	13	2	26	338
Beheloka	22	14	2	28	616
Itampolo	12	3	2	6	72
Androka	12	6	1	6	72

Catch by Unit Effort

Figure 2 presents the variation of the catch by unit effort (CPUE) in Ankilibe village from September 2000 to September 2001. The CPUE varies from 4.96 kg to 10.67 kg of sea cucumbers per fisherman per day (corresponding to 16.5 to 35.57 sea cucumbers per fisherman per day). *Holothuria scabra* and *Holothuriua scabra* var. *versicolor* are the mains species harvested during this period. Others species were not or only occasionally harvested and formed a small part of the catch.

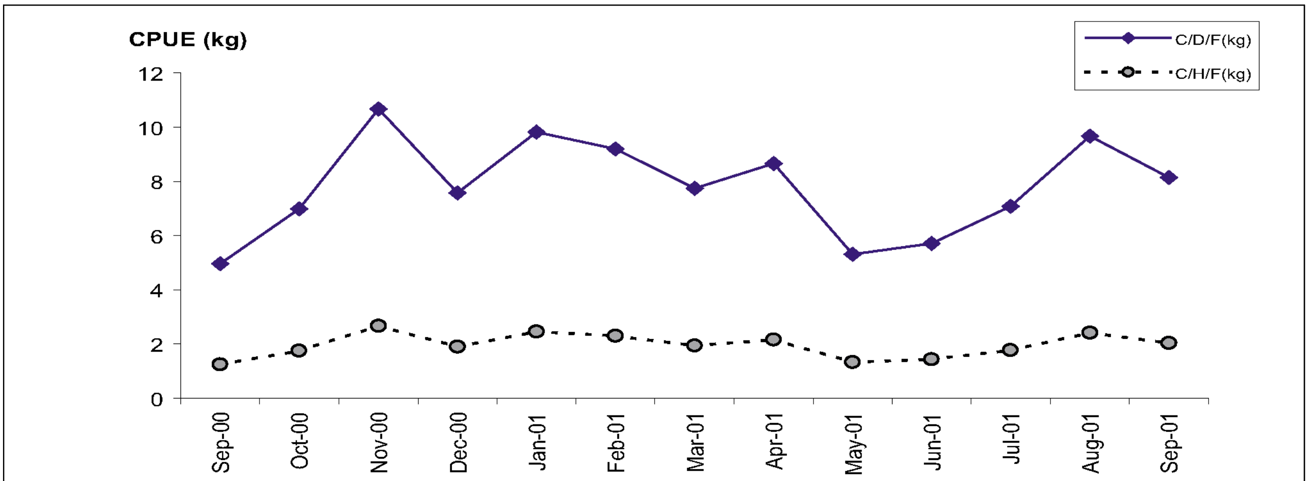

Figure 2. *Monthly variation of the mean of Catch by Unit Effort (kg) in Ankilibe village. C/D/F: Catch/day/fisherman; C/H/F: Catch/hour/fisherman.*

Processing

Preparation of trepang usually implies boiling and drying. In general, processing procedure does not vary much to the conventional procedure described by FAO (1990). Processing of sea cucumber consists basically in eviscerating, boiling (about 30 minutes) and sun-drying individuals. Two techniques are applied depending of the species group.

For "sandfish species", forming the first species group, sea cucumbers are buried (after the first boiling) to facilitate the decomposition of the outer part of the body wall where calcareous spicules occur. This species group include *Holothuria scabra, Holothuria scabra* var. *versicolor, Holothuria rigida, Holothuria maculosa* and, particularly in Toliara area, *Holothuria fuscogilva* and *Holothuria nobilis*. Harvested "non-sandfish" species form the second group. In this group, specimens are not buried during the processing.

Local differences in sea cucumber processing may occur depending on the demand of the collectors or exporters (these are in turn probably linked to the demand of the importers). Changes in procedure have been observed since 1998 in Toliara. Fishermen and collectors have used various new techniques to either minimise loss of weight during the processing or to facilitate processing tasks. In 1998, fishermen proceed as follow for specimen from Holothuridae family. Individuals are first directly exposed to sun for two days, before being processed in the usual way (boiling, [burying] and drying).

Other changes are related to the location of the incision that is either mid-ventral (stichopodid species, *H. scabra* and *H. scabra versicolor)*, mid-dorsal (*Holothuria nobilis* and *H. fuscogilva)* or anal (remaining species). For *Holothuria scabra* and *Holothuria scabra* var. *versicolor*, the incision recently changed to be anal (2 to 3 cm from the anus). In the north-east of Madagascar (Masoala Peninsula), some collectors ask that the peripharyngeal calcareous crown of some species are removed (e.g. *Bohadschia* spp.). Accordingly, the incision is an antero-ventral from the mouth that facilitates the removal of the peripharyngeal crown (Be, 2002).

From 1999, the use of salt during the processing occurred frequently in Toliara. Salting is done to limit desiccation, thus minimising loss of weight during processing. Eviscerated sea cucumbers are marinated or mixed with salt for two or three days, then processed as usual. Since 2002, the sea cucumber are marinated or mixed with salt for up to 48 hours after the first boiling. For larger species (*Thelenota ananas, Holothuria fuscogilva* and *Holothuria nobilis)*, salt was put inside the individuals during the first two days of drying.

In 2000, fishermen cleaned or scraped the outer part of the body wall when individuals (*Holothuria scabra* and *Holothuria scabra* var. *versicolor)* were still living or were recently collected.

In 2002, some collectors used leaves of papaya trees to clean or remove the outer part of the body wall of sandfish. After the first boiling, they mixed the ground leaves of papaya with the sea cucumber for 5 to 15 minutes.

Marketing in traditional fisheries

In the past, fishermen themselves performed the whole trepang processing in the village. Yet, since the late nineties they sell their catch directly to the collectors who do the processing. Now, catches are sold as fresh product in many of the villages. Figure 3 represents the fishery flow in Toliara.

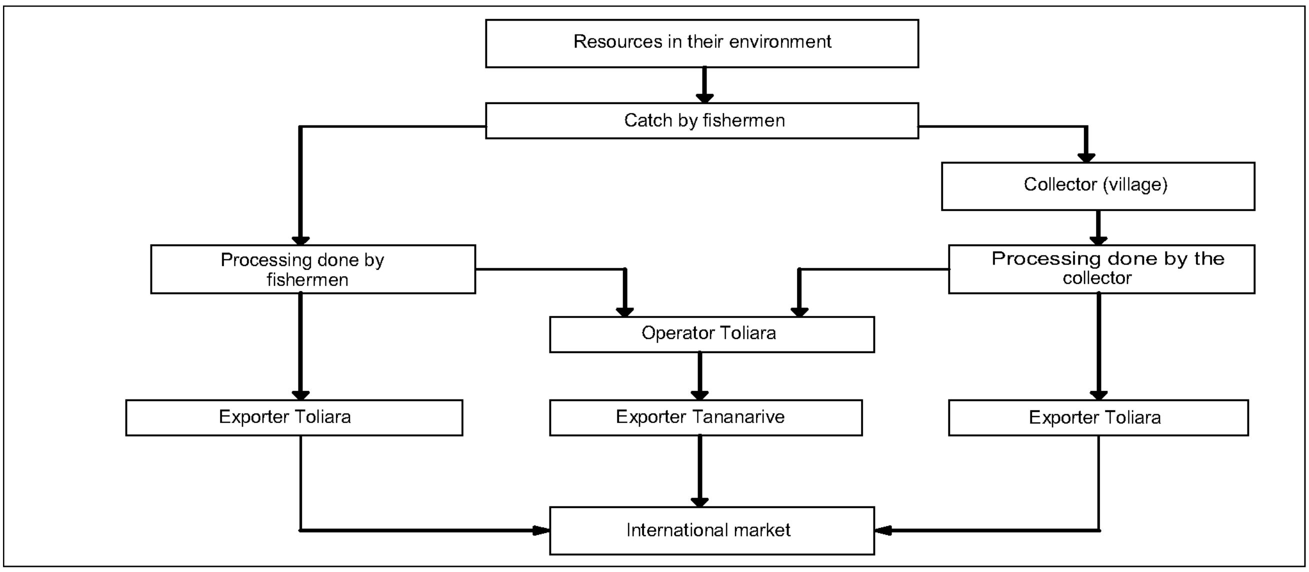

Figure 3. *Fishery schema (from natural habitat to exportation) in Toliara. (Rasolofonirina, 1997).*

Marketing in artisanal fisheries

Harvesting is done by groups of divers. The manager of the group buys the sea cucumbers by piece from the divers after harvesting. Then, they sell the processed product (trepang) to the exporter or export it themselves depending on their organisation.

Price

The price of the trepang increased during the late nineties due to competition between collectors and the increase demand in the international market. Sea cucumbers are divided in three categories depending on the species marketability (see Table 3).

***Table 3**. Selling price of trepang in Toliara in 1996 and 2002. (August 2003: 1 US$=6 190 Fmg).*

	1996		2001-2002	
Species	**Price of sea cucumber (Fmg/piece)**	**Price of trepang (Fmg/kg)**	**Price of sea cucumber (Fmg/piece)**	**Price of trepang (Fmg/kg)**
CATEGORY I				
Holothuria fuscogilva	250 - 4 000	13 000 - 35 000	10 000 - 17 500	35 000 - 60 000*
Holothuria nobilis	250 - 4 000	13 000 - 35 000	5 000 - 17 500	35 000 - 60 000*
Holothuria scabra	2 000 - 7 500	25 000 - 75 000	1 000 - 12 500	40 000 - 85 000*
Holothuria s. versicolor	500 - 7 500	25 000 - 75 000	1 000 - 15 000	40 000 - 85 000*
CATEGORY 2				
Actinopyga echinites	100 - 500	10 000 - 15 000	250 - 1 000	
Actinopyga lecanora	150 - 700	3 000 - 15 000	250 - 1 000	
Actinopyga mauritiana	100 - 500	10 000 - 15 000	250 - 500	
Stichopus horrens	100 - 600	12 000 - 18 000	250 - 500	20 000 - 35 000*
Stichopus hermanni	100 - 600	12 000 - 18 000	250 - 1 000	20 000 - 35 000*
Stichopus sp.		12 000 - 18 000	250 - 500	20 000 - 35 000*
Thelenota ananas	100 - 500	3 000 - 15 000	5 000 - 10 000	
CATEGORY 3				
Actinopyga sp.	50 - 250	1 500 - 3 000		
Bohadschia subrubra	50 - 1000	4 500 - 8 000		
Bohadschia marmorata	50 - 1000	4 500 - 8 000		
Bohadschia tenuissima	50 - 250	1 500 - 3 500		
Bohadschia vitiensis	50 - 1000	4 500 - 8 000		
Holothuria arenicola	50 - 250	1 500 - 3 000		
Holothuria atra	10 - 250	3 500 - 4 500		
Holothuria cinerascens	10 - 250	2 000 - 4 000		
Holothuria edulis	50 - 250	1 500 - 3 000		
Holothuria excellens	50 - 250	1 500 - 3 000		
Holothuria impatiens	50 - 250	1 500 - 3 000		
Holothuria insolita	50 - 250	1 500 - 3 000		
Holothuria leucospilota	50 - 250	1 500 - 3 500		
Holothuria maculosa		1 500 - 3 000		12 000 - 15 000*
Holothuria rigida	50 - 250	1 500 - 3 000		
Pearsonothuria graeffei	50 - 250	1 500 - 3 000		

** After two hours of drying.*

Sources: Fishermen; Collectors: Mme Christine (Toliara), Alibay Lakoubay (Toliara), Jean Cris (Ankilibe), Gervais (Ankilibe), Andrianjatovo (Antananarivo).

The price varies depending of the species, the size, the collector and the quality of the product (high, medium and low). In 2001-2002, some species became scarce in Toliara and had no fixed price or were not commercialised at all. It is not easy to obtain information on the price from the operator. Actually, operators buy a parially dried product (after two hours of drying).

Production statistics

Production in Ankilibe village - In 1996, *Stichopus horrens* represented 39 % of the total harvested sea cucumbers (Mara *et al.*, 1997). Presently, *Holothuria scabra* forms the major part of the harvested species.

Monthly variation of the production in 2001 (Figure 4) indicates a small decrease during the cold season (May to July). Most of the catches are represented by small specimens of *Holothuria scabra*. The monthly total number of sandfish harvested varies from 21 375 to 43 105 sea cucumbers.

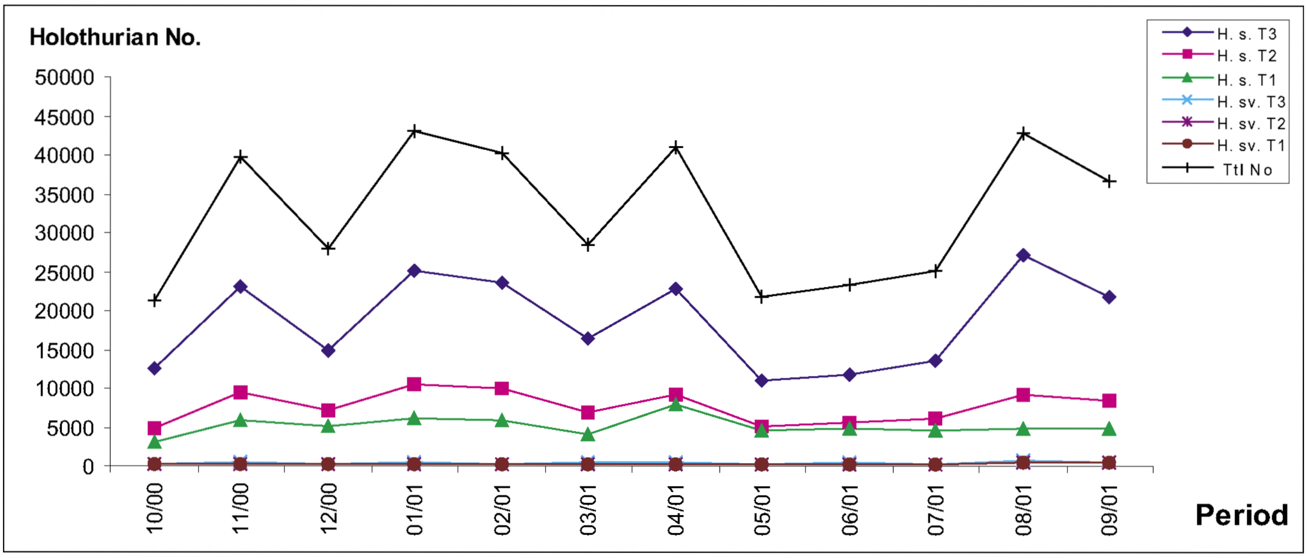

Figure 4. *Monthly variation of the total number of H. scabra (H. s.) and H. s. versicolor (H. sv) harvested in Ankilibe village from October 2000 to September 2001. Size: T3: Small, T2: medium, T1: large, Hol No: Total number of holothurians harvested.*

Production in Toliara Province - Production statistics were obtained from a survey made in 1996 in thirteen different villages. The results are presented in Table 4. The productions varied from 289 031 kg to 572 kg of fresh sea cucumbers and decreased from the northeast (Morombe) to the southeast (Androka) villages. The 1996 production in Ankilibe was 23 700 kg for all harvested species. In 2001, the Ankilibe production was estimated to be 117 465 kg for two sub-species only, *Holothuria scabra* and *Holothuria scabra* var. *versicolor* (see Figure 4 and Table 4).

The production in the Toliara Province is presented in Table 5. It indicates that, from 1987 to 1990, most of the production was exported directly from Toliara. Since 1991, the products transit through Antananarivo before being exported. From 1987 to 1991, the production in Toliara was stable (between 45 to 73.6 tonnes), then it increased abruptly to 245 and 230 tonnes in 1992 and 1993, respectively. The production then decreased to about 75 tonnes. The increased production in 2002 could be related to artisanal fishery or fishing performed outside Malagasy waters. Indeed, some Malagasy fishing ships were reported illegally fishing holothuroids (L'Express de Madagascar, N° 2379).

Table 4. *Estimation of the production in different villages of the Toliara Province in 1996.*

Villages	Estimation of the sea cucumber harvested in 1996 (kg)
Morombe	289 031
Andavadoake	198 690
Salary Nord	8 809
Andrevo	31 999
Ifaty	52 672
Besakoa	13 563
Ankiembe	6 222
Ankilibe (1996)	23 700
Ankilibe (2001)*	117 465*
Anakao	23 595
Beheloka	572
Itampolo	3 611
Androka	2 532
TOTAL	**660 134**

*: *For* Holothuria scabra *and* Holothuria scabra *var.* versicolor.

Table 5. *Production of trepang in the Toliara Province (metric tonnes).*

Year	Domestic market (tonnes)	Exports (tonnes)	Total (tonnes)
1987	6.1	45.2	51.4
1988	2.0	43.0	45.0
1989	23.7	45.9	69.6
1990	2.2	71.3	73.6
1991	61.0	7.5	68.5
1992	142.9	102.2	245.1
1993	140.6	89.6	230.2
1994	40.2	77.0	117.2
1995	4.5	68.4	73.0
1996	53.1	23.2	30.2
1997	43.9	24.3	68.2
1998	40.9	11.0	52.0
1999	35.3	17.7	37.0
2000	74.2	0.0	74.2
2001	98.2	1.2	99.4
2002	53.3	73.1	126.4

Source: SPRH = Provincial Service of Marines Resources of Toliara.

Production in the different provinces - The production in the different Malagasy provinces is presented in Table 6. The exploitation is not developed on the east coast region (Tamatave and Fianarantsoa Provinces) and no data is recorded. Toliara and Mahajanga Provinces are the main producers of trepang. Most of Diego-Suarez products are sent to either Mahajanga or Antananarivo.

Table 6. *Production of trepang in different provinces and destination (kg).*

Province		**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**Destination**
Toliara	Export	-	-	-	28 250	79 770	11 000	7 700	-	3 936	239 666	England, Italy, Japan, Singapore, Hong-Kong, Canada, Reunion
	Local market	-	-	-	24 230	143 866	36 678	17 489	231 562	221 932	201 692	Tamatave, Tananarive
Mahajanga	Export	729	-	17 180	22 025	17 360	10 720	64 374	94 043	83 592	-	Egypt, Japan, Chine, Reunion, Hong-Kong, Thailand, Malaysia
	Local market	15 643	-	43 954	46 506	269 835	15 460	18 100	12 610	23 092	11 322	Tananarive
Diego-Suarez	Export	9	-	-	-	-	-	17 794	71 516	2 479	-	Singapore, Taiwan, Reunion, Hong-Kong, Dubai, Malaysia
	Local market	18 015	-	-	-	192 338	115 732	135 711	201 426	62 756	-	Majunga, Tananarive

Source: Report of MPRH (Fisheries and Marines Resources Office).

Table 7. *Exports of trepang and All Marine Resources (AMR) in Madagascar from 1990 to 2002.*

Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Quantity trepang (tonnes)	202	545	423	357	539	317	279	162	326	327	390	355	987
Value Trepang													
(FMG '000 000)						5 335	3 042	2 292	6 839	9 900	13 532	9 818	19 592
Value All Marine Resources													
(FMG '000 000)					393 617	393 617	402 350	393 324	675 217	712 611	850 163	1 060 998	1 090 743
% Value Trepang/AMR						1.4	0.8	0.6	1.0	1.4	1.6	0.9	1.8

Source: Report of MPRH (Fisheries and Marines Resources Office)

Exchange rate: -1996: 1US$= 5 160Fmg; -1998: 1US$= 5 600Fmg; -2000: 1US$= 6 767Fmg; August 2003: 1US$= 6 210Fmg

-1997: 1US$= 5 400Fmg; -1999: 1US$= 6 600Fmg; -2001: 1US$= 6 733Fmg;

Madagascar production and exports

Table 8 indicates that Madagascar production is estimated at 1 800 tonnes from 1994 to 1997. Then, it decreased to 500 tonnes in 1998 to 1999. From 2000, the production is estimated at around 800 tonnes. These values indicate that the mean annual production is about 1 000 tonnes for Madagascar.

Table 8. *Evolution of the production in Madagascar from 1994 to 2002 (metric tonnes).*

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002
Production (t)	1800	1800	1800	1800	482	512	838	851	708

Source: Activity report of Department of Fishery and COS (Origin and Health Control).

The 1987 to 2002 exports of trepang from Madagascar are presented in Table 9. Data recorded from various services are different. The exports varied from 60.6 tonnes in 1987 to 986.7 tonnes in 2002. Most of the products came from the Province of Toliara until 1993 (more than 50 %) and then its share decreased to about 20 %. Figure 5 indicates the evolution of the Toliara production and Madagascar exports.

Table 9. *Exports of trepang from Madagascar and production in Toliara from 1987 to 2002(metric tonnes).*

Year	Production in Toliara (tonnes)	Exports from Madagascar (tonnes)	Percent of production
1987	51.4	60.6	84.80
1988	45	119.4	37.73
1989	69.6	113.8	61.17
1990	73.6	202.6	36.33
1991	68.5	545.3	12.56
1992	245.1	423.2	57.91
1993	230.2	356.6	64.55
1994	117.2	539	21.74
1995	73	317.2	23.02
1996	(30.15)[1]; 66	307.4 ; (340.5)[3]	8.85
1997	(68.18)[1]	(150.9)[1,2]; (331)[2]; (161.5)[3]	20.59
1998	(51.917)[1]	322.5, (6.5)[2]	16.09
1999	(37.01)[1]	326.6	11.33
2000	(74.2)[1]	389.8	19.03
2001	(99.4)[1]	355.209	27.96
2002	(126.37)[1]	986.9	12.80

Sources: - INSRE = National Institute of Statistic and Economic Research of Antananarivo (Customs Service); Infopêche n°8; March 1995.

[1]*: Report SIR-PRH/ MPRH (Inter-Regional Service of fishery).*

[2]*: Veterinary Service (COS).*

[3]*: Statistics Services in Fishing and Marine Resource Office.*

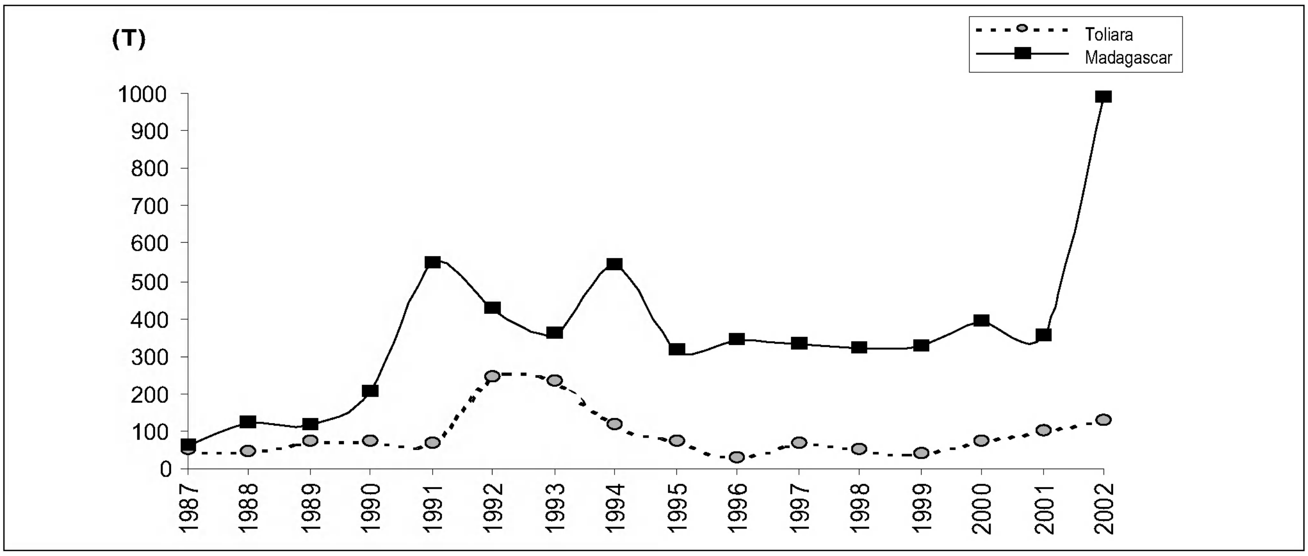

Figure 5. *Evolution of the production (tonnes) in Toliara and the exports (tonnes) in Madagascar. Source: Report of SPRH (Toliara) and MPRH.*

Management of the resources

In Madagascar, resource management problems are related to either overfishing, legislation or administration.

Problems and their consequences in Madagascar

(1) Fishing by walking appears to be declining (production statistics from Toliara indicate a decrease in the production). Fishermen often turn corals heads upside down and break them to look for sea cucumbers. This has negative effects on the resource in destroying its natural habit and damaging the environment.

(2) Fishing by SCUBA diving (which is illegal) has developed rapidly since 1990. Such practice renders the resources increasingly scarce. Presently, divers complain that they have to dive to increasing depths to harvest holothurians. Increase numbers of diving fatalities have increased (Conand *et al.*, 1997).

(3) Currently, some Malagasy ships illegally exploit fishing zones of neighbouring countries (e.g. Seychelles) (L'Express de Mada, N°: 2379, January 2003). They employ hundreds of SCUBA divers to harvest sea cucumbers. Use of this system clearly will lead to a disappearance of the sea cucumber resources in the East Indian Ocean region.

(4) Small individuals are often harvested and this will soon have a negative impact on the resources. At present, the specimen size of various species appears to have decreased especially on the reef flats. The quality of the Malagasy trepang thus decreases which means a decrease of its economic value in the international market.

(5) Intense competition occurs between collectors or operators. To obtain more products, some collectors buy semi-processed and/or bad quality products.

(6) While regulations on sea cucumber exploitation do exist in Madagascar, they are not effectively applied or even not applicable to all species exploited (e.g., the rules governing the minimum size do not consider the various harvested species). Investigations have been done by scientists to determinate the minimum size of each species and a report has been sent to the administration, hoping that the relevant laws will be reconsidered. Also, while the use of diving tanks is forbidden, this system is commonly used in Madagascar. In 2002, over 200 diving tanks were seized for illegal use (Maya Largeat, Afrikeco paper, 05/01/03).

(7) A major problem is that the different administrations ignore the exact quantity of product that the country exports. This is because the importers avoid paying the corresponding taxes and consequently do not declare the quantity of trepang sold.

Management of the fishery

Implementation of sustainable management methods will take place through actions involving the various participants in the fishing sector, from the fisherman to the exporter. Collaboration between different actors in this exploitation is necessary. Contribution of the local authorities to the management of the resource is needed. Education of fishermen should be accompanied by training in processing methods so as to obtain a better price for the products (Conand *et al*., 1998).

Some actions and programmes were undertaken:

- At the IHSM (Fishery and Marines Sciences Institute) in Toliara, a research project entitled "Study of the sea cucumber fishery and sustainable management" was undertaken in 1995-1996 and funded by the World Bank (BM/ONE/IH-SM). The objective was to present the status of the exploitation in the south-west of Madagascar and the market of sea cucumber and to propose management actions (Mara *et al*., 1997).
- The national PRE/COI/UE programme, funded by the European Union and co-ordinated in Madagascar by the CN-MAD, has helped the Fishery Department and professionals (e.g., ONET - "National Association of Sea Cucumber Producers"), to implement sustainable management actions on the sea cucumber resources (Conand *et al*., 1998). In order to reduce over-exploitation of sea cucumbers, they have planned to study the current status of the resource, the production and export statistics, to create a quality management manual for this product and to experiment sea cucumber farming.
- In Toliara, the FAO Fishery Department conducted in 1999 a training programme on techniques of processing for technicians and fishermen.

Sea cucumber cultivation in Madagascar

Conand (1998) indicates that sea cucumbers are overfished all over the world and gave perspectives on mariculture. Sea cucumber hatchery and farming are performed in some countries: China, India, and Japan. *Holothuria scabra* is the selected tropical species used in aquaculture (James, 1994; James *et al*., 1995).

The problem of over-exploitation in Madagascar is such that if no action is taken, the region is headed for disaster in both human and ecological terms. On the human level, the increasing scarcity of a high-value export product would lead to increased poverty and instability in the village communities on the west coast of Madagascar (these villages have gradually concentrated their activities around the exploitation of trepang). On the ecological level, sea cucumbers are major components for sustaining coastal ecosystems in tropical areas, as they are macro-detritivorous that consume various organic detritus (e.g. faeces, cadavers, and moult). Mariculture activity can save the situation by "doubling" the process of forming wild populations through the production of commercially exploitable specimens in farms (optimising juvenile growth). Because these juveniles would be produced in hatcheries, this should bring about a decrease in the pressure on wild populations.

A research project on sea cucumber cultivation (hatchery and farming) is now being conducted in Toliara. The project was proposed by the laboratories of Marine Biology of the ULB (Free University of Brussels) and UMH (University of Mons-Hainaut), which are specialised in echinoderm studies (Jangoux *et al*., 2002). The ongoing work is funded under the University Cooperation for Development (*Coopération Universitaire pour le Développement* - CUD) from Belgium and three associate partners (ULB, UMH and the IH.SM of the Toliara University) together with the technical assistance of the University of La Réunion (France). The project started in spring 1999 and is programmed to run to 2007.

Objectives

The general objective of the research project is to build a holothurian hatchery and farm in the region of Toliara, and to train Malagasy students to the aquaculture techniques related to holothurian growth. Its purpose was to have, after a 4-year period, the capacity to produce holothurians of marketable size from artificially fertilised eggs. The selected species is *Holothuria scabra*, a species fished all along the west coast of Madagascar. The objectives of the project cover various fields:

- Economically, the existence of an efficient hatchery and farm clearly will increase the interest of private organisations (they already propose to participate financially). The involvement of private organisations is necessary to make the link between the trepang production and trepang exportation to target countries.
- Ecologically, the capacity to produce juveniles, and to grow them, could, in the mid-term, diminish the anthropic pressure on the natural populations of the cultivated species. In the long-term, the project in Toliara should ensure that scientific training in sea cucumber resource control and production is provided to specialised staff members. Also, practical training of *in situ* methods for growing species of commercial interest will be given to those village communities that depend on sea cucumbers.

Once a simple and easy standard rearing method can be applied, it will be easily reproduced in various coastal sites (aquaculture farms) using specimens supplied by the hatchery. This would maintain a minimum level of pressure on wild populations (whose ecological importance is well known). After the natural populations have recovered, rearing techniques could be transferred to juveniles collected directly on site to ensure stock management.

Hatchery

The project's two phases (hatchery and farm) are guided by over 30 years of echinoderm research experience of the marine biology team from Brussels and Mons (Belgium) and the University of La Réunion (France). They produced a wide range of works on larva rearing and biology, and on the life cycles, reproductive cycles and feeding habits of adult echinoderms, particularly sea cucumbers.

The hatchery "Aqua-Lab" was set up at the site of the University of Tulear's Fisheries and Marine Sciences Laboratory. It has been active since April 2000. Its main section consists of a 120 m^2 air-conditioned building, with four separate rooms for growing seaweed, rearing larvae and growing juveniles, broodstock maintenance, and for laboratory analysis. Two additional rooms are used for computer processing and for maintaining aquarium equipment. The project aims at building up and then ensuring the scientific management of a hatchery designed for the mass production of *Holothuria scabra* juveniles using wild spawners. Juvenile production is presently mastered and the project is currently working on rearing the juveniles to commercial size.

Farm

Additional funding has been given by the Belgian Cooperation to set up a pilot farm to grow sea cucumber. It will be located about 20 km south of the hatchery in an area allocated to the University of Toliara by the Madagascar Department of Fisheries. The site, which is lined by mangroves, corresponds to the ecological requirements of the investigated species (*H. scabra)*.

Acquiring experimentation

Broodstock were collected in the field and retained in an aquarium. They are then induced to spawn by thermal shock. More than 20 spawnings have carried out by the Aqua-lab with the first fertilisation done in March 2000. It has led to the production of a limited number of sea cucumbers that are now 3 years old. The larvae are fed planktonic algae imported from Europe (a species of *Phaeodactylum*) and cultivated in the hatchery. Juveniles are fed finely chopped macroalgae (*Sargassum densifolium*) originating from the reef flat. The presence of mature broodstock all along the reproductive cycle of *H. scabra* in this region (Rasolofonirina, unpubl.), indicates that artificial fertilisation is possible throughout the year. Larvae development, metamorphosis and settlement of the species are now under control.

Conclusion

Until the beginning of 1990s, the production in Madagascar was more or less stable at 100 tonnes annually. Since this period, the production has increased and fluctuated. In 1991 and 1993, the production increased to 500 tonnes. Then, the production decreased. This decrease corresponds probably to the decrease of production from traditional fisheries. In 2001-2002, there were again important increases in the production (less than 1 000 tonnes) that corresponds to the development of artisanal and semi-industrial fisheries.

Species of high commercial value are in demand but currently species of low commercial value are also highly prized. Fortunately, they are not yet affected by the artisanal or semi-industrial fishery.

The mean annual production of sea cucumber in Madagascar is officially estimated at 1 000 tonnes. Official export in 2002 was near this number (987 tonnes). In 1993, official export volumes were 357 tonnes, however Hong Kong SAR (China) and Singapore reported imports of 712 tonnes from Madagascar. This number and all exports to other countries (England, Italy, Japan, Canada, Reunion, Malaysia and Egypt) in 1993 are probably estimated at 1 000 tonnes. The export statistics recorded from various services were different. The official data for exports appears to be underestimated.

The sea cucumber fishery plays an important role in the economy of the coastal villages and the country. In the south west of Madagascar, coastal villages live generally on fisheries and most or all of them exploit sea cucumber. Exports of sea cucumber have officially brought Fmg 19.6 million (US$3.1 million) to the country in 2002 (see Table 9). It represents about 2 % of the total export value of all marine resources.

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Current status of the sea cucumber fishery in the south eastern region of Cuba

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Abstract

The analysis of the sea cucumber (*Isostichopus badionotus)* fishery from August 1999 to June 2003 in the south eastern region of Cuba is summarized. During the first two years of the fishery (1999-2000) more than three million individuals were collected. During this period all the fishing effort was conducted by one fishing enterprise employing 12 boats. In 2001, the former enterprise was split into 3 fishing units, with 3 boats authorized for each unit. During the first two years the catch per unit effort (CPUE) was around 1 153 sea cucumber/boat/day. In subsequent years, production and the CPUE decreased to <500 000 individuals/fishing season and 350 sea cucumber/boat/day, respectively.

At presently, the CPUE is in the order of 1 200 sea cucumber/boat/day. The declining CPUE is not an index of a biomass decrease, as it fluctuates between 4 500 to 7 610 individuals/hectare. The low CPUE for the 2001-2002 fishing season was due to the inadequate logistical inputs into the activity (mainly availability of fuel for the boats). Efforts are being made to re-establish the normal fishery conditions. A total of 1 438 tonnes wet weight have been extracted in the south eastern region, with 920 tonnes extracted in the two first years of the fishery. A capture of 200 tonnes wet weight for this region was planned during 2003. The CPUE has been recommended for each fishery season and locality, with a maximum of 1 200 to 1 500 sea cucumber/boat/day, depending on the abundance in each fishing area. So far approximately 69 tonnes of dried sea cucumbers have been processed and sold. Prices have steadily increased during this period from US$ 13.5/kg dry product in 1999-2001, to US$ 18.0 in 2001-2002, and US$ 22.0/kg in 2003 as a result of improved product class and quality.

Keywords: sea cucumber fishery, *Isostichopus badionotus*, capture quota, CPUE, Cuba

古巴东南部沿海海参渔业现状

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摘要

本文综述了古巴东南部沿海1999-2003年间古巴等刺参（*Isostichopus badionotus*）的渔业状况。在1999-2000 年间捕获了300多万头该种海参。在此期间，只有一家渔 业公司，12艘船在东南部沿海作业。到了2001年，该公司分成3个渔业单位，每一渔业单位只允许有3艘渔船作业。前两年，每天每船的捕捞量是1 153头海参。之后，海参可捕量开始下降，一个捕捞季节只能捕获50万条，每天每船的捕获量是350条。

现在每天每船的捕捞量是1 200 头海参。可捕捞量的下降并不是总的资源量下降的指标，因为每公顷总的资源量仍然波动在4 500到 7 610头海参这一范围内。2001-2002年度捕捞量的下降主要是后勤没有跟上，例如燃料供应不足等原因。目前的主要任务是重建正常的渔业秩序。东南沿海的总捕捞量是1 438吨（鲜重），其中的920吨是前两年的产量。2003年预计是200吨。每天每船的建议可捕量是1 200 -1 500头海参，取决于资源量的丰度。现在，大约加工了68.9吨干海参。市场价格在稳步上升，从1999-2001年度的每千克13.5美元，涨到了2001-2002年度的18美元/千克。2003年由于质量等级得到了改进，价格上升为22美元/千克，。

关键词：海参渔业、古巴等刺参（*Isostichopus badionotus*）、捕捞配额、单船日捕捞量、古巴

Introduction

More than a dozen holothurian species have been indiscriminately exploited as well as being subjected to local fishing restrictions in different parts of the world. The unique culinary characteristics of sea cucumber, much appreciated in Asia, and the inadequate and/or the lack of management measures have been responsible for the overfishing of these benthic organisms (Richmond *et al.*, 1996; Conand, 1997; Ferdouse, 1999; Henkins and Mulliken, 1999; Morgan, 2000; Conand, 2001). Measures taken to protect these resources have been generally limited (Amesbury, 1996). The potential for a sea cucumber fishery in Cuba was recognised in 1997 after an investigation carried out by the Fishery Research Center in the shallow waters around the country. Following this, a southern Korean company negotiated a fishing agreement with the authorities for the extraction of commercially important species. Preliminary investigations estimated an annual harvest potential of 320 tonnes (dry weight) of the commercial species, *Isostichopus badionotus* (Alfonso *et al.*, 1998).

A research project was initiated alongside the start of the fishery in August 1999 allowing the first set of catch statistics on *Isostichopus badionotus* (Figure 1) to be collected. Furthermore, the project also carried out a preliminary stock abundance evaluation as well as estimated the production potential of the fishery. Studies on the species biology were also conducted. Considerations on the possible impact of the fishery to the sea cucumber population led to the formulation of a number of fishing regulations by mid 2000 (Alfonso *et al.*, 2000). These regulations set the catch quota for the various fishing areas, set a minimal legal size of 22 mm, and imposed a close fishing season during the reproductive months (February-April). In addition, the regulations also restricted a minimum catch of 60 sea cucumber specimens per standard collection bag and the maintenance of covered "onboard tanks" to protect the sea cucumbers from the sun and heat.

Figure 1. *Live specimens of sea cucumber (I. badionotus) in holding tanks.*

The speedboats used (Figure 2) are equipped with compressed air diving tanks and four onboard holding tanks fitted with a flow-through water system to hold the sea cucumbers. The fishery is carried out at depths of between 3-15 m and no fishing accidents have been reported.

The fishing trips commonly last around 20 days, followed by a 10-day layoff period. Evisceration of the sea cucumbers is done on board and sea cucumbers are then transported to the nearest quay for boiling and salting. Further processing and packaging is then carried out in proper processing plants.

A Technical Operational Procedure (TOP) manual (Figure 3), (Frías *et al.*, 2002), a manual of species identification (Alfonso and Frías, 2001) and catch quota documentation were developed during the initial stages of this newly establish fishery. The TOP manual comprises measures for accident prevention, decompression tables, and allowable catch number of sea cucumber/bag along with other technical information (e.g. size of the collecting bags).

Another TOP manual was developed to guarantee better yields and quality of the final product (Castelo *et al.*, 2002). The quality of the processed products has considerably improved over the years and the current yield is around 20 % of the wet weight, similar to sea cucumber fisheries in other parts of the world.

Figure 2. *Speedboats used in the sea cucumber fishery.*

Figure 3. *Counting and measuring a sea cucumber catch based on the procedures detailed in the Technical Operational Procedure (TOP) manual.*

The principal objective of this paper is to provide information about the current status of the sea cucumber (*I. badionotus*) fishery in Cuba`s south eastern region.

Materials and methods

During the first two years, fishing efforts were centred off the town of Granma. From February 2001, it expanded to coastal areas further east to include the towns of Júcaro and Santa Cruz del Sur (Figure 4).

The catch quotas were set following an estimation of the sea cucumber biomass (Amesbury and Kerr, 1996; FAO, 1990). Catch data and CPUE (sea cucumber/boat/day) were recorded in all field monitoring trips. The monthly data collected in each fishing area were compared with the daily catch data reported by the Operations Fishery Office of the Ministry of the Fishing and Industry. Fifteen monitoring trips were organized to the fishing areas to verify the actual CPUE values, the sea cucumber abundance and other biological data (length measurements, total and tegument weights). Furthermore, the gonads were used to identify the sex and the maturation stage of each individual. Starting in 2002, the reproductive cycle of this species has been under investigation (Aleaga *et al.*, unpublished).

Results and discussion

Brief fishery analysis

The highest production volumes occurred during the first two fishing seasons (1999-2000) when over three million individuals were landed (Figure 5).

During this period the sea cucumber fishery was managed by one fishing enterprise located in Granma which operated 12 boats in the south eastern region of Cuba. In mid 2001 this enterprise was split into 3 fishing units with 3 boats each; however the production remained rather low due to a series of technical and management complications. By 2003, the sea cucumber fleet consisted only of one boat in Júcaro, two in Santa Cruz del Sur and two in Granma.

Figure 5 shows a decrease in the production (catch), CPUE and the number of fishing days from 2000 to 2001. Around three million sea cucumbers were harvested in the first two years, but currently less than 500 000 are caught annually. A total of 1 438 tonnes (wet weight) have been so far extracted in the south eastern region from the start of the fishery, i.e. 920 tonnes from May 1999 to the end of 2000, 253 tonnes in 2001, 133 tonnes in 2002 and 127 tonnes in the first 6 months of 2003. To date, almost 69 tonnes (dry weight) have been processed and sold to a trading

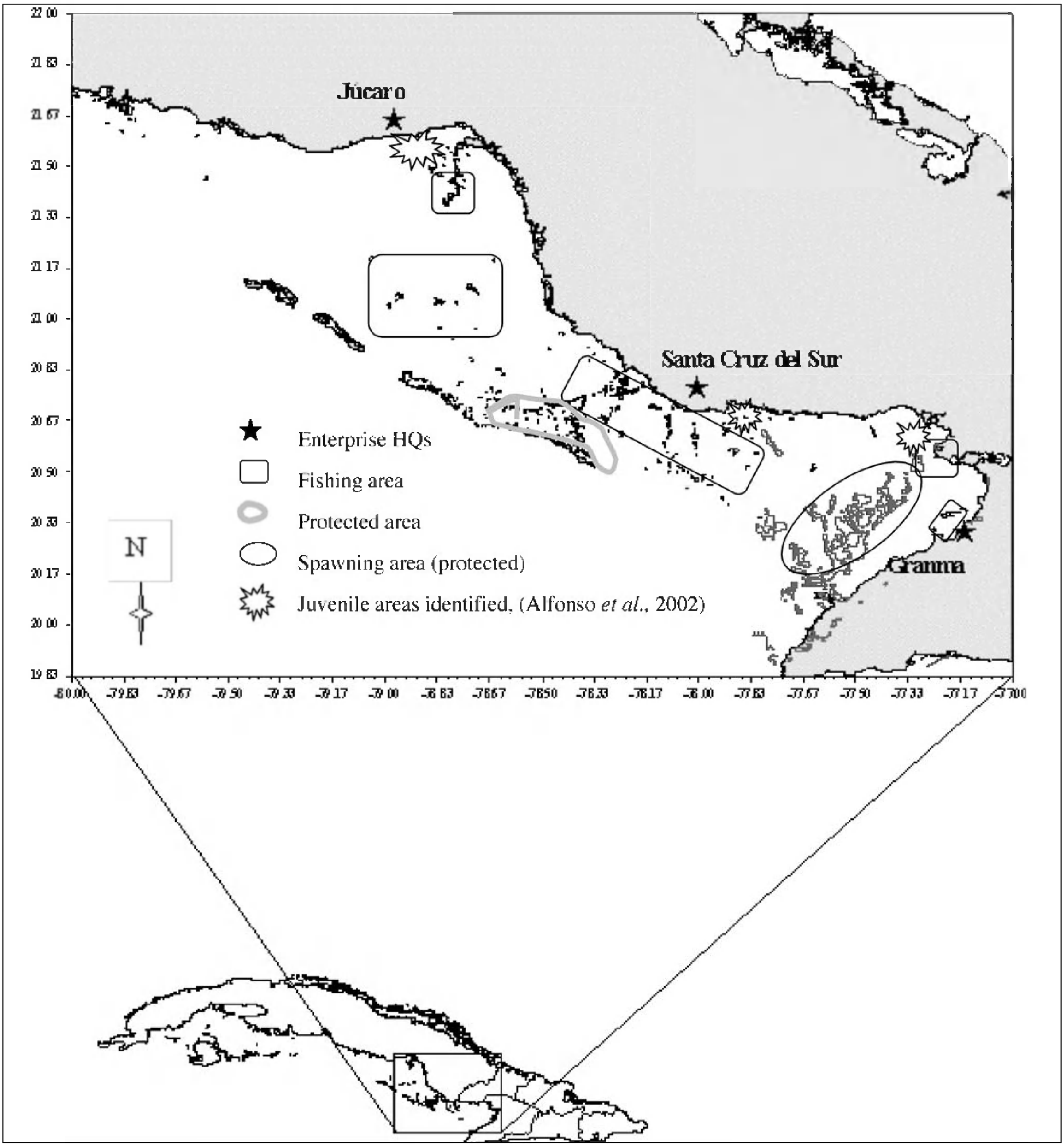

Figure 4. Map of the south eastern region of Cuba showing the sea cucumber fishing protected areas and location of the fishing enterprises.

company (NENEKA CA) (41.6 tonnes up to the end of 2000, 13.5 tonnes in 2001, 7.3 tonnes in 2002 and 6.4 tonnes at the end of the first half of 2003).

Despite a new system of payment being in place for the fishermen since 2002, some logistical support failures, for instance fuel, have created difficulties for the sea cucumber fleet. Thus, higher catches have not been possible. At present, efforts are being undertaken to re-establish normal fishery conditions and the trading company involved in the sector (NENEKA CA) is supporting the financing of boat motors and spare parts. The size of the fishery is not of great importance for the Cuban authorities at this stage even though the sea cucumber fishery provides an income to the enterprises involved and generates some employment.

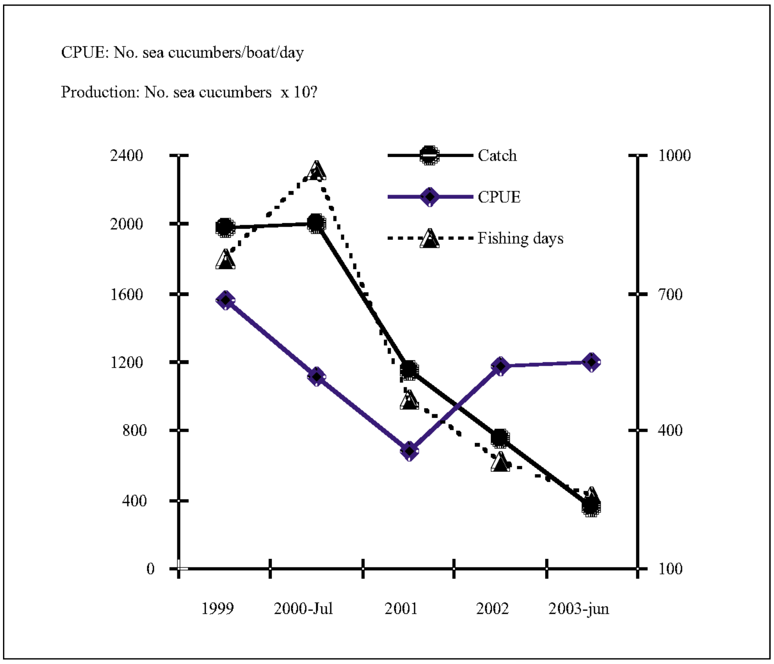

Figure 5. *Sea cucumber production, CPUE and fishing days in Cuba's south eastern region from late 1999 to June 2003.*

According to the data collected by the authorities, the sea cucumber population has not been seriously affected by the fishery, particularly as the juvenile density remains at an acceptable level. Furthermore, the declining CPUE is not an indication of biomass decrease, as the values have fluctuated between 4 500 to 7 610 ind./ha possibly indicating the aggregation behaviour noted by Sloan and Bodungen (1980) and Boada and Buitrago (1996) in the waters off Bermuda and Venezuela, respectively.

Preliminary field observations show that the sea cucumbers have fully matured gonads during February-April. This information was used by the researchers to initially recommend a close fishing season during this period. However, further research showed that a large number of sea cucumbers juveniles (22 cm in length – minimal legal size) appeared in the fishing grounds from July to September while the adult population remained scarce. For this reason the initial closed fishing season (February-April) was moved to July-September.

Tables 1 and 2 show the production of sea cucumber against the fishing efforts during the first 6 months of 2003. Only a total of 361 598 sea cucumber specimens and approximately 127 tonnes (wet weight) were produced resulting in a CPUE value of around 1 270 sea cucumber/boat/day and 225 sea cucumbers/diver/day.

New sea cucumber fishing areas were also searched. A survey carried out in the south western region of Cuba in April 2002 indicated a potential fishery of an additional 231 tonnes (wet weight). However, the infrastructure in this region still remains inadequate for establishing a fishing operation.

Table 1. *Effort and catch values of the sea cucumber fishery from January to June 2003 in the south eastern region of Cuba.*

	Effort		Catch	
Harvest Seasons 2003	**Fishing Days/ fishing season**	**Fishing boats/ harvest season**	**Number sea cucumber**	**Wet weight kilograms**
January	45	3	69 697	21 740
February	47	3	76 353	21 141
March	56	4	88 071	32 765
April	31	5	28 137	18 850
May	21	3	31 549	11 800
June	57	5	67 791	21 500
	257*	4**	361 598*	127 796*

* *Total sum.*

** *Mean value.*

Table 2. Catch per unit effort values of the sea cucumber fishery from January to June 2003 in the south eastern region of Cuba.

Catch Per Unit Effort			
No. sea cucumber/boat/day	**Wet weight Kg/boat/day**	**No. sea cucumber/diver/day**	**Wet weight kg/diver/day**
1 549	483	258	81
1 624	449	270	75
1 573	585	262	98
907	608	151	101
1 502	561	250	94
1 189	377	188	63
1 270*	504*	225*	83*

** Mean values.*

Processing

Sea cucumbers are initially sorted by size onboard the vessels (Figure 3). Upon arrival at the landing site a small cut is made beneath the oral opening of the sea cucumber to allow complete evisceration. After boiling for 30-45 minutes (depending on the size of the specimens), the sea cucumbers are drained, chilled and salted for 24 hours. Sun drying for several days follows and is done by evenly distributing the sea cucumbers over suspended mesh trays (Figure 6).

Figure 6. Sun drying and preliminary size grouping of sea cucumbers.

The final step in the processing involves drying the sea cucumber in an oven at 60 °C for 3-4 days depending on the initial moisture content of the specimens introduced (Figure 7). Once the desired level of desiccation is achieved, the sea cucumbers are packed in 20 kg capacity paper and nylon bags. Each bag contains around 1 075 to 1 200 pieces.

The dried sea cucumbers are separated, classified and packed in two classes. Class A currently commands a price of US$ 22/kg while Class B a price of US$ 8/kg. In 2003 approximately 87 % of the sea cucumber produced were Class A.

Biological characteristics of the Cuban sea cucumber

The tegument wet weight and size of the Cuban sea cucumber, *I. badionotus*, varies seasonally and reaches the optimal value from February to May coinciding with the peak maturation of the gonad. The maximum mean weight value recorded in Cuban waters was 612.4 ± 155.8 g.

With regards to the recruit of sea cucumber juveniles around the small islands off Santa Cruz del Sur it should be noted that the marine current in the study area flows from east to west. This current may be responsible for the transportation of the developing larvae probably from the Buena Esperanza Bank located off the town of Granma.

Large mature sea cucumbers have been found in this latter area which has, therefore, been declared a protected area (Figure 4).

The sustainable extraction of the few commercial species of sea cucumber in Cuba may have no or little effect on the environment as the ecological function carried out by these species may be sufficiently covered by other holothurians of no commercial value, such as *H. mexicana* (up to 17 000/ha), *A. multifidus* (up to 6 300/ha), *A. agassizii* (up to 1 800/ha), *H. floridana* (up to 2 800/ha) as well as other less abundant species.

Figure 7. *Oven used for the final drying of sea cucumbers.*

Figure 8. *Live sea cucumber specimens of* A. agassizii *(1),* H. floridana *(2 and 4) and* H. grisea *(3).*

Use of sea cucumber by-products

The use of sea cucumber by-products, such as gonads and the boiled freshwater used in processing, are currently being investigated. A joint project with the national Centre on Studies of Natural Products (CEPN) of the Faculty of Biology at the University of Havana is being considered in order to research and extract bioactive compounds from sea cucumbers for medicinal purposes and other uses. A separate project with techniques for breeding, farming and harvesting the *I. badionotus* species for other possible utilization will also be necessary.

Conclusions

The sea cucumber resources in Cuba, and in particular *I. badionotus*, are being exploited following a precautionary approach. A number of management measures have been established in order to ensure a profitable utilization of the natural marine resource. The overall volume of the fishery is not considered an important factor in Cuba, however the fishery does provide an alternative economic activity and employment opportunities to the local fishing enterprises engaged in the sector.

Further biological studies on *I. badionotus* are required in order to ensure the sustainability of the fishery.

Research needs

The following studies are recommended:

- Thorough investigation on the reproductive cycle of the commercial sea cucumber species.
- Investigation on the natural growth and mortality cycle of the commercial sea cucumber species.

- Identify the possible relationships between bottom particle composition and sea cucumber growth.
- Research on population movements of the major commercial sea cucumber species.
- Research on the extraction of bioactive compounds from sea cucumber and their by-products.
- Promote international collaboration on sea cucumber fisheries, aquaculture and trade.

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Session II
Resources management

Overfishing of holothurians: lessons from the Great Barrier Reef

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Abstract

The holothurian fishery has a long tradition in Australia that began with Macassan fishers. The interactions resulting from the sea cucumber fishery provided the first cultural contact between aboriginal and islander communities and non-Australians. The sea cucumber fishery occurred in a typical "boom and bust" fashion, with boom cycles several decades apart. The last of these cycles commenced in the mid 1980s and signs of overfishing are now apparent. The main target species in the fishery on the Great Barrier Reef (GBR) was the black teatfish (*Holothuria nobilis*). Initiated by a request from the fishing industry and supported by data obtained through studies summarised in this report the fishery for this species was closed in 1998. Surveys on over 60 reefs along the entire reef system (spanning a distance of 2 000 km) conducted in 1998/99 indicated that stocks of this species were generally lower in the southern half of the GBR. It is likely that the lower densities resulted in the concentration of the fishing effort north of Townsville (ca. 12 °S to 19 °S). The existing zoning 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 fishing reduced the densities of *H. nobilis* on the fished reefs by about 75 %. GIS-based model calculations indicate that an initial ("virgin") biomass of about 5 500 tonnes was reduced by 2 500 to 3 000 tonnes. This figure corresponds well to the total reported catch since the 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* provide an effective means for stock protection of this species. However, whether the area protected was sufficient as a source of recruits for the whole area is 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 low levels of recruitment. 3) Annual catches of (on average) less than 5 % of virgin biomass depleted stocks of *H. nobilis*. This is in sharp contrast to notions that up to 50 % of virgin stock size might be taken annually. These data suggest an extremely cautious approach should be taken in the management of beche-de-mer fisheries.

Keywords: Resource management, stock size, recruitment, no-take zones, marine protected areas

海参资源的过度捕捞：大堡礁的教训

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摘要

海参渔业是澳大利亚玛克尚（Macassan）渔民的传统渔业，也是当地土著居民和非土著居民间文化交流的结果。海参渔业呈现着典型的丰欠周期交替的规律，每一周期间隔数十年。最近的一个周期始于上一世纪八十年代，目前海参资源已经明显衰退。大堡礁(GBR)主要的海参渔业对象是黑乳参(*Holothuria nobilis*)。在海参渔业部门的请求和研究机构的支持下，该地区的黑乳参渔场已于1998年关闭。1998-1999年度对大堡礁60多个礁区（跨越2　000千米）的调查表明，大堡礁南部黑乳参的渔业资源明显下降，渔业活动只得集中在汤斯维尔（南纬12 ° S --19 ° S）。大堡礁海洋公园现有海域的可捕区和非捕区（或称之为绿色海域）表现出鲜明的对照。在可捕区内，黑乳参的密度下降了75%。根据卫星定位系统所得到的数据表明，处女地的资源量已经由原来的5 500吨降低到了2 500 －3 000吨。这一数据与渔场开放以来

的捕捞量是完全相吻合的。该计算模式对大堡礁和其他海区今后黑乳参，以及其它潜在种类的资源管理有着三项主要用途：1）建立非捕捞区为资源保护提供了有效的保护手段，但是，保护区是否能为整个地区提供足够的补充资源尚不得而知；2）渔捞报告和资源量下降数据的一致性说明，海参资源补充能力非常之低，在十多年内没有明显增长的迹象，也难以观察到资源得以恢复的数据；3）资源已经衰退的黑乳参的年捕捞量不足处女地生物量的5%，而不是原来认为的可以达到处女地生物量的50%的观点。这些资料表明，对海参渔场的管理必须谨慎从事。

关键词：资源管理、资源量、补充量、非捕捞区、海洋保护区

History of holothurian fishing on the Great Barrier Reef

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 fishermen and traders who visited this country centuries before European settlement. Matthew Flinders, one of the early explorers of Australian reported in his "*Voyage to Terra Australis*":

"The object of their [the Macassans] expedition was a certain marine animal, called trepang. Of this they gave me two specimens; and it proved to be the beche-de-mer, or sea cucumber which we had first seen on the reefs of the East Coast, and had afterwards hauled on shore so plentifully with the seine, especially in Caledon Bay. They get the trepang by diving, in from 6 to 8 fathoms water; and where it is abundant, a man will bring up eight or ten at a time. "

This Macassan fishery in the Northern Territories and West Australia was analyzed in detail in a book by MacKnight (1976). The first fishery by Europeans occurred early in the 19th century and was based on the GBR and the Torres Strait, in conjunction with trochus and pear shell exploitation. A first beche-de-mer station was reported in 1804 on Lady Elliott Island, but the operation did not last very long (Sumner, 1981). Further development of the fishery occurred about 40 years later, around 1850, when stations were opened at Green Island (near Cairns), Fitzroy Island and the Frankland Islands (Sumner, 1981). During that period, most fishermen made the long journey from Sydney and played an important role in exploring the tropical east coast of Australia (see reports in Idriess, 1957). The fishery showed the first signs of overfishing in the 1890s (Sumner, 1981). At that time, stocks declined in areas close to the shore and larger boats had to be used to access reefs further off shore.

The author estimated historical catch data for beche-de-mer on the east coast of Australia (Figure 1) with data given in Saville-Kent (1893), Sumner (1981) and Anon (1946). To do this, several assumptions and conversions had to be made (see explanation in figure legend) thus data presented can only be taken as rough estimates. However, it appears that the total volume of previous fisheries was larger than values taken in the current fishery. This may be partly explained by the fact that it is not possible to discern where holothurians were actually fished, because historic data were based on export data from Queensland. These data may therefore include animals fished in the Torres Strait, Coral Sea reefs, Papua New Guinea and the Solomon Islands. This lack of information makes it difficult to put exact figures on boom and bust cycles, but it is clear that the previous cycle ended about the time World War II began, as was also reported by Harriott (1985). It is unclear if this was caused by a single factor such as stock reductions, political or economic reasons, or a combination of factors. The cycles may also be blurred by shifts in species caught, but it appears that most of the catch on the Great Barrier Reef (GBR) at that time was black teatfish (Saville-Kent, 1893), whereas the fishery in the Torres Strait and the Northern Territory was mainly based on sandfish (*Holothuria scabra*).

Current fishery cycle and management

The current cycle for the sea cucumber fishery commenced in the mid 1980s, and signs of overfishing are now apparent. Along the east coast of Australia, there are four different fisheries, managed by different agencies.

The fishery in the Torres Strait is mainly based on sandfish catches on Warrior Reef. This reef is on the border between Papua New Guinea and Australia and was thus also visited by fishermen from Papua New Guinea. This fishery is managed by the Australian Fisheries Management Authority (AFMA), a federal agency, and after only four years of fishing effort, was closed in 1998 due to an extreme stock depletion. These stocks had not recovered when surveyed again in 2000 (Skewes *et al.*, 2000). Likewise, the fishery on black teatfish and surf redfish (*Actinopyga mauritiana*) in the Torres Strait was closed in 2003 due to over-exploitation.

Another AFMA-managed sea cucumber fishery exists on some offshore reefs in the Coral Sea and allowable catches for this fishery are currently under negotiation. However, logbook surveys (Hunter *et al.*, 2002) indicated that catch rates for high-value species have declined from the year 2000 to 2001.

Some sandfish fisheries exist in the vicinity of Hervey Bay (closed in 2000) and Moreton Bay (an exploratory fishery was opened in 2003) and are managed by the Queensland Fisheries Service (QFS). The same agency also manages the fishery on the GBR, but fishing in the Marine Park also needs to be in accordance with Great Barrier Reef Marine Park regulations. All Australian fisheries for export also need approval from the Department of Environment and Heritage (previously known as Environment Australia).

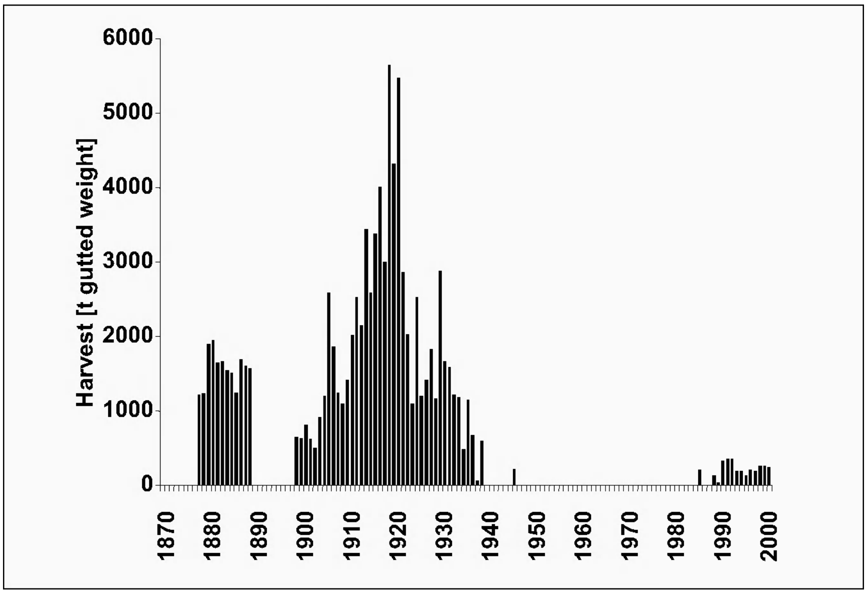

Figure 1*. Historic catch data (in tonnes gutted weight) for holothurians on the Great Barrier Reef and adjacent areas. Early export data were converted from dry-weight (beche-de-mer product) using a conversion factor of 7.6 (combining data for* Holothuria nobilis *from FAO, 1989; Benzie and Uthicke, 2003). For most years from 1901 to 1940, only the value of the export is reported. These values were converted to weight by assuming an average value of 4.4 Australian Pound per cwt (= 50.8 kg). This figure is the average for the period between 1925 and 1940, derived from Australian export data. Values for the period between 1987 and 2003 are actual catch data obtained from Queensland Fisheries Service (see Fig. 2).*

The remainder of this report will focus on the fishery in the Great Barrier Reef Marine Park, where, the main target species was the black teatfish (*Holothuria nobilis*). Initiated by a request from the fishing industry, and supported by data obtained through studies summarised here, the fishery on this species was closed in 1998. Nearly the entire fishing effort was concentrated north of Townsville (ca. 12°S to 19°S). The main management tool was a Total Allowable Catch (TAC, as gutted weight) of 500 tonnes. This TAC was not species specific, but most of the catch taken was black teatfish. The fishery was also entry-limited, with only about 18 license holders. Catch data provided by QFS (Figure 2), showed that the quota was never achieved, the maximum annual catch of black teatfish was about 360 tonnes.

Since 1994, annual catches declined and also catch rates per unit effort (CPUE) declined distinctly until the fishery for that species was closed (Figure 2). Since the closure of fishing for black teatfish, the fishery concentrated on the white teatfish (*H. fuscogilva*) and a TAC for this was set at 127 tonnes. This required a change in fishing method to SCUBA or hookah diving because white teatfish are found in deeper waters. In more recent years, fishermen have also collected prickly redfish (*Thelenota ananas*). The catch for this species increased 10-fold from about 7 tonnes in 1995 to 69 tonnes in 2000. Fishing for lower value species after overfishing of high value species is typical for holothurian fisheries and a clear indicator for over-exploitation. Unfortunately, this also appears to be the trend for the GBR, as fishery data prior to the closure of the black teatfish fishery (1998) contained very little catch of lower value species, whereas combined catches for all medium to low value species (excluding *T. ananas*) were 51 tonnes in 2001/2002 and 69 tonnes in 2002/2003.

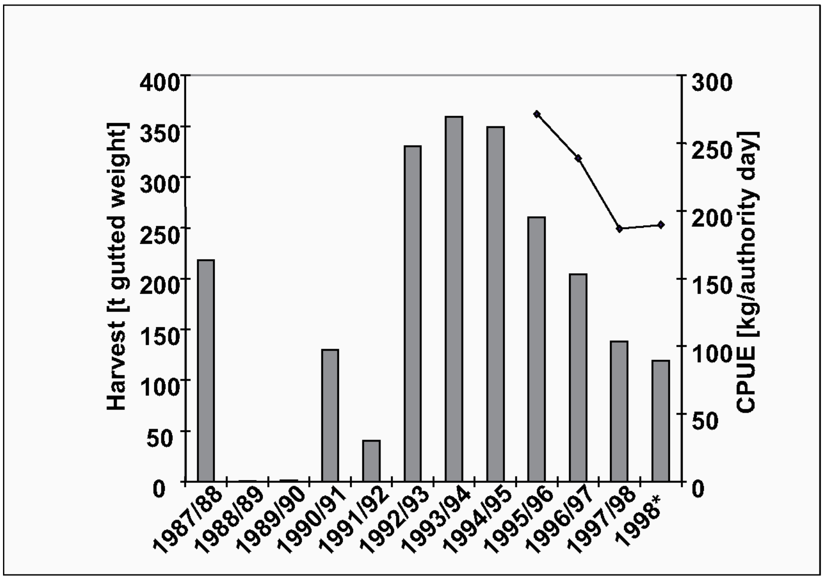

Figure 2. *Reported catch of* Holothuria nobilis *in the Queensland fishery for the most recent fishing cycle (left y-axis, bars), and catch per unit effort (right y-axis, line only for the last four years) of the fishery. The asterisk indicates that data from 1998 are only until the time of closure, thus not representing a whole year.*

Why is fishery management important?

The primary aim of fishery management is the protection of the respective stock to provide for a continuing and sustainable income for the fishermen. However, in recent years management agencies increasingly take into consideration follow-on effects on other species and on the functioning of the entire ecosystem. This is mainly based on increased understanding of ecosystem functioning and understanding of interactions between trophic groups within these systems. Therefore, the function of holothurians in their ecosystem must also be understood to evaluate indirect impacts of the fishery.

All commercial holothurians are sediment feeders and consume vast amounts of sediments. Massin (1982a) and Birkeland (1988) suggested that the main functions of holothurians on coral reefs are bioturbation of sediments and the recycling of organic matter. Indeed, it has been shown that populations of two species can move the equivalent of the upper 5 mm of sand in their habitat once a year (Uthicke, 1999). This bioturbation is potentially important for the aeration and cleaning of the sediments and may extend the oxidized layer of these.

The main food sources of holothurians are bacteria, microalgae and dead organic matter (Yingst, 1976; Massin, 1982b; Moriarty, 1982). When holothurians are kept in densities above natural levels, they can reduce algal biomass (Moriarty, 1982; Uthicke, 1999). However, when natural densities were used in experiments, it was demonstrated that benthic microalgae on coral reefs have higher production in the presence of these animals (Uthicke and Klumpp, 1997, 1998; Uthicke, 2001b). The microalgae appear to benefit from enhanced nutrient levels resulting from the excretion of holothurians (Uthicke, 2001a). Since the production by microalgae on sands is an important component of the total production on coral reefs, it can be inferred that removal of holothurians can have negative effects on the total production.

Commercial holothurians in other ecosystems, such as *H. scabra* in seagrass beds, may have other functions such as increasing seagrass production or effecting seagrass densities by their burrowing behavior. To date, most studies have been done with species of low commercial value and further large-scale experiments are required to investigate if these effects are measurable after removal of holothurians through harvesting. However, findings from experimental studies indicate that heavy overfishing, particularly where species with little commercial value are also removed, has impacts on the productivity of the ecosystem.

Large-scale holothurian surveys on the GBR

Initial Surveys

Surveys on over 60 reefs along the entire (spanning 10 degrees of latitude) Great Barrier Reef (GBR) conducted in 1998/99 indicated that stocks of the black teatfish were generally lower in the southern part of the GBR (Figure 3). The zoning of the Great Barrier Reef Marine Park allowed a comparison between reefs that were fished and reefs protected from fishing (*Green Reefs* or *No-Take Zones*). Since the southern sections of the GBR were not fished, there is no difference in densities on open and protected reefs. In the northern two sectors, which represent the main fished area north of Townsville (ca. 12 °S to 19 °S) densities are distinctly higher on reefs which are *No-Take Zones* (Figure 3). A more detailed analysis showed that densities on each of the protected reefs are higher than on open reefs and this difference is highly significant (Figure 4, updated from Uthicke and Benzie, 2000, two additional reefs added from Uthicke and Byrne, unpublished data). On average, fishing has reduced the densities on the fished reefs by about 75 %, roughly from densities of 21 individuals per hectare down to 5 individuals. It cannot be concluded with certainty that densities found on *No-Take* reefs are natural densities, still somewhat reduced from previous fishing cycles (see above), or suffer from reduced larval recruitment due to fishing on other reefs.

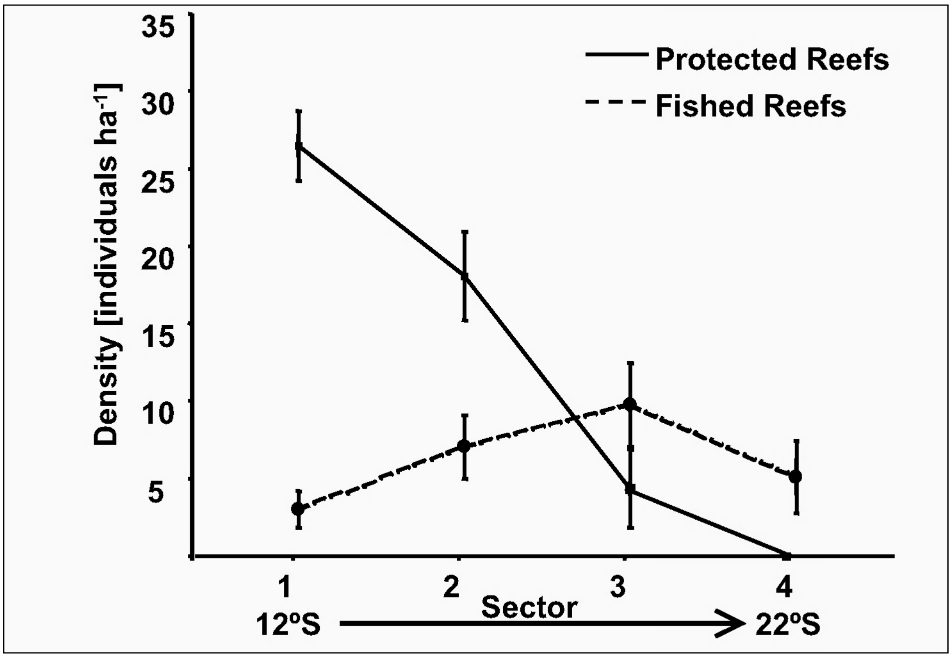

Figure 3. *Average densities of* Holothuria nobilis *in four sectors (sector* ***1****: northern most sector; Sector* ***4****: southern most), given for Protected Reefs (No-Take Zones) and Fished Reefs (open to fishing) of the Great Barrier Reef. Error bars indicate 1 SE.*

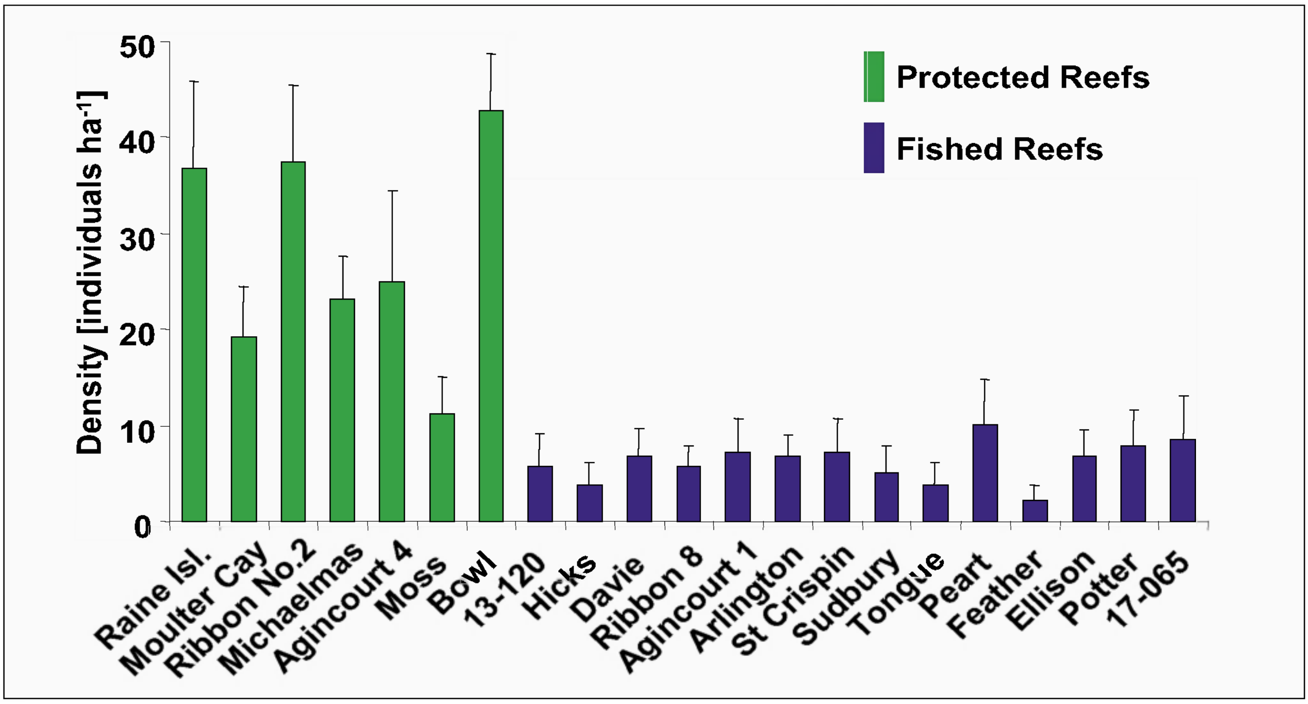

Figure 4. *Average densities of* Holothuria nobilis *on 7 reefs closed to fishing (Protected Reefs = No-Take Zones) and 14 reefs open to fishing (Fished Reefs) in the Central and Northern sectors of the Great Barrier Reef. Error bars indicate 1 SE.*

Re-surveys after Fishery closure

Nineteen reefs were re-surveyed in the formerly fished area, one and two years after the closure of the fishery, to determine if stocks recovered in that time. During this period, densities on *No-Take* reefs remained at a high level, one year (2000) and two years (2001) after the fishery closure (Table 1). No recovery was detected on the reefs previously fished. Densities on these 14 reefs remained on a level substantially below those on the *No-Take Zones* (Table 1). Although densities on previously fished reefs slightly increased, this increase was not statistically significant (Uthicke *et al.*, in press). The fact that densities do not increase significantly indicates that little recruitment takes place.

Table 1. *Individual densities per hectare (standard errors in brackets) of* Holothuria nobilis *on the reef flat of five reefs closed to fishing (No-Take Zones) and 14 reefs open to fishing in the fished are of the Great Barrier Reef (North of Townsville).*

Survey Year	*No-Take Zones*	Fished Reefs
1998/99	22.8 (±1.8)	5.0 (±0.6)
2000	27.9 (±5.6)	6.3 (±0.6)
2001	21.5 (±2.7)	6.8 (±1.1)

Estimating virgin biomass

GIS-based calculations indicate that about 25 % of the total available habitat area of *H. nobilis* was protected on *No-Take Zones* (Figure 5). Using area estimates and assuming "natural" densities as currently found on the *No-Take* zones, the initial ("virgin") biomass for the total area was estimated to be about 5 500 tonnes (Uthicke *et al.*, in press). During fishing since the mid 1980s this biomass was reduced by 2 500 tonnes to 3 000 tonnes. More than half of the remaining *H. nobilis* biomass is now located on the *No-Take* reefs. The total reduction in stock size estimated from these calculations corresponds well to the reported catch of 2 000-2 500 tonnes during the fishing period (catch data from QFS; see Figure 2, Uthicke *et al.*, in press).

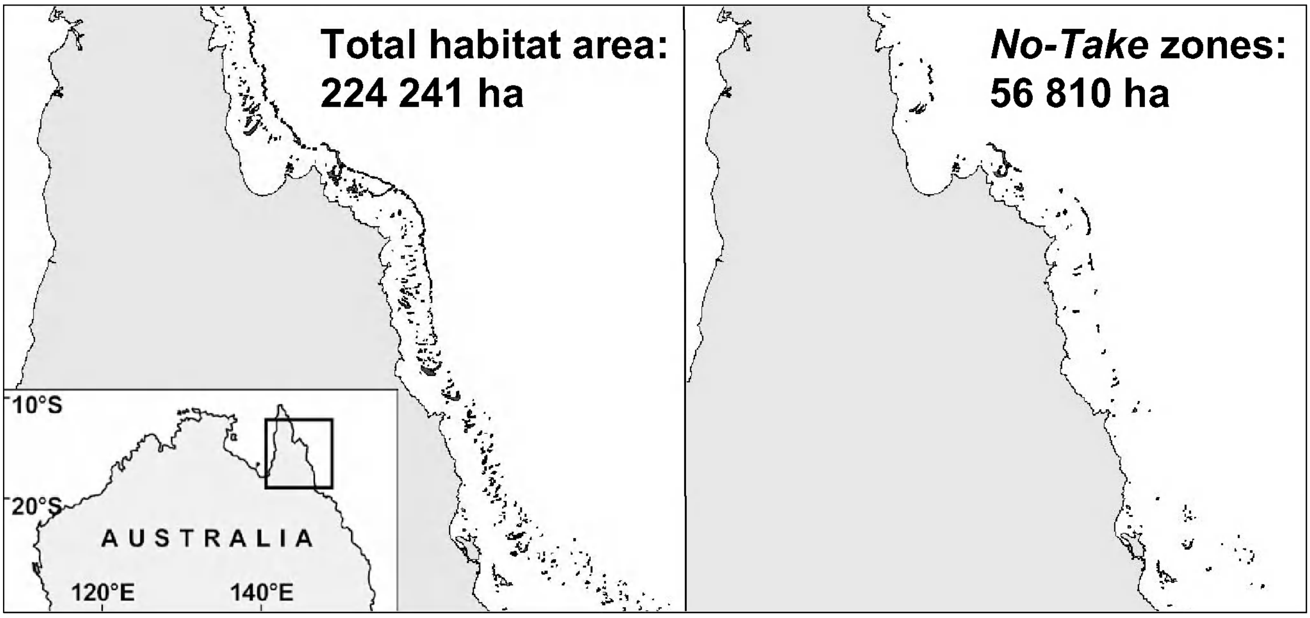

Figure 5. *Maps indicating the total habitat area of* Holothuria nobilis *in the fished area of the Great Barrier Reef and the area protected from fishing ("No-Take zones"). About 25 % of the area is protected from fishing.*

Conclusions

The results from the studies discussed here 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 tool for stock protection of these species. However, whether the area protected on reefs mentioned above (ca. 25 %) was sufficient as a source of recruits for the whole area is currently unknown. In broadcast spawning invertebrates, the number of juveniles produced declines disproportionally when densities are reduced. This phenomenon is called the "Allee Effect" due to proximity of mates, and involves the problem of sperm dilution, the declining probability of sperm encountering eggs when animals are further apart (Levitan and Petersen, 1995). For example, a fourfold decline in densities as was seen in the fishery on the GBR, results in the doubling of the average distance between individuals of *H. nobilis*. Assuming animals are randomly dispersed, this means that average distances between animals increase from about 22 to 44 m. Applying a model developed for scallop populations, Claereboudt (1999) found that fishing scallops to 50 % of their original density reduced larval output of the population to 10 % of the initial value. Although not enough information on fertilization kinetics is known for *H. nobilis*, it may be assumed that populations fished to 25 % will have very limited larval output. These calculations suggest protecting sufficient spawners in *No-Take* zones may be a more efficient management tool than controlling Total Allowable Catch rates. However, if this were done it would still be necessary to investigate how many holothurians could be removed from fished areas without impacting on the ecological functioning of these areas.

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. These data are corroborated by the fact that no recovery was discovered two years after the fishery closure and the fact that very few recruits or juveniles (animals < 500 g) where ever found during the course of these studies. It is uncertain if the small number of recruits is already a result of reduced larval output due to reduced adult density (see above), or a general feature of *H. nobilis* populations of the GBR. Very few other studies on the recovery and recruitment in holothurian populations exist. One study in the Solomon Islands (Lincoln-Smith *et al*., 2000) detected very little or no recovery for several holothurian species after the declaration of a Marine Park. Similarly, sandfish stocks on the Warrior Reef complex had not recovered even four years after the fishery closure (Skewes *et al*., 2000). Further anecdotal evidence suggests that reefs are often not fished for several decades after the "boom" of a fishery, a situation that may arise from slow recovery of the stock.

3) Annual catches of (on average) less than 5 % of virgin biomass distinctly reduced stocks of *H. nobilis* on the GBR. This is in sharp contrast to notions that 50 % of virgin stock size might be taken annually (Long *et al*., 1996). This was based on the assumption of a natural mortality rate of 1 (equivalent to 37 % survival annually). Data collated here suggest that mortality rates are likely to be much smaller than that. These data, in conjunction with indications for very low growth rates of this species (Uthicke and Benzie, 2002; Uthicke *et al*., in press) and little recruitment as discussed above, suggest an extremely cautious approach should be taken in the management of this species, and potentially holothurian fisheries in general.

Recommendations and research needs

- Unless indications for higher recruitment are shown, the TAC for *H. nobilis* should be below 5 % of virgin biomass.
- To ensure sufficient production of juveniles, large areas should be set aside as *No-Take* zones.

Further research on the following topics is urgently required:

- effects of density reduction on larval production in holothurians;
- natural recruitment rates and recovery of populations after fishing;

- growth, mortality and longevity of holothurians;
- the effects of holothurian removal on ecosystem functioning in coral reefs and seagrass beds.

Until further data are available, fisheries should only continue with strict adherence to the precautionary principle. This may require a large percentage of the total habitat protected in *No-Take* zones and calculations of catch rates based on worst case scenarios.

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

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Abstract

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., a total moratorium on fishing or artificially aggregating and protecting some of the wild adults to promote spawning success. This will require an evaluation of population recovery rates under various interventions and restocking scenarios using both theoretical (life table analysis and population modelling) and empirical approaches. The information needed for such comparisons includes: remnant stock size, population age/size composition, generation time, longevity, 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, optimal stocking density, 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 programs: the assessments described above need to be made at the level of self-replenishing populations within the stock.

Keywords: Restocking, stock enhancement, management, population modelling

何时增殖放流有利于海参渔业？

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摘要

试图通过生产和放流海参种苗来维持海参渔场的可持续生产和增产，从原理上讲，尚有待商榷。更清楚地讲，在做出这一决定前，要了解为了改善生产而采取这一措施在成本上是否合算。虽然增殖放流是为了增加资源严重衰退渔场的资源补充量，但是若与其它方法，如延迟捕捞期、人为地将亲参聚集到一起，或者保护野生成年个体来提高生殖能力等相比，在资源恢复的时间上是否会明显地缩短是值得研究的。这就需要对各种增殖方式、方法，无论是理论上的（如死亡率分析和种群模式）还是经验上的做法，都需要从资

源恢复率的角度予以评价。若要做好对比分析，需要如下资料：剩余资源大小、种群年龄/大小组成、世代间隔时间、寿命、生殖力、资源补充量的年变化、不同生活周期的天然死亡率、以及在低种群密度时影响产卵率和受精率的种质行为等。为资源增殖而投资于海参苗种生产只有当上述模式证明，人工培育的海参用于放流会相当快地使得资源得到补充才可考虑。

资源增殖是期望重建海参渔业，使得产卵群体生物量达到所希望的水平，因为这类渔场自然幼苗补充量达不到所要求的水平。要评价资源增殖是否有效，管理者需要掌握全面的信息：海参栖息地的容纳量、最优资源密度、资源量的丰度和年龄结构、每年的自然幼苗量、人工育苗费用和放流前的存活率等。即使幼苗补充量低于所需水平，但繁殖幼苗的费用超过了放流前所期望的收获物的附加值，资源增殖也是不合适的。

另一要点是，考察放流和资源增殖项目成功与否，要看种群内部自身补充量是否达到应有的水平。

关键词：放流、资源增殖、管理、种群模式

Introduction

Populations of sea cucumbers are being overfished worldwide (Battaglene and Bell, 2004; Conand, 2004; Lawrence et al., 2004; Altamirano et al., 2004; Uthicke, 2004). This is now causing major concerns for fishers and managers because these easily accessible, inshore resources are no longer able to provide their potential economic benefits. Not surprisingly, managers are investigating whether the release of hatchery-reared juveniles may be a useful tool to restore the production of sea cucumbers. Indeed, considerable efforts are now being made to develop methods for mass-production of juveniles in hatcheries (Battaglene, 1999; Battaglene et al., 1999; Hamel et al., 2001; Chen, 2004; James, 2004; Mercier et al., 2004; Pitt and Duy, 2004), and for releasing juveniles in the wild at good rates of survival (Purcell et al., 2002; Battaglene and Bell, 2004; Dance et al., 2003; Purcell, 2004). However, we believe that not enough thought has yet been given to whether the relatively expensive option of producing juveniles in hatcheries will actually add value to other measures to promote replenishment available to managers of sea cucumber fisheries. Rather, assumptions seem to have been made that any additions of cultured juveniles will be of benefit and that it is just a matter of learning how to produce them at low cost, and release them at sizes and in ways that enable them to survive in high proportions.

It is now apparent that many other questions need to be answered before decisions are made to invest in a hatchery program for sea cucumbers. These questions include:

1. Is the fishery comprised of one large homogeneous population, or is it divided into several, largely self-replenishing, populations?
2. What is the abundance and size structure of each population comprising the fishery, and how does the current status of the population compare to the original unexploited level?
3. What is the purpose of releasing cultured juveniles? Is it to restore spawning biomass to a more productive level? (a process referred to as "restocking" by Battaglene and Bell, in press; Bell, in press), or is it to increase yields from a fishery where spawning biomass is close to the desired level, but production is lower than the potential carrying capacity of the habitat due to recruitment limitation? (a process described as "stock enhancement" by Doherty, 1999; Battaglene and Bell, in press; Bell, in press).
4. Can the aims of management, to rebuild the spawning biomass of severely overfished populations, or to increase the productivity of "healthy" populations, be met cost-effectively with other forms of management?

In this paper, we discuss these issues in more detail to provide guidance on the main factors that need to be considered in restoring depleted fisheries for sea cucumbers, or enhancing the production of those fisheries that are still in

[1] *The information in this paper draws heavily on previous and planned publications by the authors and is presented here in the interests of making the proceedings of the FAO workshop on Advances in Sea Cucumber Aquaculture and Management representative of current research aimed at improving the management of sea cucumbers. These publications are Bell (in press), and a manuscript by J.D. Bell, P. Rothlisberg, J.L. Munro, N.R. Loneragan, W.J. Nash, R.D. Ward and N.L. Andrew entitled "Restocking and Stock Enhancement of Marine Invertebrates" due to be published in Advances in Marine Biology in 2004.*

relatively good condition.[1] Our main conclusions are that: 1) population modelling is needed to assess whether hatchery release programs will add value to other forms of management designed to replenished over-exploited fisheries; and 2) the immediate purpose of research on the hatchery production of sea cucumbers, and effective ways for releasing them in the wild, should be to provide the information needed for the models designed to evaluate the merit of different approaches to restoring the productivity of sea cucumber fisheries.

Why is stock delineation so important?

To date, there has been interest in identifying the genetic population structure of various species of sea cucumber (Uthicke and Benzie, 2001; Uthicke and Purcell, in press) to ensure that hatchery-reared juveniles are produced and released in ways that do not affect the natural genetic diversity of the species. These studies have shown that for at least one species, *Holothuria scabra*, there can be marked differences between populations at relatively small spatial scales. This is strong evidence that national fisheries for this valuable species are likely to be targeted at more than one largely self-recruiting population. The implication is that each of these populations will need to be managed separately.

This begs questions about the population structure and exploitation patterns of other species of sea cucumbers. How many self-recruiting populations occur within the distribution of the species? What is the spatial scale of these populations? Which groups of fishers share in the harvests from each population? Without this information, national managers cannot begin to develop optimum strategies for restoring or enhancing the production of each species of sea cucumber.

A word of caution here: population genetic studies may not be sensitive enough to detect the number and scale of all largely self-recruiting populations within a fishery because relatively low levels of reproduction between adjacent populations may be sufficient to maintain gene flow even when the populations are largely self-recruiting. This means that the results of the most sensitive genetic analyses should be taken as a measure of the minimum number of management units. Other analyses, e.g. of symbionts and parasites, may be needed to help identify the distributions of all largely self-recruiting populations of the species. Hamel *et al.* (1999) report an interesting example of a symbiotic relationship between a pea crab and *Holothuria scabra* at a small spatial scale in Solomon Islands.

The role of stock assessments

Once the number of largely self-recruiting populations within a fishery has been identified, assessments of the abundance of size/age classes need to be made for each population. For many species of sea cucumbers, this can be done relatively easily using underwater visual transects (Lincoln-Smith *et al.*, 2000). However, for species that occur in turbid water, standardized trawl or dredge surveys will be required. Estimates of population size using either of these area-based sampling methods are not straightforward because the distribution of sea cucumbers is often highly patchy, which can lead to substantial errors in total abundance when the fished population covers a large area unless the survey is stratified and replicated appropriately. In cases where resources are inadequate for such surveys, it may be possible to make estimates of population depletion and, importantly, the remnant population from temporal changes in catch rates, size composition and localities fished. Data on the status of each population can then be used to decide whether it is at such a low ebb that stringent measures need to be taken to restore the spawning biomass to more productive levels, or whether the primary need is to find efficient ways to make the relatively robust population more productive.

Modelling the potential benefit of releasing hatchery-reared juveniles

Restocking

For populations where stock assessments reveal that spawning biomass is at chronically low levels, the temptation will be to assume that the release of hatchery-reared juveniles will help restore the number of spawners. However, for such restocking to be effective, the remnant wild sea cucumbers and the released animals would need to be protected until they and their progeny replenish the population to the desired spawning biomass. If this is the case, managers need to ask whether a moratorium on fishing for the remnant wild population alone would be sufficient to achieve replenishment. This important decision can be made on the basis of some relatively simple modelling.

By estimating how long it would take for the number of spawners to be restored to the desired level using a moratorium alone, managers should then be able to determine whether the addition of more juveniles through a restocking program will add significant value. The basic information needed to construct a model for predicting the exponential rate of replenishment under a moratorium includes: remnant stock size and density, population age/size composition, generation time, longevity, 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.

Modelling whether the release of hatchery-reared juveniles would be a cost-effective way of reducing the time needed to re-build the desired number of spawning sea cucumbers, compared to replenishment under a moratorium alone, would depend on the following additional information: survival to adulthood of cultured juveniles released in the wild, and the cost of producing the juveniles. Assumptions are made here that the cultured juveniles do not have deficits that would prevent them from spawning; that they are released at densities that do not inhibit their growth or survival; and that they are produced and released in way that does not alter the gene pool of the population into which they are placed (Munro and Bell, 1997; Battaglene and Bell, 1999, in press; Uthicke and Purcell, in press).

Modelling the benefits of adding cultured juveniles should be made at several different magnitudes of release to identify what numbers of animals are needed to substantially reduce the time needed for replenishment. The gain in terms of reduced number of years before the fishery can be re-opened at different levels of restocking can then be weighed against the cost of the investment in a hatchery to produce the required number of juveniles. Clearly, a restocking program should only be used if the value of harvests in the years gained from reopening the fishery earlier (due to the hatchery releases) exceed the costs of producing the juveniles.

Variations on the modelling proposed above might include, for example, the use of marine protected areas to protect a large portion of the remnant wild stock in situations where it is not possible to put a moratorium on sea cucumbers because they form part of the catch of a multi-species trawl fishery, and where survival of animals returned to the water is not good due to damage in the nets. Where it is possible to apply a moratorium, recovery could also be accelerated by aggregation of the remnant stock at several places within the distribution of the population and transplanting aggregations large enough to spawn effectively to areas within the distribution of the self-replenishing population where successful settlement of juveniles has not occurred (Battaglene and Bell, in press). These measures should increase the probability of reproductive success and promote the dispersal of larvae to unoccupied settlement habitat.

One problem with applying this approach to sea cucumbers is that with the exception of a few species, e.g. *Apostichopus japonicus* and *Holothuria scabra*, the basic life history information needed for the modelling is often not available. In such cases, however, it should be possible to place species into broader 'life table' categories (see Hempell and Crowder, 1998) to approximate the response to total protection from fishing and to addition of cultured juveniles, where urgent restoration of a population is needed. Where the minimum necessary information to place species into life table categories is not currently available, managers should commission the research urgently.

Stock Enhancement

Assessing the potential benefit of releasing cultured juvenile sea cucumbers in a stock enhancement program requires a different approach. Such interventions should only be considered where there is strong evidence that the habitat does not regularly receive as many juveniles, through the natural supply of post-larvae, as it is capable of supporting and as are desired by managers (Munro and Bell, 1997; Doherty, 1999; Battaglene and Bell, in press). If this is the case, managers need to calculate how many more sea cucumbers could be supported if they were available and to identify optimal stocking densities. The latter point is critical - for species that take several years to reach the recommended minimum legal size, it would be a mistake to release as many individuals as the habitat could support in one year, i.e. they should not seek to fill the "carrying capacity" of the habitat. To do so would limit the number of individuals that could recruit successfully the following year without retarded growth and survival and result in an age structure dominated by one year class. Ultimately, this will result in a large harvest one year, followed by years of much lower production. Such variation is not in the best interests of fishers or markets.

A better approach would be to release fewer animals each year so that the optimal biomass is achieved by an accumulation of year classes. This process can be optimised by using average natural mortality and growth rates to allocate carrying capacity to size/age classes in a way that delivers comparable harvests each year. This (hypothetically ideal) size/age structure can then be compared to that of the wild population, and juveniles can then be added each year to provide the number needed to give the optimum harvest by the time the sea cucumbers grow to the minimum legal size (see Figures 2 and 3 in Bell, in press, for more details). In practice, this requires close monitoring of settlement success to detect sub-optimal levels of recruitment, or recruitment failure, followed by swift production and release of the desired number of juveniles when there is a shortfall in the natural supply. Where this cannot be done practically, which will be the case for some species, stock enhancement will need to be planned in a coarser way. For example, if settlement success cannot be measured until the animals are one year old, then managers have little option but to respond then, although they will always run the risk of releasing juveniles in response to a previous recruitment failure at a subsequent time of adequate natural supply. Alternatively, managers could hedge their bets by releasing low densities of juveniles each year and accept that in some years their efforts will be negated by good natural supply, while in others the releases will not be sufficient to maintain the desired age structure for optimum harvests.

Regardless of the sophistication of the approach used, the variation in the natural supply of juveniles each year, and the projected survival of released juveniles to harvest size, can be used to identify the range of juveniles likely be needed to supplement natural recruitment among years. This range will determine the investments needed to construct hatcheries with the necessary capacity. Ultimately, decisions to invest in stock enhancement programs will need to be based on assessments that the added value of the increased harvests stemming from hatchery releases exceeds the cost of producing the juveniles.

Other important considerations

Much of the research to date on hatchery production of sea cucumbers, and methods for releasing them in the wild, has been done by national research agencies, universities and regional and international organizations. Future decisions about when to apply these interventions, and payment of the cost involved, are likely to be made by different groups for restocking and stock enhancement. There is rapidly growing awareness that stock enhancement programs should no longer be funded by government. Rather, the direct beneficiaries should bear the costs (Lorenzen *et al*., 2001). However, there must be an incentive for doing so. Consequently, decisions to engage in stock enhancement by the private sector, or fisheries co-operatives, are only likely to occur in places where fishers are granted access or property rights (Bell, in press and references therein). Identifying who should pay the costs of restocking programs is not so straightforward. Rebuilding severely depleted fisheries with the assistance of restocking programs will probably remain the responsibility of governments until the private sector is convinced that the process will succeed. Then, the private sector may be prepared to bear the costs in exchange for property rights.

Conclusions

Although the release of cultured sea cucumbers holds much promise as a tool to assist managers to restore severely depleted populations, or to optimise the production from populations that are still in relatively good condition, there has been little understanding about how research on development of hatchery and release methods best helps managers to assess whether such interventions will be cost-effective. It is now clear that research to reduce the cost of producing environmentally fit, genetically diverse cultured juveniles, and to release them in the wild so that they survive in high proportions, should be used for two different purposes.

The first purpose is to enable managers to model whether hatchery releases are likely to add value to other forms of management, e.g. a moratorium on fishing, where the imperative is to rebuild a severely overfished population.

The second purpose is to improve the efficiency of using hatchery-reared juveniles where these interventions have been deemed to be of benefit on the basis of thorough analyses. Investments in release programs for sea cucumbers in most other circumstances run the strong risk of misappropriating resources that could have been used to increase productivity in other ways.

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Criteria for release strategies and evaluating the restocking of sea cucumbers

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Abstract

Conservative 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 jeopardizes the success of restocking programs.

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, release habitat, times of the day and season for release, 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.

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 tagging methods for juveniles are developed, such research is likely to utilise experimental designs involving multiple release sites and control sites without released animals. Such "BACI" designs are appropriate for analysis by ANOVA statistics or by Non-Linear Mixed Effects Models using repeated surveys. In order for restocking to gain credibility as a wise investment for resource management, programs will need to rigorously demonstrate that releases of hatchery-produced juveniles contribute substantially to the replenishment of stocks.

Keywords: Restocking, release methods, conditioning, BACI designs, modelling, sea cucumbers, holothurian

海参渔业增殖策略

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摘要

资源保护是发展可持续海参渔业的关键，放流人工苗种有可能加速已衰退资源的恢复。海参养殖技术上的进步可以在高密度下将幼参养到可供放流的规格，然而，在放流技术和资源评估方面的研究不足，影响到资源增殖的成功。

在放流前，一个关键的指标是放流的幼参在遗传性上要与亲参采集地和放流点的海参遗传性相近。在放流方法上，需要研究最佳的运输方法、放流地的生境、放流的季节和时间，以及放流成本与幼参规格之间的关系。为了提高放流的成活率需要研究海参幼体在育苗池中和暂养时防范敌害的行为。在新喀里多尼亚进行的野外网围实验表明，人工育成的糙海参（*Holothuria scabra*）苗在一定的生态环境条件下，最初阶段的成活率和生长都很高

有关放流方法尚待进一步研究，包括大规模放流的经济效益分析和增殖效果的精确评估。在幼参标志放流尚未成功前，海参资源增殖的研究只能在实验方法的设计上予以考虑，如选择多重放流地点和不放流的对照点。这种BACI(Before After Control Impact)设计模式采用统计学上的方差分析或是用非线形混合效果

模式进行分析是适合的。为了获得对海参资源增殖放流投资的可信度，尚需要严格地论证人工苗种放流对资源补充的贡献率。

关键词：放流、放流方法、行为、BACI设计，模式、海参

Introduction

Overfishing of sea cucumber stocks worldwide has raised the importance of fisheries management in sustaining this industry because populations do not recover quickly (Uthicke, 2004). Restocking of sea cucumber stocks with hatchery-produced juveniles, as a management measure for remediation of breeding populations, is likely to be employed only when sites are depleted by overfishing. Less frequently, releases of juveniles could be used for stock enhancement (sensu Bell and Nash, 2004), i.e. to improve the productivity at sites with relatively low natural recruitment, or to increase access of species to alienated habitats (Bell, 1992). If the problem is overfishing, then the solution in the first instance is to ensure firm and conservative management to prevent overfishing.

Management of sea cucumber resources should ideally be based on the knowledge of stock size through visual surveys or statistics on catch per unit effort. Several options for management may be applied in combination, using management tools common to other marine invertebrates (see Purcell, in press), with an understanding of the biology and ecology of the species involved. For instance, some species, such as *Holothuria nobilis*, are usually found only at a large and mature size (FAO, 1990; Uthicke and Benzie, 2000), so minimum size limits may be inappropriate for this species. In artisanal fisheries, the strategies should be adopted in participation with fishers and customary owners to promote respect and compliance of regulations. Once these strategies are in place, restocking may be an effective way to rebuild breeding populations for fisheries.

A theme arising from restocking programs is the relatively high cost of culturing and releasing animals in the high numbers needed to restore breeding populations (Bell and Nash, 2004). Released juveniles also tend to have high mortality in the initial period following release. Therefore, release of hatchery-produced sea cucumbers may not be cost-effective for a 'put-and-take' mode of stock enhancement. This is because the financial returns per animal surviving to harvest size are likely to be low. In contrast, if sufficient numbers of animals survive and are protected from fishing, the flow-on benefits to restoring larval production of the population and promoting self-recruitment at sites could make restocking cost-effective in the long term. The latter case of restocking requires a fishery closure at the release site for long enough to allow several reproductive seasons of the surviving animals (Bell and Nash, 2004).

In contrast to the volume of literature on culture methods for sea cucumbers, the published information on restocking is limited. The success of restocking marine invertebrates is poor unless the protocols for releasing hatchery-produced juveniles are well determined (e.g. queen conch, Stoner and Glazer, 1998; rock lobster, Mills *et al.*, in press; abalone, Heasman *et al.*, 2003). It can be detrimental to future programs when restocking is conducted without an understanding of these release criteria, because poor success due to inappropriate release methods can be inferred as proof that restocking with that species is not viable. To ensure that restocking reaches its full potential, credible experiments must be conducted to determine where, when and how to release juvenile sea cucumbers so that post-release survival and growth are maximised (Battaglene and Bell, 1999).

Once release criteria are identified by field experiments, research is still needed to show the efficacy of larger-scale restocking (Leber, 1999). The second phase of experiments would need to be longer in duration to allow an assessment of the relative costs per animal surviving to a mature size. Of importance too is knowledge of the number of breeders needed to regenerate the fishery through self-recruitment. The methods used in these two research phases - identifying release criteria and assessing cost-effectiveness of restocking - will differ due to the scale and time frames of the experiments. The focus of this paper is to illustrate some of the considerations for these experiments, using examples from current research from a collaborative program in New Caledonia on the development of restocking methods for the sandfish, *Holothuria scabra*.

Release Strategies

Establishing criteria for release

Experiments on release methods are important in the case of sea cucumbers because hatchery-produced juveniles (Figure 1) are vulnerable to predators (Dance *et al.*, 2003) and can undergo stress upon release into the wild or during transport from the hatchery to the release site. The hatchery environment is quite different from natural habitats. Natural behaviours, such as seeking refuge, predator avoidance and feeding, may be poorly developed at the time of release. Research is needed to identify modes of transport that minimise stress, then to determine the best strategies for the locations, habitats, juvenile sizes and times of release (Purcell *et al.*, 2002).

Figure 1*. A group of juvenile* Holothuria scabra *(1-5 g) produced in the hatchery in New Caledonia, ready for release in an experiment to test restocking strategies. (Photo: S. Purcell).*

Preserving genetic diversity

A prerequisite for releasing juvenile sea cucumbers, either for experimental purposes or for restocking, is to minimise the risk of modifying the genetic diversity of stocks at release sites. This is an issue when juveniles are translocated to non-native sites, i.e. away from sites where the parental stock was collected. This issue goes beyond theoretical concepts of genetic contamination, as empirical examples from stocking of fishes show that the genetic effects of translocations tend to be detrimental to wild stocks, and that these effects can be irreversible (Hindar *et al.*, 1991; Waples, 1995; Utter, 1998).

In the case of sea cucumbers, some species, such as *Holothuria scabra*, can have restricted gene flow between populations over distances of less than 100 km (Uthicke and Purcell, in press), whereas gene flow can be relatively broad for other species, like *Holothuria nobilis* (Uthicke and Benzie, 2000). If the juveniles are to be translocated away from native sites, genetic studies should be conducted to determine if stocks (albeit remnant) at release sites are different from parental stocks. In New Caledonia, two southern sites were excluded for release experiments because populations there were found to be significantly different from populations at other release sites and from populations where broodstock were collected. Efforts should also be made to use as many spawning broodstock as possible to produce a group of juveniles with a range of alleles reflecting the breadth of genetic variation within the parental stock.

Transfer of disease

Before releasing progeny from the hatchery, strict checks for disease and parasites should be carried out to avoid introduction of harmful organisms to the wild stock. Diseases and parasites for sea cucumbers are not well documented but this is an area of recent research (Eeckhaut *et al.*, 2004; Wang *et al.*, 2004). Diseases can arise from bacterial, fungal and viral infections and are more associated with intensive culture conditions in the hatchery. Limits should be set *a priori* on the acceptable level of disease, parasites and infections of juveniles to be released from the hatchery. The entire group of juveniles should be quarantined and not used for restocking if an unacceptable proportion is unfit as this may indicate that a high number are disease carriers. Further research is needed to understand the frequency and range of diseases occurring naturally in wild juveniles so comparisons with the situations in hatcheries can be made.

Transportation methods

Transport and handling from the hatchery to the wild are stressful and juveniles can die or become vulnerable to predators if transportation methods are crude. It is necessary to know the densities and duration of transport that can be comfortably sustained by the animals without producing adverse effects, particularly for restocking to distant sites. Juvenile sandfish produced in the hatchery have proven to be very hardy for transport at high density over 24 h (Purcell *et al.*, in prep).

Reducing the temperature for transport may be useful in reducing the activity of juveniles and promote lower rates of oxygen consumption and excretion of wastes. However, caution is needed when modifying transport temperature because juveniles may be more prone to temperature shock once released into warmer water in the wild. Some effort should be made to determine the best transport media, which may not be water. For instance, substrata such as damp cloth or vegetation have been shown to be better transport media than water for many other marine invertebrates used in stock enhancement, such as trochus (Dobson, 2001) and abalone (Heasman *et al.*, 2003).

Habitats for release

The best habitats for releasing juveniles may not be the same as the habitats where adults are found. Recruitment of larvae may occur in certain habitats, with juveniles migrating to 'adult habitats' later in life. Settlement of sandfish can occur in shallow seagrass beds (Mercier *et al.*, 2000) and distributional patterns suggest that they move to deeper areas later in life at some sites (Hamel *et al.*, 2001). Adult habitats may offer better foods but a higher risk to predators, or may not have suitable substrata for larval settlement. Moreover, juveniles may survive and grow better in certain micro-habitats within the general habitat in which they occur with adults.

A study in New Caledonia showed that micro-habitat features can account for a majority of the variation in the survival of hatchery-produced sandfish released in the wild (Purcell and Blockmans, unpublished data). In optimal habitats, survival of juveniles released into enclosures (non-covered) over one week was consistently greater than 90 %, whereas survival in other habitats was much lower and highly variable. Identifying the right habitat features to release juveniles is thus critical for restocking.

Experiments should examine a broad range of biotic and abiotic variables, rather than testing habitat types (e.g. "shallow seagrass") that are too broad and can vary in specific features from one location to another. In New Caledonia, the percentage survival of juvenile sandfish released into enclosures was often highly variable at the scale of tens of metres, with standard deviations averaging 32 % of the mean (n = 12 experimental treatment combinations). A high level of replication is therefore needed at local (e.g. within-site) scales, in addition to broader (e.g. site or location) scales, in field experiments on restocking strategies.

Size and density for release

The time and space required to culture sea cucumber juveniles to a large size is a primary impediment to land-based culture. Large-scale enhancement trials with other marine taxa indicate higher survival of hatchery-produced juveniles when released at a larger size (Zhao *et al.*, 1991; Bell, 1992; Munro and Bell, 1997). Releases of hatchery-produced juvenile *Apostichopus japonicus* into ponds in China indicate that survival is positively related to size (Chang *et al.*, 2004). Clearly, the germane issue is the trade-off in costs to produce large juveniles compared with the increased post-release survival. It could be that producing and releasing many more small juveniles at low cost is more economical for restocking, despite lower survival (e.g. Zhao *et al.*, 1991). A sound knowledge of the most cost-effective size for release is thus vital to the economic viability of a restocking program. Evaluating the optimal size-at-release requires knowledge of rates of survival and production costs for juveniles of various sizes, which is part of a program in New Caledonia on developing methods for restocking of sandfish (Purcell *et al.*, 2002).

Studies have shown that restocking of temperate abalone would be most effective at low density, because survival of released progeny is positively density-dependent (e.g. Heasman, 2003). The effect of the density of released juvenile sea cucumbers on their survival in restocking should therefore be investigated.

***Figure 2.** Juvenile sandfish (*Holothuria scabra*) produced at a hatchery in New Caledonia. The sizes range from about 2 g to 15 g. Knowing which size is most cost-effective for release is pivotal to restocking (Photo: S. Purcell).*

Times for release

The time of release of sea cucumbers into the wild could be important because they have diurnal behaviours, which may make them less susceptible to predators at certain times. For example, juvenile sandfish have a daily burrowing cycle in which they hide in mud during the day, and would be less vulnerable to visual predators during daytime (Mercier *et al.* 1999, 2000). Dance *et al.* (2003) hypothesised that releases would be better at night when predators are less abundant. However, juvenile sandfish released in New Caledonia survived equally at different release times, indicating that this was not a critical release criterion at that site (Purcell, unpubl. data). In that experiment, the juveniles took some hours to burrow and were presumably vulnerable immediately upon release. Thus, the time of release may be important only at sites where predators are active at certain times.

Seasons for release

Similarly, the release season is likely to have an important bearing on survival and growth of juveniles, mainly in sub-tropical/high-latitude sites. The natural spawning period for sandfish in New Caledonia is November to February (Conand, 1993) and the pentactula larvae would settle on seagrass blades after a couple weeks in the plankton (Mercier *et al.*, 2000). Natural recruitment to the benthic population living on and in the sediments would presumably be at least a month or more after the juveniles had gained size from feeding epiphytically on the seagrass.

Two release experiments using juvenile sandfish (of approximately the same size and from the same culture batch) were conducted in New Caledonia at the same site using similar methodology during two months, April and July. Juveniles of this size would probably occur predominantly from February to April, in view of spawning in November to January (Conand, 1993). Although this comparison is limited to just two periods, the results suggest that releases of juveniles are best in the natural season for recruitment. In July (winter), survival of juveniles was lower and the average growth was slightly negative, compared with high survival and positive growth in April (Figure 3).

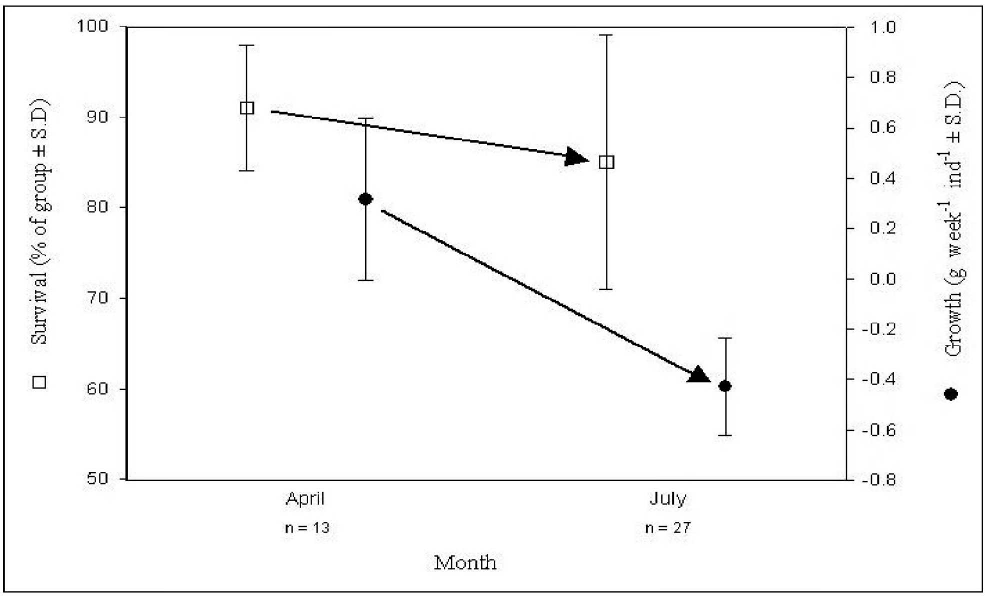

***Figure 3.** Mean estimates for survival and growth of hatchery-produced juvenile sandfish (1-10 g) released in two experiments at Ouano, New Caledonia. To compare seasonal differences, the data for the April experiment are displayed only for enclosures in the same habitat used in the July experiment. Arrows indicate trends in the seasonal changes in survival and growth. The numbers of enclosures (n), which each received 25 juveniles, are indicated below the graph.*

Behavioural conditioning of juveniles

The juveniles of many sea cucumber species are rarely found in the wild. Very small juvenile sandfish of less than 10 mm in length were found by Mercier *et al.* (2000) on seagrass blades when still in the initial phase of feeding on hard surfaces. They also found that, once off seagrass, wild sandfish juveniles (10-100 mm) predominantly burrow in sediments during the morning and early afternoon, and only 5-15 % of individuals can be found on the surface at these times. In contrast, Mercier *et al.* (1999) showed that a greater proportion (>20 %) of hatchery-produced juveniles are on the surface in the morning and early afternoon. Likewise, results from the field releases in New Caledonia show that around 15-75 % of hatchery-produced juveniles are on the surface (Figure 4) during morning and early afternoon at the end of three separate experiments (Figure 5). Hatchery-produced juveniles therefore appear to be less cryptic than wild juveniles of the same size range.

Figure 4. *A hatchery-produced juvenile sandfish (approx. 3 g), in the centre of the photo, partially buried in sediments at a field site in New Caledonia. (Photo: S. Purcell).*

A common problem with restocking of marine invertebrates is the naïve behaviour of cultured juveniles compared to wild ones, particularly regarding behaviour in seeking refuge (e.g. abalone, Schiel and Welden, 1987; queen conch, Stoner and Glazer, 1998). If the burrowing of sandfish during the day is a natural behaviour to avoid predation, as suggested by Mercier *et al.* (1999), the findings suggest a benefit in releasing juveniles from the hatchery earlier and at a smaller size to avoid the development of naïve behaviours from long-term culture. It may also be advantageous to employ methods for behavioural conditioning at the hatchery to encourage a higher frequency of burrowing of sea cucumber juveniles like sandfish, or cryptic behaviour in reef species.

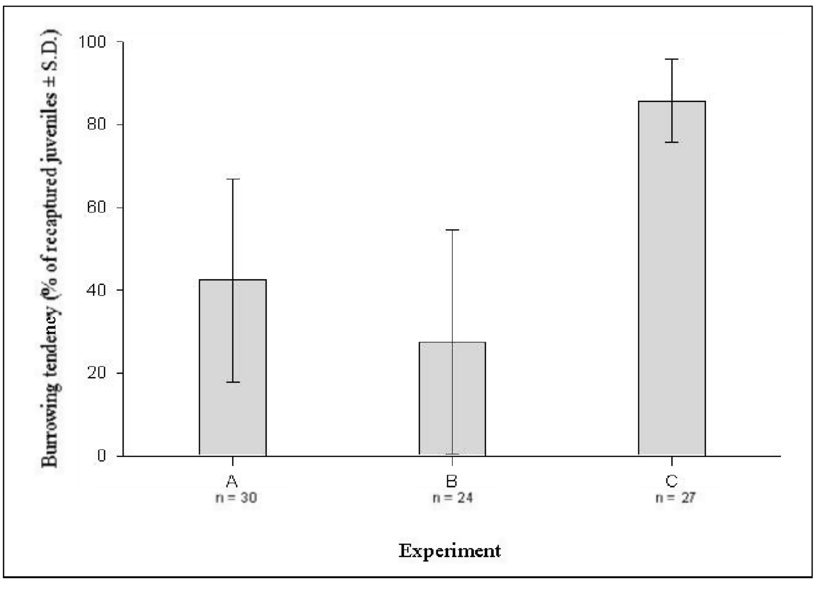

Figure 5. *Bar graph of mean percentage of hatchery-produced juveniles buried in sediments in the wild at the end of three release experiments in New Caledonia.* ***A****: experiment using 2-10 g juveniles, 8-10 d duration, 25 juveniles per enclosure, n = 30 enclosures.* ***B****: experiment using 2-10 g juveniles, 5 weeks duration, 25 juveniles per enclosure, n = 24 enclosures.* ***C****: experiment using 1-5 g juveniles, 5-7 d, 25 juveniles per enclosure, n = 27 enclosures.*

Acclimation of juveniles

Acclimation of juveniles in the wild before releasing them to the risks of predation is a further approach that could increase survival rates for restocking programs. Enclosures or cages for temporarily holding juveniles could be placed at sites prior to release, acting as an intermediate 'half-way-home' to acclimate juveniles during the first days or weeks of release. Predation can be intense in the early stages of releasing sea cucumbers, particularly from fishes (Dance *et al.*, 2003). An experiment in New Caledonia indicated that survival of sandfish could be increased twofold in the first month of release by containing the juveniles in enclosures to exclude large predators (Purcell and Blockmans, unpubl. data).

Protecting juveniles until they recover from the stress of translocation, or until they reach a larger size, could increase the success of restocking (Dance *et al.*, 2003) and could overcome to some extent the need for pre-release behavioural conditioning. But containing juveniles for long periods of grow-out is impractical when considering high numbers, such as hundreds of thousands, as this would need large areas of enclosures.

Assessing restocking success

There is much recent interest worldwide in restocking of sea cucumbers in the wild using hatchery-produced juveniles (Battaglene and Bell, 1999). However, no study to date has evaluated this approach, by estimating the survival of juveniles released in the wild, to know if it is viable for rebuilding breeding populations.

Once release methods are developed, studies should be conducted to estimate the rates of post-release survival (Bell and Nash, 2004), at least over the short-term. In this regard, marking juveniles with a long-lasting tag would be an effective way to test the success of restocking. Tagging studies could permit an evaluation of temporal changes in mortality rates, sightability in surveys and movement of released animals, which would allow a forecasting of the likely survival and time frames for replenishment of breeding populations. Some visual and chemical tags have been successful for relatively short periods (Harriott, 1980; FAO, 1990), but are not applicable for marking juveniles that need to be identified 2-3 years later. Some genetic tagging methods are available (Shaklee and Bentzen, 1988), but these rely on selecting broodstock with rare alleles and it is unclear that this approach would not contaminate the genetic diversity of remnant stocks at release sites (even when supposedly selectively-neutral markers are used). The development of a simple chemical or visual tag for juveniles is needed, as noted by Hamel *et al.* (2001). Until tagging methods for juveniles are developed, such research is likely to utilise experimental designs involving multiple release sites and control sites without released animals (discussed below).

Two possible designs that could be used to assess the effects of restocking, for example two years after juveniles are released and expected to be at a mature size, are illustrated in Figure 6. In both cases, there is a residual population of the species of sea cucumber at the time of release, and the release sites and control sites are both protected from poaching or fishing. These two designs are explained in more detail below and anticipate some natural recovery of the populations at control sites, due to natural recruitment, but increased recovery at release sites due to the release of juveniles.

Figure 6A illustrates a BACI (Before-After-Control-Impact) design (after Green, 1979) in which surveys are conducted at a release site and a control site, both before and after the restocking effect (i.e. after 2 years). Due to variability among replicate surveys at the restocked site, the power of this design to detect a restocking effect is relatively weak and the estimate of population increase would have a large error.

In contrast, Figure 6B illustrates a simplified version of the "Beyond BACI" design (Underwood, 1991, 1992), in which multiple control sites are used and the surveys are conducted at multiple times before and after the restocking effect. The design is more powerful for detect restocking effects and should not necessarily be restricted to one restocked site. If abundances of sea cucumbers vary seasonally, for example due to migration or shifts in cryptic behaviour, then Non-Linear Mixed Effects models are more appropriate, and rely on repeated surveys through time.

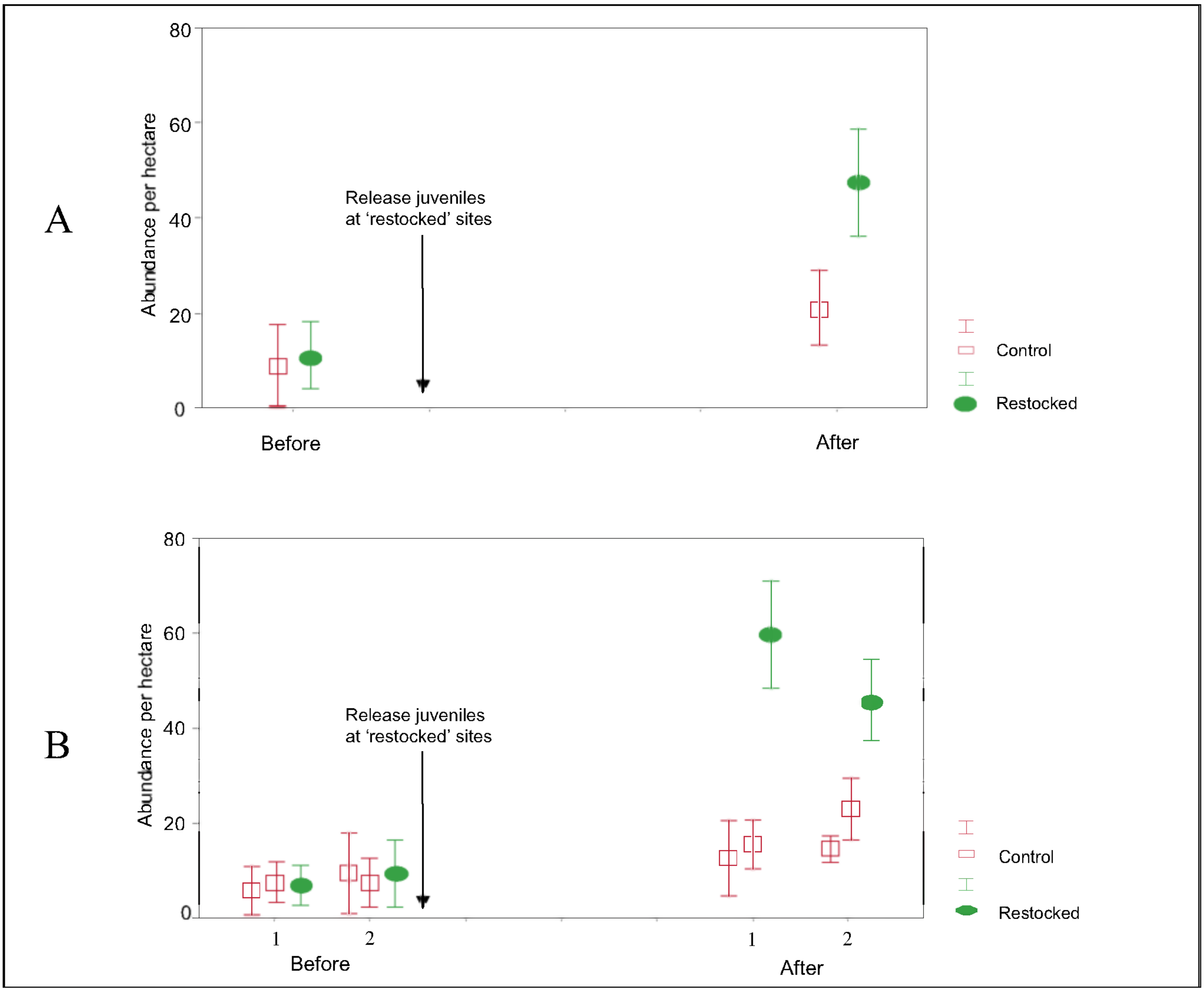

Figure 6. *Plots of mean abundance with error bars at sites in a hypothetical experiment to test restocking of sea cucumbers.* ***A*** *= BACI design;* ***B*** *= Beyond BACI design. The "After" surveys could be, for example, 2 years post-release when released animals would be mature.*

Further to experiments on release methods, cost-benefit analyses at a scale relevant for fishery replenishment will require larger experiments and an accurate evaluation of restocking effects beyond natural recruitment. It is therefore essential to define the explicit indicators of restocking success, in terms of contribution to fishery production, and how these indicators will be measured (Leber, 1999). In order to assess the potential of restocking, the time frames to detect effects should be long enough to allow the hatchery-produced juveniles to reach maturity and contribute reproductively to rebuilding stocks (Heppell and Crowder, 1998). It is likely to be safer to restock at multiple release sites because larval dispersal can be restricted (Uthicke and Purcell, in press) and therefore would result mainly in localised replenishment of neighbouring grounds, and because the survival of juveniles at some sites may be unexpectedly poor.

Conclusions

To enable the release of hatchery-produced juveniles to restore depleted stocks, management plans must protect the sea cucumbers from fishing. The surviving animals can then contribute to egg production and natural rebuilding of the stock on a broader scale. For restocking programs to be cost-effective, criteria for release will need to be determined well. Experiments in New Caledonia have confirmed that survival and growth can be significantly improved if we can understand how, where and when to release the juveniles. Tagging studies would be useful for understanding the post-release survival rates of juveniles over time, but long-term tags for juvenile sea cucumbers need to be developed. Researchers should then take care in designing experiments to test large-scale restocking so that natural variability in time and space are accounted for, otherwise, these factors may well reduce the power of large-scale (and expensive) experiments to detect and estimate restocking effects.

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Sea cucumber fishery in Tanzania: identifying the gaps in resource inventory and management

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Abstract

The story of over-exploitation 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 homemade goggles and (iii) SCUBA diving in a few locations. Neither fishery regulations, nor mariculture or resource inventories have been conducted as steps towards management and conservation of sea cucumber in Tanzania. Data was compiled from various works carried out on the sea cucumber resource in Tanzania and from questionnaires that were given to sea cucumber dealers and fishery officials. This approach revealed several factors underlying the lack of management of sea cucumber resources, notably (a) the extent to which the stock size of this resource is known to fishers of Tanzania, (b) the lack of a proper management framework and stock assessment on sea cucumbers, and (c) scientific orientation of funding agencies and research findings contrary to dealers' level of education and technological capacity. The appropriate actions to achieve successful management of sea cucumbers should be taken in phases. That is, to raise the fishers awareness, carry out resource assessment, implementation of regulations and establishment of a pilot small-scale mariculture activity of the most known species in Tanzania, *Holothuria scabra.*

Keywords: Holothurians, exploitation, mariculture, Western Indian Ocean

坦桑尼亚的海参渔业：资源量和渔业管理之间的差距

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摘要

坦桑尼亚海参资源遭到过度捕捞在印度洋地区广为人知。捕捞的方法有以下几种：（1）手拣，（2）戴上自制的潜水镜潜水捕捞，（3）穿轻潜水服潜水捕捞。在坦桑尼亚既无渔业法规，也无海参养殖，更不了解本国的海参资源量，故在资源管理和保护上举步维艰。本文中的资料来自于不同途径，有来自于分发给海参商贩的调查问卷，也有渔业官员提供的情况。结果显示，根本性的问题是缺乏对海参资源的管理：（1）不了解坦桑尼亚海参资源的状况，（2）缺乏一套对海参资源施行正确管理的框架和资源评估方法，（3）资助机构和科研部门所确定的方向与海参商贩的文化素质、技术能力相悖。 欲在海参渔业管理上取得成功，应该采取如下措施：让渔民了解海参的现状，开展资源评估，执行渔业法规，以及在坦桑尼亚建立一个示范性的海参养殖场，来繁殖培育坦桑尼亚最有名的糙海参（*Holothuria scabra*）

关键词：海参、开发、海水养殖、西印度洋

Introduction

Sea cucumbers have been harvested in the Indo-Pacific region for over 1 000 years (Hamel *et al.*, 2001). In East Africa the fishery began in the 18th century (Conand and Sloan, 1989). However, inadequate management of the sea cucumber fishery has resulted in severe overfishing in many countries, resulting in widespread depletion of stock.

Overfished populations of sea cucumbers, especially *Holothuria scabra,* could take decades to recover if harvesting continues, unless ways to protect or manage the stock are implemented. James *et al.* (1994) suggested that most overexploited species are likely to be depleted unless conservation measures are adopted. Lokani (1996) proposed a number of potential measures to protect the resource. These include: establishment of minimum size limit for capture, introducing strict quotas, limiting numbers of fishers, closed seasons, banning SCUBA diving, establishing reserves and promoting stock enhancement.

In recent times, numerous countries have increased interventions to protect the resource through different approaches (Hashim *et al.*, 1999). In Malaysia, the Malaysia Network for Holothurians Conservation established conservative management guidelines and baseline surveys prior to the start of a fishery (Hashim *et al.*, 1999). There is also a national programme to monitor sea cucumber fisheries at the landing sites (Baine and Choo, 1999). In Saipan Mariana Island, the Association of Coastal Resources Management Office (CRMO) conducts surveys of sea cucumber resources and documents any changes in populations (Tsuda, 1997). In the Galápagos Islands, prohibition of fishing for sea cucumber was a presidential decree (Martinez, 2001) and they practice a consensus-based, participatory management involving fishing, tourism, science, education and the national port authority.

In some areas of India, fisheries are restricted in waters between 2 and 3 m depth as juveniles are located in shallow coastal waters (Guruman and Krishnamurthy, 1994). In Yemen protective measures include the minimal legal fresh size limit of 10 cm and restriction of the harvest season (Gentle, 1985).

Sea cucumber fishery in Tanzania

During the first fishery survey in Tanzania, completed in 1963 (FAO/UNDP, 1964), emphasis was placed on efficient exploitation of the aquatic environment including marine waters (Singh, 1976). Sea cucumbers constitute one of the marine resources of Tanzania (Semesi *et al.*, 1998). There has been rapid expansion of sea cucumber exploitation at some sites of Tanzania (Mgaya *et al.*, 1999). The fishery developed without baseline biological data and without any monitoring. Therefore to date, Tanzania has an unknown and unquantified resource of sea cucumber, but the fishery provides income to local collectors and generates exports. The fishery is largely artisanal with small commercial operations owned by exporters. Tanzania does not yet have the resources for regulation or to enforce restrictions on catches.

Local exploitation occurs year-round on reefs close to the shore sheltered from prevailing winds. The main collection seasons are October to December and April to May when winds are usually light, and trips can be made to the outer reefs. Sea cucumbers are purchased by a number of traders based in Dar Es Salaam, Tanga and Zanzibar from where they are exported to eastern Asia and elsewhere, mainly Hong Kong SAR (China) and Singapore (Marshall *et al.*, 2001). Some importation statistics for sea cucumbers collected at Hong Kong during January-March 1996 showed that Tanzania ranks high in the Western Indian Ocean region (Infofish Trade News, 1996). Apart from official trade records, during this survey, traders claimed that illegal and unrecorded trade in beche-de-mer exists between Zanzibar, Tanga, Dar Es Salaam and Mombasa, Kenya. Barnett (1997) reported that beche-de-mer is sometimes exported as fish offal or fish maws to evade duty. Table 1 depicts official export figures for the period 1989 to 1997, showing the increase in the trade flow over the years.

Table 1. *Official beche-de-mer export statistics from Tanzania from (1989-1997 (metric tonnes).*

Year	1989	1990	1991	1992	1993	1994	1995	1996	1997
Export (tonnes)	107.9	189.2	193.0	219.9	398.2	565.6	292.8	324.6	277.9
Export (US$)	333 143	460 030	351 299	414 449	481 098	884 169	353 910	450 405	-

Source: Marshall et al., (2001).

The age and scale of various fisheries can be estimated from historical export data. In Tanzania it is not known whether the historical activity of the sea cucumber fishery fluctuated according to resource availability or for other reasons, and whether the fishery has been exploited on sustainable basis. However, during an informal interview with retired fishers, the common issue that arose was that trawling by commercial harvesters of prawns in the 1970s was clandestinely fishing for sea cucumbers. This trend is still active in the southern regions of Tanzania. Commercial prawn trawlers in Kilwa and Bagamoyo often land a small by-catch of sea cucumbers. Commercial species collected in Tanzanian waters are shown in Table 2.

Some studies that have been done along some coastal villages in Tanzania are part of wider programmes of research work. These studies are generally scattered and localised to specific areas such that there is no national approach for establishment of fishery regulations and management of the resource.

Table 2. *Commercial species of sea cucumber in Tanzania (Source: Modified from Richmond, 2002).*

Scientific name	Common name	Local name	Value[1]
Actinopyga mauritiana	Surf Redfish	Mbura-Khaki	2
A. miliaris	Blackfish	Kijino	2
Bohadschia argus	Leopardfish	Barango	3
Holothuria atra	Lollyfish	Pesa	3
H. edulis	Pinkfish	-	3
H. fuscogilva	White Teatfish	Pauni-nyeupe	1
H. leucospilota	-	Sumu	3
H. nobilis	Black Teatfish	Pauni–nyeusi/Chui	1
H. scabra	Sandfish	Jongoo mchanga	1*
Thelenota ananas	Prickly Redfish	Spinyo mama	2

*Note1: Value rankings: * = the most over-exploited species, 1= high, 2= medium, 3= low.*

Collectors and opportunists sell the sea cucumbers to the processors at prices ranging from US$ 0.10 to 0.50 per fresh animal, processors sell the dried product to middlemen for US$ 0.90 to 6.00/kg, who in turn sell to exporters at US$ 3.00 to 17.00/kg dry weight. The export prices range from US$ 1.80 to 23.70/kg dry weight (some after reprocessing).

Resource assessment and fishery regulation

The fishery and processing activities are generally carried out by small scale localised enterprises, therefore statistics are scarce, not detailed and resource assessment is generally based on direct visual evaluation (Mmbaga, 2002). There is general lack of fishery management.

According to the Fisheries Act of 1970 and the Fisheries (General Amendment) Regulations of 1997 there are three types of licence fees paid annually by dealers and exporters. These licences include, (a) Local-individual or company with approved shore-based fish processing facilities, (b) Local-individual or company without approved shore-based fish processing facilities, and (c) Foreigner-individual or company with approved shore-based fish processing facilities. Foreigner-individual or company without approved shore-based fish processing facilities is prohibited (Marshall *et al.*, 2001). There is no specific legislation existing in Tanzania that refers to sea cucumbers and indicators of overexploitation are seen in many landing sites (Mmbaga, 2002).

This study aims to identify the knowledge gaps and analyses the existing situation in order to determine the proper ways to train fishers, processors and traders for better resource inventory and management.

Materials and methods

Study sites

Site selection was based on the extent of sea cucumber fishing, infrastructure, distance from the main port and disturbances due to tourist activities. Kunduchi (long exploited site and most disturbed shore), is compared to Sahare (in Tanga, the north region of Tanzania), Kaole at Bagamoyo (a moderately disturbed site with a long history of exploitation), Mjimwema (near the port South of Dar Es Salaam with no history of exploitation), Buyuni (remote site of Dar Es Salaam with poor infrastructure and undisturbed site) and Kilwa Masoko (disturbed site with a long history of exploitation south of Dar Es Salaam). These sites represent main sea cucumber exploitation areas along the mainland coast of Tanzania.

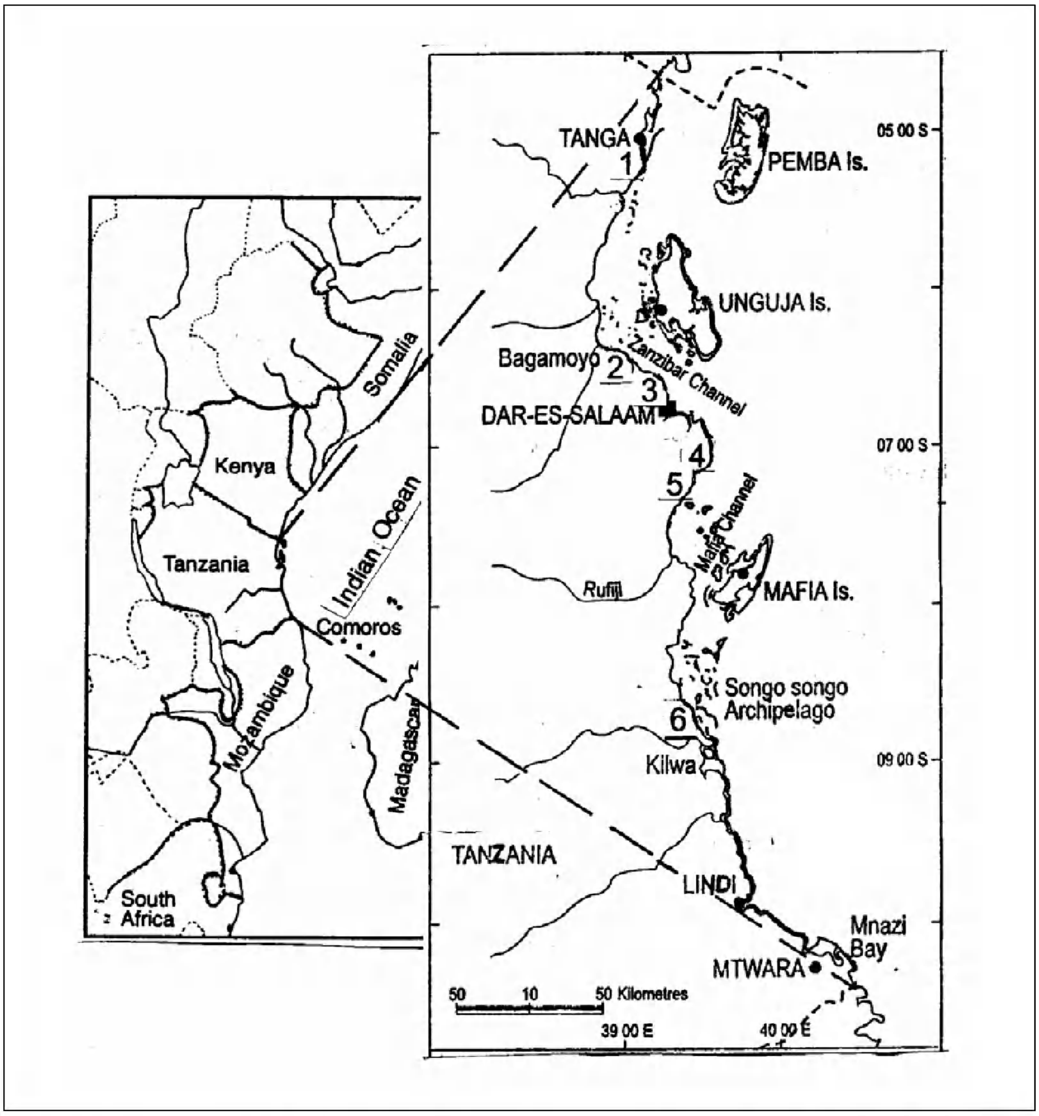

Figure 1. Map showing study sites: 1. Sahare, 2. Kaole, 3. Kunduchi, 4. Mjimwema, 5. Buyuni, 6. Kilwa.

Data collection

Data on sea cucumbers from studies so far carried out in Tanzania was searched from libraries and the internet while information on potential and key issues for mariculture in Tanzania was obtained using informal interviews and questionnaires given to sea cucumber dealers at the landing sites, homes, market places, and also to mariculture specialists and fisheries authorities. Data were collected from January to September 2002. The main characteristics of the surveyed population were obtained by noting: geographical distribution, number of people and gender, age, civil status, principal occupation, part played in sea cucumber fishery, education, access to sea cucumber information (fishers, radio, newspapers, TV and the internet) and communication with other sea cucumber dealers.

Results

A review of sea cucumber studies carried out in Tanzania revealed that most recommendations relate to fishery resource use and management measures (Table 3). No study on the sea cucumber stock size and area conducive for sea cucumber mariculture has been conducted in Tanzania. The recommendations from the studies do not show a methodological approach to be used in implementation of management measures.

***Table 3**. Review of previous studies carried out on sea cucumbers in Tanzania.*

Study	Coverage	Study category	General / Specific species	Recommendations
Tanzania/SWIOP (1985)	Handling and processing of sea cucumbers (Dar Es Salaam)	RU	General	Collectors and processors could gain by joining to form co-operatives.
Darwall (1996)	Resource use (Songo Songo)	RU	General	Appropriate conservation, management and regulatory measure.
Jiddawi (1997)	Reef dependent fisheries (Zanzibar)	GE	General	Sea cucumbers be looked upon and considered for farming.
Guard (1998)	Resource use (Mtwara)	RU	General	Regulatory measures should be established.
Horsfall (1998)	Sea cucumber depletion indicators (Tanzania)	DI	General	The role of sea cucumber on coral reefs and effect of their over-exploitation should be studied.
Mgaya *et al.* (1999)	Fishery and resource use in Bagamoyo District	RE	General	Need for effective enforcement of existing regulations and proper management.
Marshall *et al.* (2001)	Trade (Tanzania)	T	General	Develop legislation, limiting exports of juveniles and closed seasons in depleted areas.
Mmbaga (2002)	Fishery, ecology (Traded species) and biology of *Holothuria scabra* (Dar Es Salaam)	FEB	Specific	Provision of permanent transect for extensive data collection. Establishment of section to deal with: Stock assessment, Licensing, Quality control and Educational programmes.
Kithakeni & Ndaro (2002)	Some aspects of reproductive biology of *Holothuria scabra* (Dar Es Salaam)	RB	Specific species	Banning harvesting of juvenile *H. scabra* below 16.8 cm and during spawning season (August-September and December-January). More studies needed on the status of the resource. Application of closed season in most overexploited shores.

*Key: **RU** =Resource Use, **GE** = General Ecology, **DI** = Depletion Indicators, **RE** = Resource Evaluation, **RB** =Reproductive Biology, **T** = Trade, **FEB** = Fishery Ecology and Biology.*

Questionnaire findings

The percentage contribution of sea cucumber dealers for each village, out of the total number of dealers in sites surveyed, varied widely (Figure 2). The proportional number of dealers depended on the level of awareness, sea cucumber abundance, infrastructure development, nature of the shore and species available. The number of sea cucumber dealers was not the same all the year round. During the survey, a shifting of dealers was noted depending on the weather and abundance of sea cucumbers. Once the weather turns poor or an area is depleted, dealers move to the next shore where the animals are abundant.

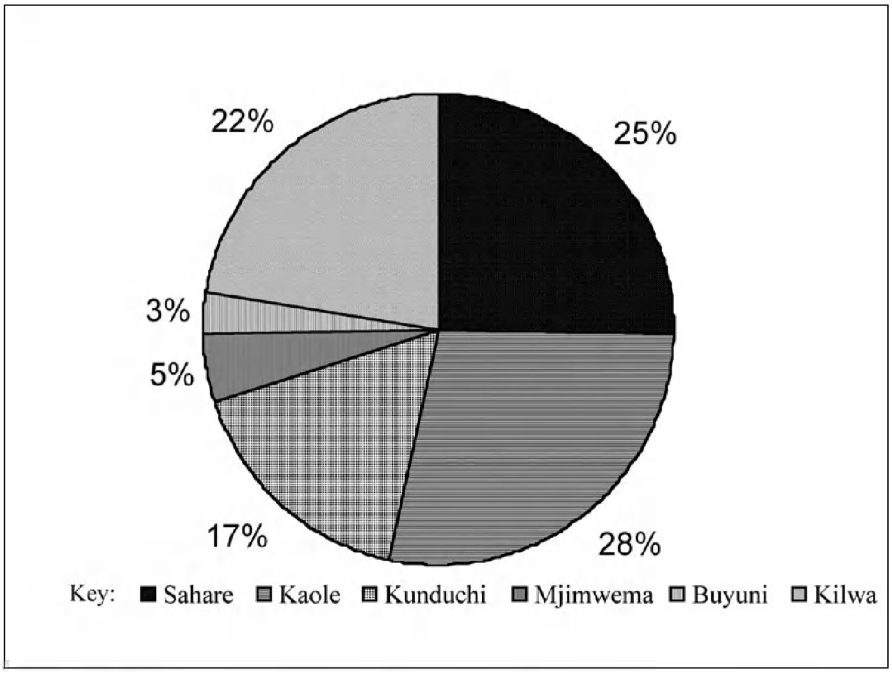

Figure 2. *Percentage number of sea cucumber dealers in the selected sites.*

The percentage of opportunists (people who collect sea cucumbers just because they have come across them) is high (32 %) compared to other dealers, namely, collectors (23 %), middlemen (17 %), processors (16 %) and traders (12 %) in the fishery.

Adult males predominantly operate this fishery (male = 99 %, female = 1 %) because collection is physically difficult. This is due to scarcity of the resource, which necessitates exploiting sub-tidal areas by diving. Married people indulge in sea cucumber fishery more than young unmarried people (66 % and 34 %, respectively).

Almost all adult male members (31-50 age group) of the remote coastal village communities participate in this fishery. Some peasants and people from other occupations collect sea cucumbers as a supplementary way to earn income (fishers 73 %, peasants 12 %, traders 12 %, middlemen 1 % and teachers 2 %). The large number of traders is an indicator of the lucrative nature of the business, as most processors are not aware of the relationship between prices and processed quality of sea cucumbers. For example, highly valued species like *Holothuria nobilis* and *H. scabra* are sold with low valued species.

Most sea cucumber dealers are primary school leavers (45 %) or below. Few secondary school leavers from Form 4 and 6 and diploma holders (19 %, 2 % and 2 % respectively) are middlemen and exporters in many surveyed areas. This implies that most of the information available (since it is in English language) cannot be understood and applied for fishery regulation and management of the resource.

The major source of information is from sea cucumber dealers (84 %), followed by television (10 %), newspapers and journals (3 %), radio (2 %) and the internet (2 %). There are neither NGOs nor dealers' associations addressing issues of sea cucumbers (e.g. overexploitation, legal size limits, prices in relation to species and required quality of the dried products in Tanzania). Problems faced by most sea cucumber dealers in this fishery include: lack of proper processing equipment, poor preparation knowledge, low price, lack of transport facilities to the selling station, scarcity of sea cucumbers in accessible depth and shores and lack of information on markets.

Some fishers are aware and against the collection of juveniles, but blame a lack of legal recognition of the traditional systems of management. Under the traditional system of management, older fishers command respect and authority on customs and traditions related to fishing practices. However, this system has collapsed as a result of the erosion of the authority of the elders as guardians of the system. Political developments (e.g. grouping of villages in communes) encouraged newcomers who did not feel that they had to submit to the authority of elders or adhere to long established customs. The elders' ability to impose sanctions on individuals who disregarded the regulations was hampered by the growing importance of government regulations.

Currently when sea cucumber dealers face problems related to price, quality and preparation methods they consult middlemen, processors and collectors. Middlemen, followed by the processors and collectors, seem to be the most informed group in this fishery in all surveyed sites.

Discussion

Problem analysis - sea cucumbers fishery

Most studies carried out on sea cucumbers in Tanzania are based on resource use, particularly processing, exploitation and trade. A recent study (Mmbaga, 2002) focused on reproductive biology of *Holothuria scabra*. Studies on biology, morphometrics, reproductive cycle and size at sexual maturity of most commercial species are lacking. Research results on the biology, stock status and trade can provide important information for application of surplus-yield models. The paucity of data on species catches and size of the processed products leads to a failure in management on a sustainable basis. These studies are essential if size limits and seasonal breeding closures are to be considered as management criteria (Conand, 1983). Some scientific methods of assessment have been employed in different countries to reveal the standing stock of sea cucumber depending on the nature of the fishery and environment (Conand, 1983).

For proper initiation of fishery management systems in Tanzania, the standing stock of commercial species should be assessed; catches should be recorded as a contribution on the fishery statistics. Broad scale patterns of distribution of commercially important species of holothurians combined with significant correlation of abundance with characteristics of the main habitats should be known. Surveys of boats, processors and traders of sea cucumber should be undertaken so as to get an insight into the status of the sea cucumber fishery in Tanzania.

The Tanzania/SWIOP workshop conducted in 1985 imparted some knowledge on how to process sea cucumbers. This was endorsed by some people (middlemen) among the surveyed group who admitted that the elementary knowledge they have was obtained from this workshop. The workshop on processing was vital for the fishery as the price of sea cucumber depended on their processed quality.

After many years of overexploitation, the sea cucumber price is currently affected by the reduced size of the animal and poor quality hence the differences in export earnings between Tanzania and neighbouring Madagascar. Although Tanzania leads in terms of tonnage (73.8 tonnes), the overall export income is lower (HK$ 1.676 m) compared to Madagascar (40.3 tonnes; HK$ 4.242 m). Low earnings are likely to continue as newcomers to the trade lack the necessary technology to prepare quality beche-de-mer.

The collectors, processors and some middlemen were concerned over the lack of sea cucumber fishery information (stock size, spatial distribution and biology). The information available in publications such as the *SPC Beche-de-Mer Information Bulletin* is not accessible to fishermen, given their low education, lack of money and lack of access to the internet. However, most of the surveyed population get information from their peers while a very few have information on processing methods from the 1985 Tanzania/SWIOP workshop documents, with others obtaining general fishery information from radio and television. This calls for an immediate start of a radio broadcast in Kiswahili, newspapers and television educational programmes to raise people's awareness about sea cucumbers and its fishery potential.

Tanzania, like other sea cucumber producing countries, should strive to disseminate information on sea cucumbers useful to dealers from within and outside the country. In Madagascar, Conand *et al.* (1998) suggested that sustainable management requires that scientific knowledge about the fishery biology be disseminated as soon as possible to dealers. Again, in Madagascar a National Trepang Traders group (ONET) has been set up to conduct national meetings to exchange information between the different participants in the beche-de-mer fisheries system (fishermen, processors, traders, administrators and scientists) (Hamel *et al.*, 2001).

Proper Management Framework

The lack of proper management in Tanzania is shown by a lack of documented regulations for the sea cucumber fishery. The Fisheries Act of 1970 is general and does not specify anything on sea cucumber exploitation and management. The Government should address the following issues: (i) research and documentation, (ii) identification and implementation of sustainable management actions, and (iii) exchange of information through seminars and workshops. The sustainable management of sea cucumber fisheries requires production models that combine data on fishery activity, population dynamics and socio-economic aspects that are particularly important for these small artisan activities (Hamel *et al*., 2001).

Poor management frameworks were also a problem in the past for other sea cucumber producing countries. For example, the government of Papua New Guinea imposed a partial moratorium to protect the endangered resource but, due to a lack of proper management frameworks, Lokani *et al.* (1995) indicated that the size limit of 15 cm and the gear restrictions did not prevent overfishing. The government of India imposed a ban on the export of small sea cucumbers in 1982, but this created a crisis in the Indian sea cucumber fishery industry (Silas *et al*., 1985). In the Solomon Islands the government banned the collection and sale of *Holothuria scabra* in 1997 (Battaglene, 1998), but illegal harvesting continued (Hamel *et al*., 2001).

An effective management framework for sea cucumbers has been achieved in some countries, e.g., by establishment of a sea cucumber fishery sector and association (ONET) in Madagascar (Conand *et al*., 1998), a Malaysian Network for Holothurians Conservation and Management (HCSM) (Baine and Choo, 1999) in Malaysia, PESCOM international in Mozambique (Dutton and Zolho, 1994; Costa and Montecino, 1990), and the Queensland East Coast Beche de mer Industry Association (QECBIA) in Australia (Schoppe, 2000). These sectors and organisations have clearly identified action plans for sustainable management that could be easily transferred to Tanzania.

Scientific orientation of funding agencies, research results and recommendations

Some funding agencies place emphasis on scientific content in the proposals at the expense of resource management and conservation. Emphasis should be placed on utilization of human resources within local communities which do not require skills beyond the capacity of the available personnel to monitor and implement recommendations. Most of the sea cucumber dealers surveyed (artisanal fishers) have a low level of education. Most of them are primary school leavers without any knowledge on fisheries biology and management. The findings from studies carried out in Tanzania have been difficult to understand by sea cucumber dealers who are unable to relate them to the everyday fishery practices.

Rewriting some research results and recommendations in simple language spoken or understood by sea cucumber dealers (possibly in Kiswahili) can fill this gap. This will raise understanding and ease implementation of shared management activities for sea cucumbers. In Madagascar, Conand *et al.* (1998) pointed out the shared management approach, involving the organised profession (exporters, harvesters), the fishery administration, the scientific research interests and local communities was established to reduce overexploitation of sea cucumbers.

Prospects for sea cucumber mariculture in Tanzania

The coastline of Tanzania consists of mangrove areas, seagrass meadows, fringing coral reefs, intertidal flats, estuarine lagoons and bays with high biodiversity and a relatively unspoiled environment (Ngoile and Francis, 2001) within which there are potential sites for mariculture (Muhando *et al*., 2001). The requirements for establishment of sea cucumber fishery management systems and mariculture include availability of information from fishery research (e.g. on its potential and standing stock). However, at a national level, the Division of Fisheries receives only limited funding for mariculture development while at the regional and district levels there is no budget for mariculture activities (Mafwenga, 1994).

One gap for Tanzania is the lack of understanding of the potential of sea cucumber mariculture as a supplementary economic activity. This is reflected by an overwhelming (86 %) number of respondents (including collectors, processors and middlemen) who endorsed lack of awareness on sea cucumber mariculture. The traders (14 %) expressed awareness on the potential of sea cucumber mariculture as an economic activity due to direct contact with sea cucumber traders in other countries.

Sea cucumber mariculture skills developed in other countries can be transferred to Tanzania in the same way as seaweed farming technology. In some cases, sea cucumber mariculture and seaweed farming can be integrated. Although sea cucumber development, mariculture research and technical capacity do not exist in Tanzania, technical assistance can be obtained through training, study tours and workshops.

Technological capacity

Generally sea cucumber dealers lack sea cucumber fishery and mariculture technology. The information from the Tanzania /SWIOP (1985) workshop is fading away and it is likely to continue diminishing as old fishers retire and newcomers to the business have no knowledge of this fishery. This was observed in various levels of the fishery, for example, the skipping of some procedures in the handling, preparation and drying methods of beche-de-mer. Different species are mixed and prepared by the same methods and procedures. This results in a low price at the selling station and no actions have been taken to make information available to the newcomers so as to rectify this problem.

Conclusion

In Tanzania, marine resources are regarded as belonging to the community. Open access to unmanaged sea cucumber resource will likely lead to depletion of the stock. However, to prevent such consequences, the FAO World Fisheries Conference in Rome (1983) recommended that governments should seek to ensure that fishers have clearly defined fishing rights and that the allowable catches do not exceed the productivity of the resource (King, 1995). Fishing methods for sea cucumbers are less selective, and protecting small individuals seems to be difficult. Therefore since beche-de-mer from Tanzania is for export, monitoring of legal size limits can be done at the level of the middlemen, buyers and exporters.

In the case of conservation and aquaculture, technical and financial support is necessary to effect changes in dealers' behaviour and for the adoption of new technology and management measures for sea cucumber resource in Tanzania. Collaborative efforts (community-based associations, policy-makers, researchers, educators, NGOs, funding agencies) are needed to ensure large-scale changes and rapid knowledge adoption. Associations should (i) plan an organised fishery system, (ii) set action plans appropriate to local setting, and (iii) be involved in the transfer of technology.

Recommendations

1. Resource assessments should be carried out by surveying all shallow areas to estimate the population (stock size) of each species traded in Tanzania and a socio-economic analysis carried out of the sea cucumber fishing community. Both governmental and non-governmental organizations could team up to accomplish this task.
2. Capacity building programmes (e.g., training, study tours, participation in national and international meetings and workshops on sea cucumbers) should be conducted and supported by both governmental and non-governmental organizations.
3. Law and policy enforcement should be ensured through regulatory mechanisms and collaborative management by government, dealers and private sectors to protect the wild sea cucumber stocks.
4. A demonstration sea cucumber farm should be established with the help of government institutions. This is expected to stimulate sea cucumber mariculture activities in the country.

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

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Abstract

Papua New Guinea annually exports more than 400 tonnes of dry beche-de-mer mainly to China Hong Kong SAR and Singapore. A total of 21 species are being harvested each year. The annual average for the last five years shows a gradual decline in catch rates each year. As a result, a National Beche-de-mer Fishery Management Plan was developed to manage the fishery in the country sustainably.

The objectives are to ensure that the economic benefits and social and environmental impacts of the fishery are recognised. Stakeholder participation is administered through the establishment of the National and Provincial Management Arrangements, among the most important advisory components of the management plan. This ensures that all stakeholders involved in the fishery are regularly advised on the management of the fishery. The representatives bring perspectives from different provinces so that many issues are considered when management recommendations are agreed.

A National Management Advisory Committee was formed and includes stakeholders from across the country. The Committee is appointed by the Papua New Guinea National Fisheries Authority and provides advice to the Managing Director on most of the key management measures as well as the need for revisions to the plan. The committees at the provincial level advise the National Management Advisory Committee on provincial management measures, thus forming a link with all stakeholders.

Management measures prescribe the type of licenses, licence eligibility, licence requirements, export requirements, prohibitions, closures and reporting requirements. Licensees are closely monitored by the National Fisheries Authority (NFA) to ensure they comply with all management measures. In particular, reporting by exporters is important as the reports provide the only trade information that NFA collects.

A Total Allowable Catch (TAC) is set for both the higher value species and the lower value species, as the more valuable species are more heavily fished. Once the TAC of a value group has been reached, the NFA closes the whole fishery as it is too difficult to monitor the harvest of just one value group.

Trade in undersized beche-de-mer is banned to protect the population. Trade of beche-de-mer in pieces is also banned to prevent undersized animals being broken up for sale, making detection of any undersized product difficult.

A single closed season applies for the whole country during the spawning season from 1st October to 15th 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 arises 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 are consistent with the plan are recognised by the National Fisheries Authority and will be incorporated into the plan as schedules.

Keywords: Management plan, National Management Advisory Committee, stakeholders participation

巴布亚新几内亚海参渔业管理计划

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摘要

巴布亚新几内亚每年大约向中国香港特别行政区和新加坡出口400吨干海参。出口的海参包含21个种。过去5年的捕捞资料显示，年捕捞量逐年呈现下降趋势。鉴于这一现状，制定了国家海参渔业管理计划，试图保持该渔业的可持续发展。

实施该计划的目的是为了保护渔民的经济利益和解决海参渔业所面临的社会和环境问题。全方位参与管理体系通过国家和省两级管理机构来实施，也是该管理计划中最重要的组成部分。它可以保证有关各方能够对海参渔业管理有序地提供咨询。各省的代表可以带着有待解决的问题要求解决。

巴布亚新几内亚渔业局指定成立了国家管理顾问委员会，其成员中覆盖全国的各有关方面。顾问委员会由向管理主任提供关键的管理措施，在必要的时候对计划进行修改。省级委员会向国家级顾问委员会提交各省的管理措施，这样就将有关各方连接在一起。

管理措施规定了执照的类别、执照的有效性、申请执照的必要条件、出口的必要条件，还规定了发布禁令和关闭渔场所要求的条件，以及提交报告的内容。国家渔业局对执照的发放和执行情况进行跟踪调查，以求各项管理措施得以实施。特别是出口商提供的报告极为重要，因为它是国家渔业局唯一的海参贸易信息来源。

总的可捕捞量包含高商品价值的海参和低价值海参两类，因为较高价值的海参往往会遭遇过度的捕捞。一旦某一类别海参的捕捞量已经达到规定的限额，国家渔业局将下令关闭整个渔场，因为很难对某一类别的海参捕捞量单独进行跟踪。

为了保护种群资源，个体大小未达标的海参禁止捕捞。在海参头数上也有规定，防止将未达标的海参切成碎片予以销售，因为切碎后的产品很难进行监控。

在海参繁殖季节，全国的海参渔场从10月1日到来年的1月15日全部关闭。对于某一个省而言，只要某一类别海参的配额已达到，或是禁捕季节已到，渔场将立即关闭。其它省的渔场尚可继续作业，直止捕捞配额已达到，或是禁捕期已到，才予以关闭。

任何传统的作业方式若与该计划相一致，渔业局将予以认可，并将其列入该计划中。

关键词：管理计划、国家管理顾问委员会、全方位参与

Introduction

Papua New Guinea (PNG) has an extensive and valuable fisheries sector. The largest fishery in PNG is the tuna fishery. Other significant sectors are shrimp, beche-de-mer, lobster, trochus (shell) and reef fish. There is also potential for inland river fisheries and aquaculture.

The Papua New Guinea exclusive fisheries zone of 2.4 million km^2 is one of the largest in the South Pacific. The fisheries zone includes an extended reef system, numerous islands and a long coastline. The vast area provides huge opportunities in terms of resources, but also presents an enormous challenge in terms of monitoring, control and surveillance.

The beche-de-mer fishery is one of the most important sources of income for local communities throughout coastal communities. The fishery has by far the greatest number of participants when compared to other commercial fisheries in the country. This is owing to the nature of the product and the simple, low technology method of processing, making it an ideal industry for the rural areas.

Establishment of the National Management Plan for the beche-de-mer fishery in 2000 was to mitigate any long-term unsustainable harvest in the country. The management plan was designed to manage the fishery to ensure sustainable exploitation of the beche-de-mer resource as well as to facilitate maximum economic return to the communities.

Description of the Fishery

The increasing demand for beche-de-mer from Asian markets and their over-exploitation in some of the neighbouring Pacific island countries has encouraged the introduction of tough management regimes to control the harvest of the fishery, but more importantly to maintain resource sustainability.

In the past only a handful of beche-de-mer species were considered valuable, but declining populations of these species in the last 20 years has led to the less favoured species being harvested increasingly. Today there are 20 different species harvested commercially in PNG.

There has been a marked decline in the volume of high value species and an increase in the volume of the low value species taken. The opening of the market to new species that traditionally had no commercial value has dramatically impacted on the volume of export. Figures for 2000 showed PNG exported about 607 tonnes, valued about K16.2 million. Of that, the low value species accounted for 61 % (370 tonnes), the remainder being high value species. In 2001, PNG exported 484 tonnes valued at about K17.2 million and again the low value species accounted for more than 60 % of the total export._

The price paid to fishers per unit (kina/kg) (1 kina ≈ US$ 0.31) has also increased dramatically (Table 1). In 1994, prices paid to fishers in PNG were said to range from K1/kg to K12/kg whilst importers paid from K4/kg to K23/kg. Valuable species fetched premium prices.

Table 1. *Beche-de-mer price changes from 1980 to 2001 in Papua New Guinea.*

Year	Product/Species	Location	Price ((Kina/kg)	Grade
1980-1983	Beche-de-mer	--	2.34 - 3.36	--
1985	Beche-de-mer	--	3.67	--
1986	Beche-de-mer	--	4.64	--
1994	Beche-de-mer	--	1 - 12	--
	Sandfish	North Solomons Province	12.19	--
	Sandfish	Manus Province	18	--
	White teatfish	North Solomons Province	30	C
	White teatfish	North Solomons Province	46	A
2000	Chalkfish	--	3.5	--
	Sandfish	--	60	A
2001	Chalkfish	--	10	--
	Sandfish	--	100	A

Despite its economic importance to PNG and the income provided to some 200 000 fishers scattered in coastal villages, the fishery is not well studied. The National Fisheries Authority (NFA) is therefore envisaging conducting 2 to 3 provincial stock assessments annually. This will be done in partnership with reputable public and/or private institutions. The research will update the information on growth, mortality, recruitment and movement patterns. These data are needed to estimate the yield and stock sizes required for the review of the management plan.

Socio-economic studies pertaining to the impact of the fishery on the communities is being considered, once the results of the community studies currently being conducted in Milne Bay Province (Trobriand Islands) by the National Research Institute (PNG) in collaboration with the Australia Maritime College are known.

Environmental Impacts

Beche-de-mer trade has had environmental impacts. In areas where product is smoked, mangrove stands may be deforested because trees are used as firewood. Estimates have been made that ten tonnes of wood is needed to smoke 1 tonne of beche-de-mer.

Sea cucumber processing also results in the production of stickwater, which contains a toxin (holothurine) that originates from the boiling of the holothurian skin. In other countries, the release of stickwater directly into the marine environment has resulted in fish kills in shallow coastal areas.

Other potential environmental impacts from beche-de-mer harvesting are poorly understood. All sea cucumbers extract bacteria and organic matter from bottom sediments and some are responsible for bioturbation and oxygenation of the sea floor. Consequently, intensive collection may cause changes to the condition and nature of seafloor sediments with unknown impact on other resources.

The PNG National Beche-de-mer Fishery Management Plan

1. Interpretation

In this Management Plan, the following definitions (unless otherwise indicated) apply:

"Maximum sustainable yield" means the highest possible catch of beche-de-mer that may be taken from the management area with minimum effect on the ability of the stock to continue to replenish itself.

"Precautionary Approach" means setting down restrictions to control harvesting in absence of adequate scientific data. These restrictions include setting of TACs, seasonal and area closures and controlling fishing effort.

"National Management Advisory Committee" (NMAC) means an advisory committee established under this plan to provide advice for NFA.

"Provincial Management Advisory Committee" (PMAC) means an advisory committee established in the province to provide advice to the NFA or NMAC on specific provincial issues.

"Sustainability" means ability for a resource to maintain its stock at a fishable level given a level of effort or harvest.

"Total Allowable Catch" (TAC) means the set amount of catch that is allowed to be taken out of the fishery in any one year or season. The TAC is set at a safe level based on the average annual production or on stock assessment work.

"Traditional Management Practices" means methods for conservation of marine and coastal resources practiced by traditional indigenous inhabitants that have been passed down from generation to generation and which are not usually formally recorded.

2. Application

a) This beche-de-mer fishery management plan is cited as the "Management Plan".

b) This Plan applies to all animals belonging to the Class Holothuroidea, commonly known as sea cucumbers, beche-de-mer, pislama or trepang.

c) This Plan applies to the beche-de-mer fishery and includes all fishing and activities associated with the collection, processing, storage, buying, selling and exporting of beche-de-mer products.

d) The Schedules to this Plan form part of the Management Plan and shall be read together with the Management Plan.

e) This Plan is to be interpreted in accordance with clause 1 of this Plan, Section 2, Interpretation, *Fisheries Management Act* 1998 and Part 1.1, Interpretation, *Fisheries Management Regulations 2000*.

f) Unless otherwise expressed, words and expressions used in the Management Plan shall have same meanings as defined in the *Fisheries Management Act 1998* and *Fisheries Management Regulation 2000*.

g) Where there is inconsistency between the Plan and *Fisheries Management Act 1998* and *Fisheries Management Regulation 2000*, the *Fisheries Management Act* shall prevail.

3. Objectives

a) To manage the fishery to the maximum economic benefit of Papua New Guinea.

b) To ensure that the development of the beche-de-mer fishery benefits coastal communities, particularly customary fishers.

c) To ensure use of the beche-de-mer resource is sustainable and that beche-de-mer fishing has minimal impact on the marine and coastal environment.

4. Precautionary Approach

Consistent with relevant international instruments including the most common principles of the precautionary approach developed pursuant to the FAO Code of Conduct for Responsible Fisheries (1982) and management objectives of the National Fisheries Authority, precautionary approaches of management shall apply in respect of the species specified in this Plan in the following manner:

a) In the absence of adequate scientific data, the NFA shall take into account any uncertainties with respect to the size and productivity of the stock, to other management reference points such as maximum sustainable yield, the level and distribution of fishing mortality, and the impact of fishing activities on associated and dependent species, and including climatic, oceanic, environmental and socio-economic conditions.

b) In managing the beche-de-mer fishery, the NFA shall consider the associated ecosystems on reefs within PNG. The NFA shall develop data collection and research projects to assess the impact of fishing on non-target species and their environment, adopt plans as necessary to ensure the conservation of non-target species and consider the protection of habitats of special concern.

c) The absence of adequate scientific information shall not be used as a reason for postponing or failing to take measures to protect the target and non-target species in each provincial beche-de-mer fishery.

d) The precautionary approach shall be based on the best scientific information available, including appropriate techniques and be aimed at setting stock specific minimum standards for conservation and management.

e) The NFA shall, in collaboration with relevant persons and reputable organisations in PNG or the world, develop systems to collect data and to undertake research into conservation of the stock and the protection of habitats.

5. National Management Arrangements

a) The beche-de-mer fishery will be managed nationally. A National Management Advisory Committee (NMAC) will be formed in accordance with clause (g) to provide advice to the Managing Director on the management of the beche-de-mer fishery.

b) The NMAC will provide advice to the Managing Director on management measures as the Managing Director may specify, including total allowable catches, closed seasons, reporting, restrictions, trade, and any other relevant issues that the Managing Director may direct from time to time. The final decision on the fishery management remains with the Managing Director.

c) The NMAC may take responsibility for advising on management of other marine species if directed to do so by the Managing Director or the Board.

d) The Managing Director or the Minister may direct the NMAC to examine a particular issue in the fishery or to review all or part of the management plan.

e) The plan will be reviewed by the NMAC at the direction of the Managing Director at least every three (3) years or at such earlier time as the Managing Director shall direct.

f) Subject to prior approval of the board, any review of the management plan shall be made public by the NMAC and comments will be invited from all stakeholders in the fishery.

g) The National Management Advisory Committee will consist of the following persons, appointed by the Managing Director:

i. two NFA representatives (one will be appointed Chair);

ii. one fishery scientist;

iii. two customary fisher representatives;

iv. two fishing industry representatives nominated by the fishing industry;

v. a representative from a non-government organization whose objectives include conservation of the marine environment and resources; and

vi. one representative each from the Region Fisheries Secretariats for Southern, Momase and New Guinea Islands.

h) No more than two members may represent groups or government from the same province.

i) Elected political office holders are ineligible for membership of the NMAC. Should an NMAC member be elected to political office during their term he or she must resign their membership. Persons who are nominated for provincial or national election shall stand down.

j) The two representatives from the NFA will serve as permanent members. Other members to the NMAC will serve for three-year terms. Representatives from Regional Secretariats will serve for one year and on rotational basis between provinces.

k) The NMAC and its members will operate in accordance with the following procedures and such other procedures and standards as may be set by the Board:

i. a quorum requires two thirds of all members and must include one NFA representative;

ii. the Managing Director shall, with the endorsement of the Board, lay down operational procedures for the NMAC, including place and dates for meeting and the NMAC shall meet at least once a year;

iii. prior to taking up membership, representatives will be required to disclose any direct or indirect personal or pecuniary interests in the fishery, otherwise than as a member of, and in common with the other members of, an incorporated company consisting of not less than 25 persons. The nature of his or her interest shall be disclosed as soon as possible to the NMAC. Such a disclosure shall be recorded in the minutes of the NMAC and submitted to the Managing Director;

iv. the NMAC and Managing Director must be advised of any substantive changes in such interests, or new interests, during the course of membership. The Managing Director will determine if a change in interests will affect that member`s term; and

v. where a member who has an interest described in subsection 5(k)(iii), has not made a disclosure in accordance with that subsection, his or her vote shall be null and void retrospectively from the time such interest is considered and determined by the Managing Director and the Managing Director shall terminate the appointment of such a member.

6. Provincial Management Arrangements

a) To ensure strong input from the Provinces, NFA will encourage provinces in the formation of Provincial Management Advisory Committees (PMACs).

b) PMACs will advise the NMAC on province-specific management arrangements.

c) The NFA will only recognise PMACs that comprise broad representation of marine resource users in the province, and the membership of each PMAC must include:

   i. one representative from Provincial Administration;

   ii. one District Administrator;

   iii. three customary fisher representatives (from different local government areas);

   iv. two local fishing industry representatives;

   v. one NFA representative;

   vi. one provincial fisheries officer; and

   vii. one representative from a non-government organization whose objectives include conservation of the marine environment and resources.

d) The PMAC may submit a request to the NMAC, with justification, for members representing other stakeholder groups in the province.

e) The PMAC and its members will operate in accordance with the following procedures and such other procedures and standards as may be set by the Board:

   i. the Chair of the PMAC will be voted in by a two thirds majority;

   ii. a quorum requires any six members and must include one customary fisher representative, the Chair and an NFA representative; and

   iii. the PMAC will meet as required, but, not less than twice a year.

f) The Managing Director will determine, on the recommendation of the NMAC, if a PMAC will be represented on the NMAC. The composition of the PMAC will be the deciding factor. A PMAC must not include any elected political office holders from the national or Provincial Government or person nominated for such office.

g) PMAC may be consulted on other fishery.

h) The PMAC may, in consultation with the Provincial Government, develop a schedule to the National Beche-de-mer Management Plan that covers province-specific management measures. The NMAC will endorse PMAC schedules for Board approval if they are consistent with the provisions of the management plan.

7. Management Measures

The following management measures set out in the Management Plan shall have the force of law upon notification in the National Gazette.

A. Licensing

Licence Types

   i. Under this plan the only licences required in the beche-de-mer fishery will be export and storage facility licences.

ii. There is no limit to the number of export licences in any given province. However, the PMAC of each province may recommend to NFA a specific number of export licences for the province based on the resources available.

iii. Export licences are not transferable.

iv. Licences are valid for one year and subject to renewal.

Licence Eligibility

i. The beche-de-mer fishery is reserved for the use of citizens of Papua New Guinea.

ii. Only PNG citizens and PNG citizen enterprises may hold an export licence, or engage in any part of the beche-de-mer fishery.

iii. Storage and trade of beche-de-mer or/and beche-de-mer products are restricted to licensed operators only.

Licence Requirement

i. Licensed exporters will be required to provide returns (in the form on Schedule 2) to NFA detailing all purchases made during the month. Failure to do so will result in the export not being permitted.

ii. New or renewed export licensees will have to meet certain criteria set by the Managing Director with endorsement of the Board to qualify for an export license.

iii. Licences for the beche-de-mer fishery will only be issued or renewed if the Board is satisfied that the company will meet, or has met, all licence conditions, and will comply, or has complied with the provisions of the plan, *Fisheries Management Regulations 2000* and the *Fisheries Management Act* 1998, including any that may have prevailed prior to this plan.

B. Total Allowable Catch (TAC)

TAC Allocation

i. Each province will have an individual total allowable catch (TAC), applicable to a twelve month period that is calculated using the best information available.

ii. The TAC will be divided into two groups: high value species and low value species. Schedule 1 sets out which species belong to each group. These will be referred to as value groups.

iii. The Managing Director, with the endorsement of the Board, will set TACs for the beche-de-mer fishery in each province. The NMAC will advise the Managing Director on TACs using information provided by the NFA. TACs will be set after the yearly closure of the fishery in each province and prior to the opening of the fishery the following year. TACs for each province will be recorded in Schedule 4 to this Plan and once set shall not be changed until the following year.

Monitoring

i. The NFA will monitor the total allowable catch for each value group in each province.

ii. The NMAC will review the TACs for each province annually taking into consideration any new and relevant research or information that is available.

iii. The NFA will close the fishery on a date it estimates the entire TAC, or TAC of a value group, will be reached. This will be based on the best estimates of weight traded during the season.

Penalty

i. If the allocated TAC for a province is reached and exceeded by a considerable amount (more than 5 tonnes), that excess amount will be taken off the next season's TAC.

C. Export Requirements

i. Licensed exporters will only export beche-de-mer of the sizes set out in Schedule 1 to this Management Plan.

ii. Export of frozen beche-de-mer shall be consistent with the standards set out under Section 13.3 of the Fish Quality Control (Export) Standards.

iii. Trade of undersized beche-de-mer is prohibited and any undersized product will be confiscated and the licence may be revoked or cancelled.

iv. The export of part or parts of, or broken beche-de-mer, is prohibited.

v. Parts of, or broken beche-de-mer, weighing more than 40 kilograms found on export premises or packed for export will be confiscated and the export licence held may be revoked.

vi. Beche-de-mer product for export must be packed by species and the holding container clearly labelled with the name and quantity of the product and the name and licence number of the exporter.

vii. Movement of beche-de-mer product between provinces is not permitted except with written authorisation from the Managing Director of the NFA.

viii. Where an exporter's nearest port for export is in another province, or is not functional, the company may apply for written authorisation, from the Managing Director of NFA, to use another port for export. If granted, such written authorisation shall:

  a) be attached to the licence;

  b) apply for one year only; and

  c) be reviewed at the time the licence is renewed.

ix. Samples for export shall be limited to 2 pieces of each species at any one time. Samples bound for overseas for personal consumption shall be limited to 2 kg per person.

D. Prohibitions

i. Non-citizens shall not take part in any aspect of the beche-de-mer fishery. (Refer to G57 National Gazette 4th April 2002).

ii. The use of hookah and SCUBA for the fishing of sea cucumbers is prohibited. (Refer to G57 National Gazette 4th April 2002).

iii. The use of underwater lights or surface lights for the fishing of sea cucumbers is prohibited. (Refer to G57 National Gazette 4th April 2002).

iv. Collection, buying, selling of all species of beche-de-mer is prohibited during the closed season or when a TAC is reached.

v. Storage and trade of beche-de-mer and/or beche-de-mer products are restricted to licensed holders only.

E. Closure of the fishery

i. The NFA will close the fishery when the TAC is reached or the compulsory season closure date is reached, whichever occurs first.

ii. A compulsory closed season will occur each year, from 1 October until 15 January of the following year, inclusive. The compulsory closed season applies to all provinces.

iii. If a fishery in one province is closed early, other provinces may continue to fish until their TAC is reached, or the season closure date is reached, whichever occurs first.

iv. All collection, buying and selling of all species of beche-de-mer will cease at the beginning of a closed season declared by the NFA. Exceptions for export may be granted in writing by the Managing Director of the NFA and such exceptions may be with conditions deemed approved by the Managing Director.

v. The NFA will advertise the closure of the fishery through national and local media, as approved by the Board.

vi. On the fishery closure date, exporters must report holdings of beche-de-mer product to the NFA on the form set out in Schedule 3.

vii. The NFA may specify a date by which all holdings of beche-de-mer must be exported, or impose other measures for holding of product during the closed season.

viii. The NFA reserves the right to close any area of the fishery for conservation or regeneration purposes if it is considered necessary to do so for the sustainable management of the fishery.

F. Reporting

i. Standard trade names must be used in all reporting. These are set out in Schedule 1 to the Plan.

ii. Licensed exporters must submit holding data to the NFA on all beche-de-mer products handled. This includes species composition, grades, ward of origin, supplier's name, weight in kilograms and any other information that the NFA may deem necessary. The ward names as in Schedule 5 (not included in this paper) should be used.

iii. Monthly holding reports containing the information set out in Clause 7(f)(ii) must be submitted by the fifth (5) day of the following month on the form in Schedule 2 to this Plan.

iv. Exporters shall declare all beche-de-mer products they intend to export on the form as in Schedule 2 of this Plan to the NFA, before the NFA will issue approval for export and shall submit to the NFA detailed proof of remittance.

v. Five (5) working days after the closure of the fishery, export licensees must submit a report to the NFA stating how much beche-de-mer they hold at the start date of the closure set in Clause 7(e)(i). These will be submitted in the form set out in Schedule 3 to the Plan.

vi. Failure to submit the required reports within ten (10) days, or submitting incorrect data, including incorrect trade names, may result in suspension or cancellation of the export licence under Sections 19 and 20 of the *Fisheries Management Regulations 2000*.

8. Specific Management Objectives

The NFA will work with stakeholders in the beche-de-mer fishery, non-government organisations and research institutions to carry out research and information gathering activities to allow refinement of the Plan, particularly the conduct of resource surveys and assessments.

A. Stock Assessment and Fisheries Management activities aim to:

i. Collect fishery data in a way that will test current assumptions of population abundance and productivity.

ii. Sample specific areas according to the agreed sampling protocols to enable the collection of a time series of fishery dependent information, which can be examined to determine harvest impacts within these areas. If need be, NFA will commission, or encourage research to identify negative environmental impacts to the beche-de-mer industry in PNG, and develop mitigation methods against them.

iii. Develop research and fishing protocols that will enable NFA and provinces to acquire the needed information for the fishery and aquaculture initiatives.

iv. Collaborate with any reputable institution to conduct abundance surveys and test harvest rates. Where necessary the information be made available to Provincial Governments and other relevant organisations to establish local programmes of fishery statistics collection.

B. Aquaculture and Enhancement

The NFA recognizes the aquaculture industry as a legitimate user of PNG aquatic resources and will provide access to broodstock for industry development purposes (growth and diversification), and by aquaculture licences on an as needed basis, subject to conservation and environmental requirements. Request to access the wild stock for development purposes must be supported by a detailed project proposal by the proponent.

9. Customary Rights

i. Existing customary management measures, which are consistent with this plan, are recognised by the NFA, and PMACs will be encouraged to notify the NFA of such measures and incorporate these into their provincial schedules.

ii. Customary open seasons that are inconsistent with closed seasons as set out in Clause 7(e)(i) & (ii) are prohibited under Section 30 of the *Fisheries Management Act* 1998.

SCHEDULE 1

Value Groups, Trade Names and Minimum Size Restrictions

Value Group H - High Grade Species

	Trade Name	Scientific Name	Alternative Names	Live Length (cm)	Dry Length (cm)
1	Sandfish	*Holothuria scabra*	Golden sandfish [this is really *H. scabra* var. *versicolor*]	22	10
2	Black teatfish	*H. nobilis*	Black mama	22	10
3	White teatfish	*H. fuscogilva*	--	35	15
4	Greenfish	*Stichopus chloronotus*	--	20	10
5	Prickly redfish	*Thelenota ananas*	--	25	15
6	Surf redfish	*Actinopyga mauritiana*	Rough surf	(20)	(8)
7	Blackfish	*A. miliaris*	Big blackfish	15	10
8	Curryfish	*Stichopus hermanni*	--	25	10
9	Stonefish	*Actinopyga lecanora*	--	15	10
10	Tigerfish	*Bohadschia argus*	Leopard fish	20	10
11	Brown sandfish	*B. vitiensis*	PK fish	20	10

Value Group L - Low Grade Species

	Trade Name	Scientific Name	Alternative Names	Live Length (cm)	Dry Length (cm)
1	Amber fish	*Thelenota anax*	Giant beche-de-mer	20	10
2	Lollyfish	*Holothuria atra*	Biglolly	(30)	(15)
3	Chalk fish	*Bohadschia similis*	False teatfish	(25)	(7)
4	Elephant trunkfish	*Holothuria fuscopuntata*	Trunkfish	(45)	(15)
5	Pinkfish	*H. edulis*	Smallbelly	(25)	(10)
6	Snakefish	*H. coluber*	--	--	--
7	Flowerfish	*Pearsonothuria graeffei*	Lollyrough, Butterfly fish	--	--
8	Deepwater redfish	*Actinopyga echinites*	--	(25)	(15)

Note: Figures in the brackets are provisional estimates only. NFA endeavours to update these values once new information is made available.

SCHEDULE 2

NATIONAL FISHERIES AUTHORITY

Monthly Buying Summary Report

This form should report all marine product bought within a month

Name of Exporter:

Month/Year: Export Licence No:

Province: Product Type:

Species NFA trade names	**Dry Weight** kilograms	**Supplier** first name and last name	**Ward** where bdm was collected

Send or Fax form to:
Facsimile: (675) 3202069
Telephone: (675) 3090444
Email: nfa@fisheries.gov.pg

Manager, Licensing & Information
P. O. Box 2016
Port Moresby
Papua New Guinea

SCHEDULE 3

NATIONAL FISHERIES AUTHORITY

End of Season Holding Report

This form should report all marine product held at the close of a season

Name of Exporter:

Month/Year: Export Licence No:

Province: Product Type:

Species One per line NFA trade names	**Dry Weight** kilograms	**Species** One per line NFA trade names	**Dry Weight** kilograms

Send or Fax form to:
Facsimile: (675) 3202069
Telephone: (675) 3090444
Email: nfa@fisheries.gov.pg

Manager, Licensing & Information
P. O. Box 2016
Port Moresby
Papua New Guinea

SCHEDULE 4

Total Allowable Catch for each Province

Province	High Value Species (tonnes)	Low Value Species (tonnes)	Total TAC (tonnes)
Bougainville	20	40	60
Gulf	(0.5)	(0.5)	(1)
East New Britain	10	20	30
East Sepik	7	13	20
Madang	15	25	40
Milne Bay	60	80	140
Manus	18	32	50
Morobe	10	20	30
NCD & Central	(25)	(55)	(80)
New Ireland	25	55	80
Oro	15	25	40
West New Britain	20	40	60
West Sepik	7	13	20
Western	10	7	17
	242.5	**425.5**	**668**

Note: Figures in the brackets are provisional estimates only.

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

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Abstract

Australian federal, state and territory fishery agencies are committed to the concept of ecologically sustainable (ESD) 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 (NT) of Australia is being reviewed and a new research program 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 the 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.

Geographic Information System software (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. Basic analysis of the data using fuzzy logic found several apparent size classes within the data, although their significance was not determined.

A fishery-independent survey of the existing trepang fishery and of potential new grounds is proposed for the next 2 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 % 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.

Keywords: Trepang, management, fishery, survey, Northern Territory, Australia

澳大利亚北部海域海参的资源管理和深入认识海参渔业的研究

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澳大利亚达尔文水产养殖中心；澳大利亚达尔文EWL

摘要

澳大利亚联邦、州和海区渔业机构承担着发展生态可持续渔业的任务，其成果对澳洲渔业起着示范作用。目前正在对澳洲北部海域的海参渔业进行评估，一个新的研究项目已经启动，将进一步量化目前的海参渔业状况，并研发合适的监测程序确保海参渔业的可持续性。

从19世纪末和20世纪初的考证和历史纪录显示，现有的渔场已经持续捕捞了300年。所以，保持海参渔业长期的可持续发展是可能的。

渔捞日志原始数据经过处理后，利用地理信息系统软件(ArcView)可为现代化渔业提供可视化渔场结果。该软件也可用来确定海参的数量和重量的关系。利用模糊逻辑数据进行的基础数据分析可从资料中按照外观尺寸予以分类，但是，这些功能的重要性尚未得到肯定。

一个不受渔业部门牵制的，而对现有海参渔业和潜在的新渔场进行为期两年的考察已在计划中。这项工作将包括潜水观测和使用由拖轮拖弋的目标专用采样器，利用分层采样方法获取海参栖息地的相关信息。这次考察中重点将对占到捕捞总量90%的12个海参渔场展开调查，对所获得的生物、物理和栖息地的数据进行相当精确的分类处理。

关键词：海参管理，海参渔业，独立于渔业的调查，北方领海，澳大利亚

Sustainable fishing in Australia

Australian fisheries that export product have had to produce a report that demonstrates their ecological sustainability by December 2004 under the Environment Protection and Biodiversity Conservation Act 1999. If the report is assessed as demonstrating the fishery is managed in an ecologically sustainable manner, the fishery is approved for export for a 5-year period. Otherwise temporary approval for export can be provided if the fishery is moving toward sustainability or, if considered unsustainable, export can be prohibited. The trepang fishery in the Northern Territory (NT) is currently going through this public and expert assessment process. Details of this program, operated by the Department of the Environment and Heritage, can be found at the following web address - www.deh.gov.au/coasts/fisheries.

To assist in further understanding the existing trepang fishery in the NT and to ensure its long-term sustainability, the NT Fisheries Group, in collaboration with industry, is to commence a fisheries independent survey of the fishing grounds during 2003/04. The proposed methodology is addressed later in this paper.

History and description of the trepang fishery in the Northern Territory

Macknight (1976) documents the involvement of Macassans in trepang collecting in the NT since 1700. He states that the use of trepang by the Chinese can be dated to the late 16th or early 17th century and its name, hai-sen (sea ginseng) reflects its supposed medicinal properties. Not surprisingly, the distribution of Macassan trepang processing sites, shown in Macknight's (1976) work, is in general shoreward of contemporary trepang fishing grounds in the NT. In his work, annual estimates of trepang collected by the Macassans were put at over 350 tonnes (dried weight) on average, but up to 600 tonnes in an exceptional year. They collected trepang by diving and by the use of dredges towed behind double out-rigger canoes.

Two partial surveys of the trepang fishery have been undertaken since 1989, first Vail (1989) and then Carter (1995). Like most trepang surveys, population densities were found to vary widely within areas, making attempts to extrapolate to total standing stock very difficult, with extremely high variability. Whilst Carter (1995) found that stock density was not related to the tide or lunar cycle, she did note that trepang were generally absent from habitats adjacent to exposed coastlines.

The trepang fishery in the NT is restricted to 3 of the 12 coastal bioregions found in NT waters (Anon, 1998). All 3 bioregions are characterised by an underlying non-depositional land form, which extends from the coast to the sub-tidal zone; they experience high annual rainfall (1 000-1 400 mm per year); annual surface seawater variations in the range of 5-8 °C; relatively few mangroves fringing the coast and have relatively low tidal ranges from 2-5 m. The sandfish, *Holothuria scabra* accounts for almost all the catch in the NT, although some other commercial species are collected.

Trepang management in the Northern Territory

Currently trepang fishing in the NT is controlled by regulation. It is predominantly input controlled. There are only six licences in the fishery which are limited by area, species, minimum size, and the number of divers and assistants on each vessel. The fishery extends three nautical miles seaward from the high water mark. Trepang can only be collected by hand or hand held instruments.

In the NT, a special unit of the police undertakes all fisheries enforcement. In the case of the trepang fishery, vessels leaving or arriving in port can be inspected and catch returns may be verified against processing or wholesaler records. At sea, the police can undertake inspections of vessels and their operations if they so wish. Daily records on fishing activity and sales are submitted to the Fisheries Group each month and that data is saved in a database.

Visualisation of trepang catch data using a Geographic Information System (GIS)

Trepang catch data recorded by fishermen for the NT Government prior to this study has only been analysed using standard statistics. It is difficult to visualise possible patterns in trepang harvesting practices along the several thousand kilometres of the NT coastline from a spreadsheet of 1 700 data points. The purpose of undertaking a GIS study was simply to visualise the data in their geographic context and, if possible, identify patterns over time, which would cast some light on the dynamics of the trepang harvesting industry in the NT.

The GIS software used throughout this study was ArcView 3.2 with the Spatial Analyst and free extensions downloaded from the ESRI website (http:\www.esri.com).

Dataset description

The original dataset was extracted from the NT Government Oracle database and provided as an Excel spreadsheet. A table was derived from the original dataset after eliminating all empty records, assigning a consistent format to all data in the same field and checking site names against the Australian Gazetteer[1] database. The fields of the table were:

- ID: unique identifier of each record
- Year: derived from the collection date
- Licence_no: the NT Government issued six licences for trepang harvesting
- Hours: number of hours spent harvesting
- No_of_peo: number of people involved
- Collection: four digit code number of the one degree fishing grid cell where trepang were harvested
- No_collect: number of trepang collected
- Weight: wet weight of trepang collected
- Location: name of the location within the grid cell defined in Collection where harvesting took place
- Prop_nam: Proper name (by reference to the Australian Gazetteer) of Location
- Dlong: Official longitude, as a decimal number, listed in the Australian Gazetteer under Prop_nam
- Dlat: Official latitude, as a decimal number, listed in the Australian Gazetteer under Prop_nam

Once created this initial dataset was imported into ArcView GIS as an "Event theme" using the coordinates Dlong and Dlat available for all but about twenty records. The latter were eliminated as no Prop_nam, extracted from the Australian Gazetteer, could match the entry recorded by the fishermen under Location. For all other records Collection, Location, Prop_nam, Dlong and Dlat were consistent.

Figure 1 displays all locations where trepang were harvested between 1996 and 2002.

The initial intention was to display yearly catches expressed as wet weight, in kilograms, of trepang collected in each location. The first discovery was the near complete absence of weight data in the 1996 records, only numbers of trepang harvested in 1996 were available. The first task therefore consisted in extrapolating weights missing in 1996 from records, in subsequent years, on the basis of the correlation between number and weights. In the past, total wet weight of trepang caught had been divided by total numbers of specimens caught to derive an average wet weight for missing records. This approach however was clearly unsuitable when dealing with specific locations.

Deriving weights from numbers of specimens harvested

The relationship between wet weight and number of trepang harvested was explored using Gstats, a free (in its beta version) extension created by SDS Data Services (info@sds.com.au).

The first attempt at regressing weights against numbers of trepang harvested for all records where these two fields were complete produced the plot displayed in Figure 2.

[1] *http://www.ga.gov.au/map/names/*

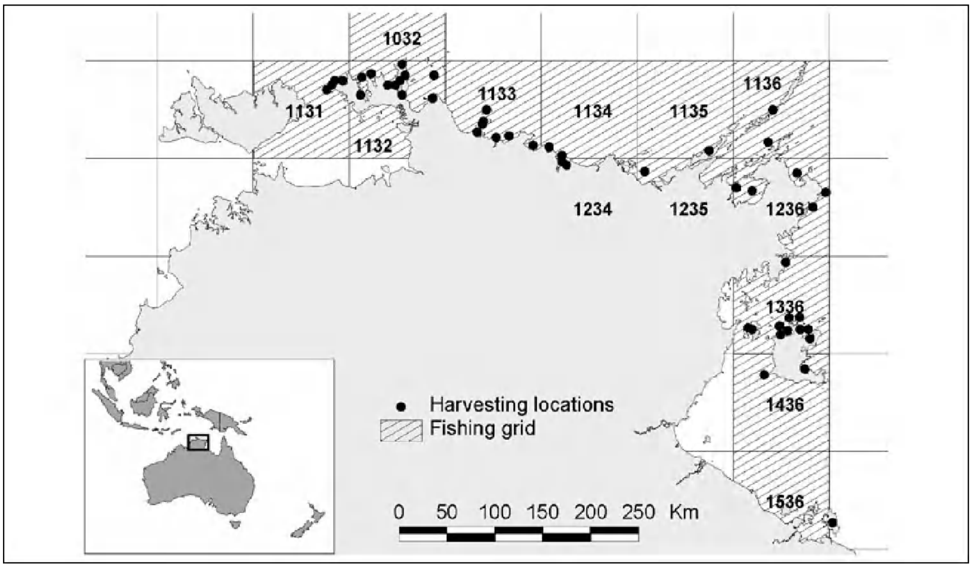


Figure 1. *A map of the Northern Territory, illustrating the thirteen cells of the fishing grid in which catches were recorded and individual harvesting locations identified. (Each cell of the fishing grid is one degree of longitude wide and one degree of latitude high (60 nm x 60 nm).*

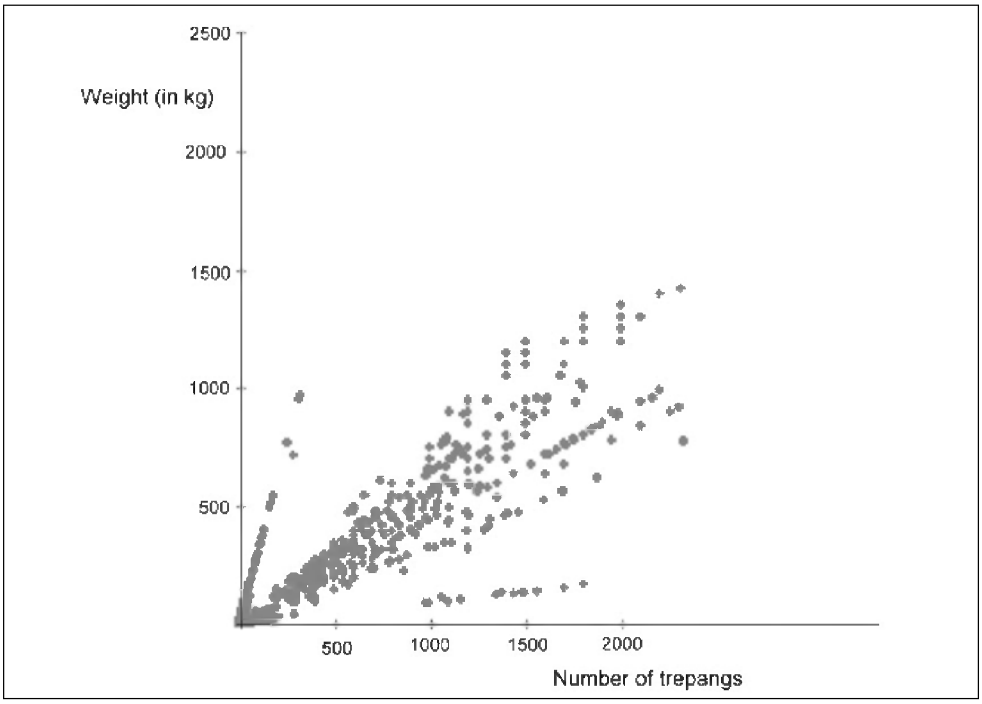


Figure 2. *A scattergram of wet weight against number of trepang, for all logbook records, 1996-2002.*

Examination of Figure 2 suggested that an average wet weight calculation was inappropriate for extrapolation purposes. Points appeared to line up along a number of well defined slopes.

As a result, a systematic exploration of regression patterns at all harvesting locations with substantial catches was undertaken. Figure 3 demonstrates the disparity of regression lines observed at different sites.

Regression lines of the data in Figure 3 reflect the variability of the relationship between wet weight and number of specimens. Patterns of regression lines observed did not appear to be the result of random errors or processes.

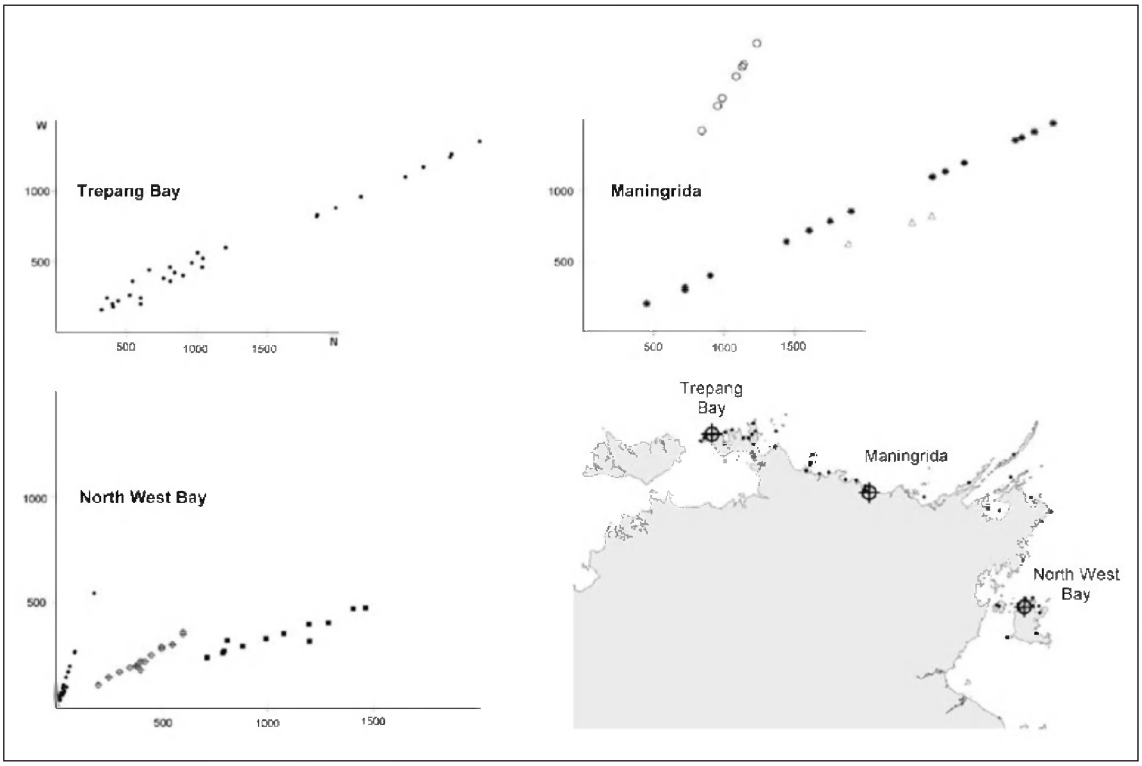


Figure 3. Plots of wet weight (y-axis, kg) against number of trepang (x-axis) for Trepang Bay, Maningrida and North West Bay, which are respectively in the west, centre and east of the study area. The different symbols on the plots represent different fuzzy logic classes.

They showed, across all harvesting sites, from east to west, an increasing number of well defined slopes. Individual regression slopes were calculated (Table 1) for the eleven most productive locations (Figure 4). The twelfth location, Melville Bay, was not included as many records lacked wet weight measurements.

A fuzzy classification algorithm designed by Hong and Lee (1996) was selected to derive representative wet weights for each class (age group, species or other common characteristic). This automatic classification is the first step in the design of fuzzy rules. In this study, however, it only provides an objective categorisation of trepang based on their weight derived from regression lines, and assigns to each category a weight, which is not an average weight but the most representative weight.

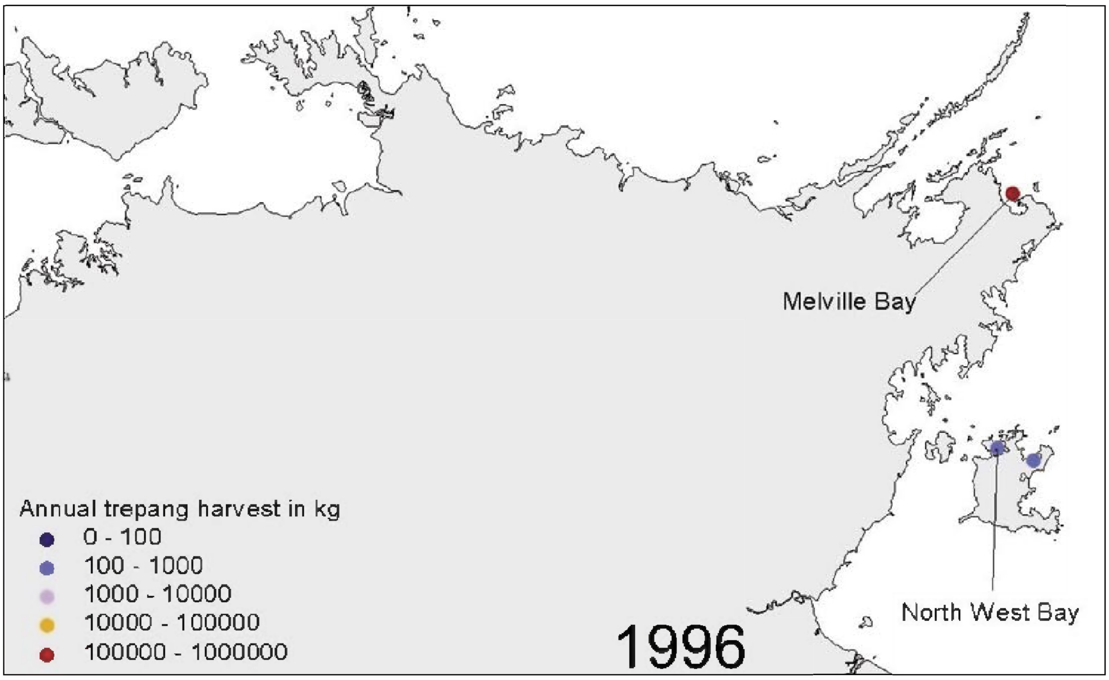
Table 1. Individual slopes of regression lines for the eleven most productive trepang harvesting sites, sorted by slope. Classes of trepang 1, 2, 3 and 4 were derived using a fuzzy classification algorithm published by Hong and Lee (1996). Each class corresponds to a triangular membership function defined by the three vertices V1, V2 and V3. V2, the apex, is the most representative value of each class.

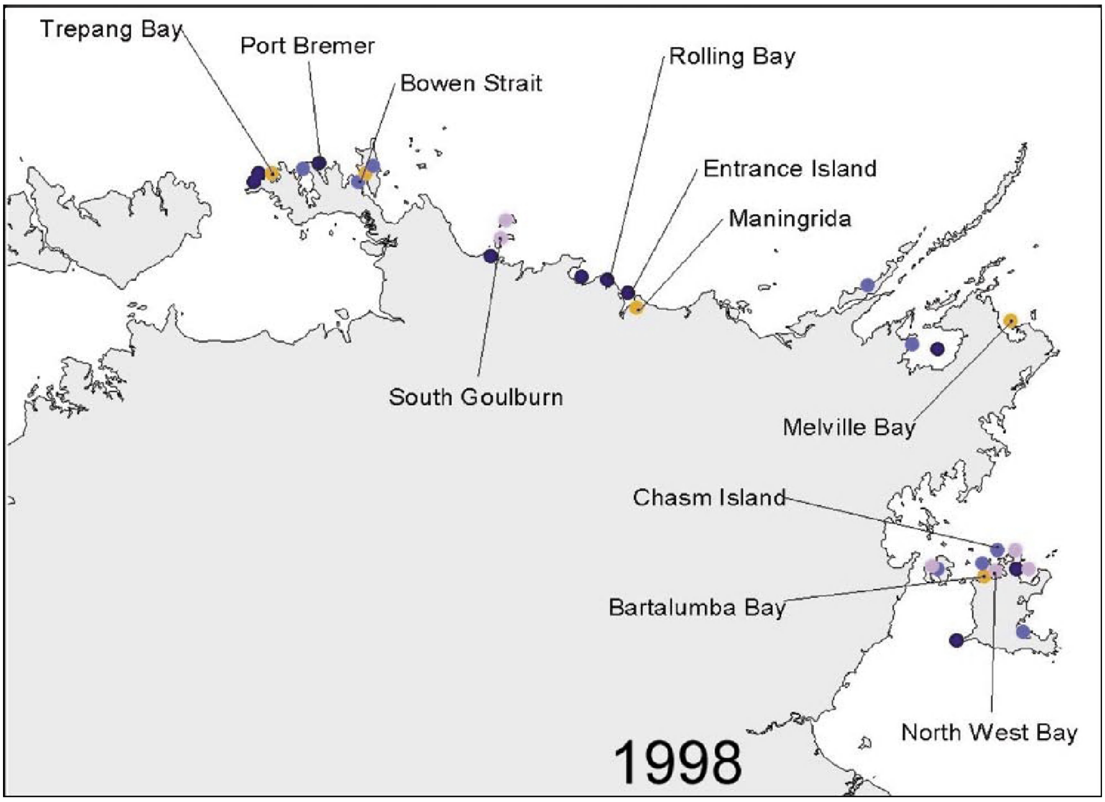
Location	Slope	Class	V1	V2	V3
Northwest 1	0.319	1			
Bartalumba 1	0.333	1			
Chasm	0.478	1	-2.885	0.451	4.92
Bartalumba 2	0.504	1			
Maningrida 1	0.629	1			
Bartalumba 3	1.15	2			
Bowen 1	1.161	2			
SouthGoulburn	1.487	2			
Entrance	1.512	2	-2	1.46	4.044
Maningrida 2	1.576	2			
Northwest 2	1.639	2			
Port Bremer	1.692	2			
Bowen 2	2.245	3			
Rolling Bay	2.269	3	1.765	2.265	6.315
Trepang	2.282	3			
Irgul	2.428	3			
Northwest 3	3.116	4	3.116	3.116	6.754
Bartalumba 4	3.244	4			

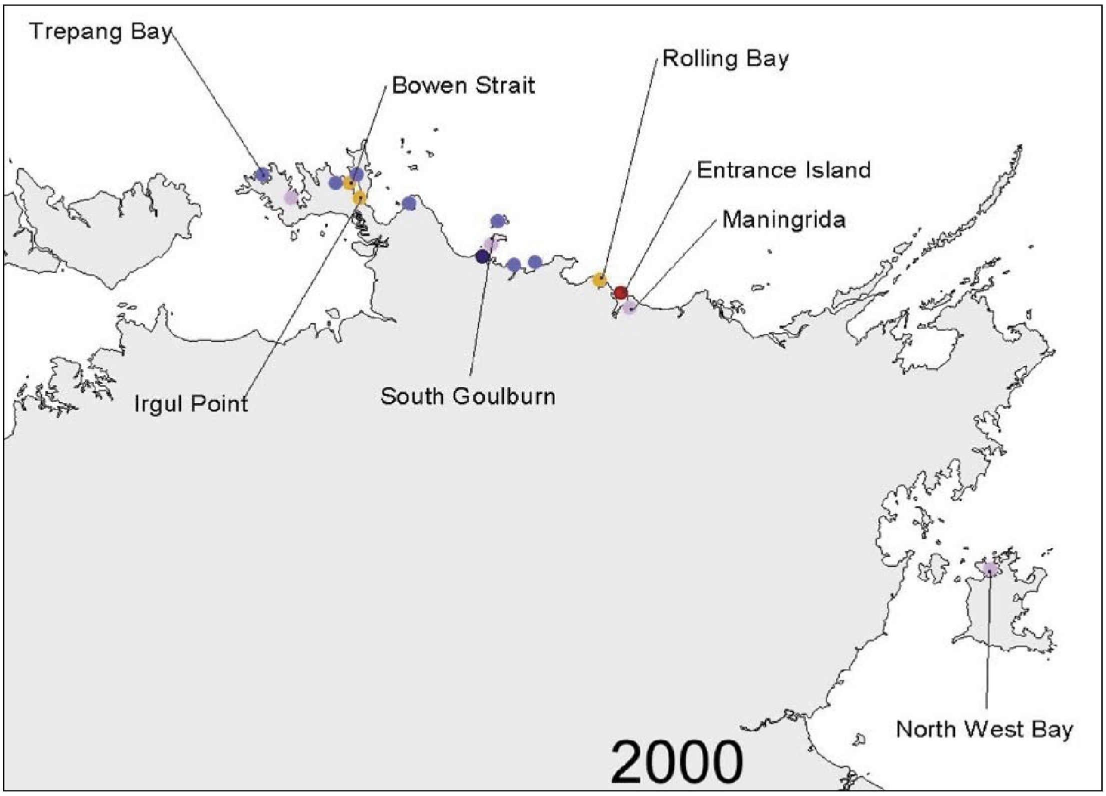
Table 1 suggested that, on the basis of their weight, trepang harvested in NT waters between 1996 and 2002 could be grouped into four classes. The most representative specimens in each class had the following wet weights:

- Class 1 → most representative weight = 0.451 kg
- Class 2 → most representative weight = 1.460 kg
- Class 3 → most representative weight = 2.265 kg
- Class 4 → most representative weight = 3.116 kg

What is the significance of these classes? Perhaps they reflect different size classes. Results from the proposed survey will hopefully shed more light on the value of this classification.







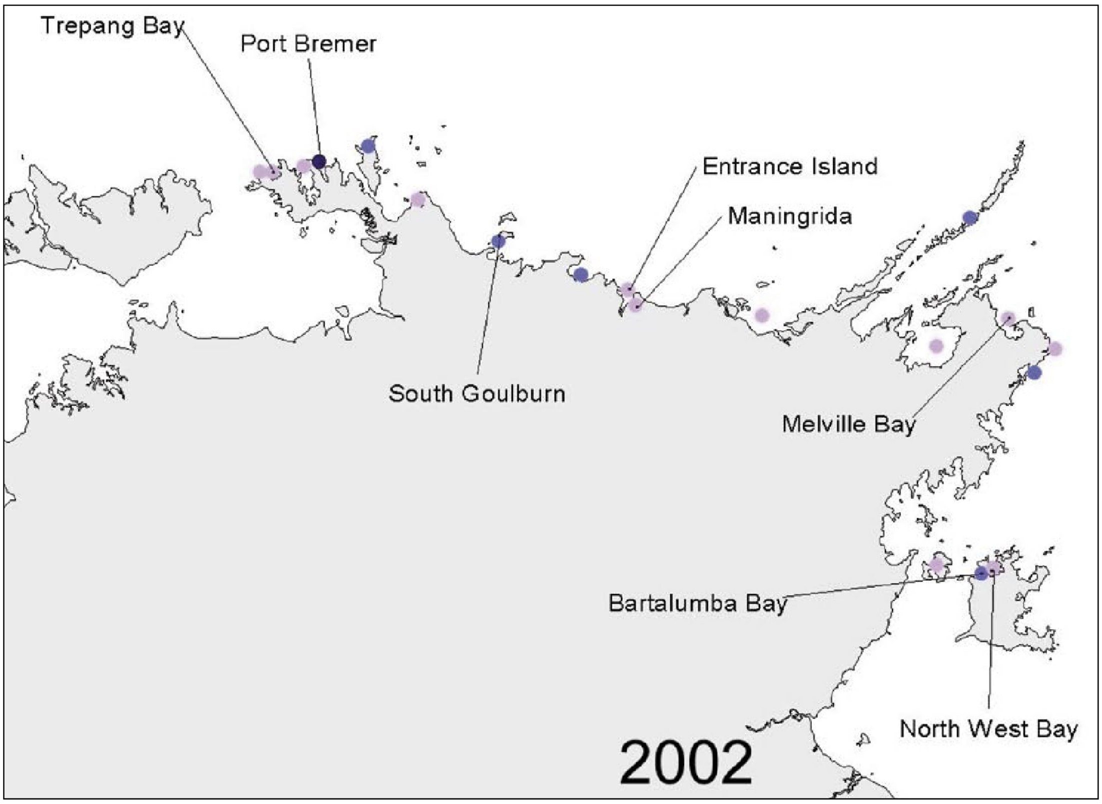


***Figure 4**. Annual harvest from the twelve most productive sites (the same sites used in the previous fuzzy classification) displayed every second year since 1996.*

The visualization of the trepang catch on an annual basis demonstrates that areas harvested vary from year to year, as do catches from different sites. Whilst an interesting approach, the value of visualization of harvest data should be carefully assessed, in that fishing in different areas may well have been controlled by factors such as weather conditions, economics (distance from port to fishing site), crew availability and serviceability of boats, in addition to on-the-ground stock densities.

Trepang survey methodology and design

Analysis of trepang and other sedentary benthic surveys has identified the use of transects as the main technique utilised to generate population estimates. The size of transects used has varied from 40 m x 2 m diver transects (Friedman, pers. comm.) to 1 500 m tows of trawls (Joll, 1995).

The use of specialised towed gear to collect *H. scabra* in the forthcoming survey, recognises Vail's (1989) assertions that a trawl could collect from 80-85 % of the catch, and that because of the soft, silty substrate on which trepang were found in the NT, there was little damage to the environment. He found that *H. scabra* was found between depths of 0-10 m, with most being found down to 4 m, although Carter (1995) found little difference in inter-tidal and sub-tidal population densities.

Skewes *et al.* (2000) stated that the burrowing habit of *H. scabra* could result in underestimates of abundance, of up to 60 % in seagrass beds at high tide. The survey to be undertaken in the NT will use the same stratification by substrate approach as used by Skewes *et al.* (2000) to estimate stock.

The proposed survey will include several sites previously surveyed (Vail, 1989; Carter, 1995), so enabling an immediate comparison over time. When combined with fishing effort data from those sites, the results may increase our understanding of the dynamics of the fishery.

An initial pilot study will be used to refine the methodology for the main survey. The pilot and then the main survey will take a stratified approach examining trepang densities with depth, and in relation to seagrass cover and sediment type. A few depletion trials will be undertaken on selected transects to determine if underestimates of stock density are as significant as described by Skewes *et al.* (2000), using techniques as described by Rago *et al.* (1999). Sediment samples will be routinely collected and analysed for size distribution and organic content. In waters less than 5 m depth (m.l.w.s – mean low water spring tides), transects will be undertaken by divers. In deeper water, target-specific sampling gear, designed specially for this work, will be utilised. Habitat strata used in the survey will be estimated using GIS tools, so that gross estimates of stock from different habitats at the different sites can be made, as was undertaken by Long *et al.* (1993) for trochus and Skewes *et al.* (2000) for *H. scabra.* There are to be two surveys, one of the existing fishery and one of areas in NT waters outside of the existing fishery to establish what other resources might be available. For all trepang collected during the surveys, the species, length, wet mass, gonad mass, sex, gutted weight and weight of internal organs will be recorded.

Discussion

In the Torres Strait, Skewes *et al.* (2000) carried out 165 transects for *H. scabra* on Warrior Reef and found maximum densities in the seagrass zones. That survey was the second of its kind and it was suggested that such surveys repeated every year would be a useful monitoring tool for the fishery. Whether or not annual stock surveys for most trepang fisheries can be considered an economically useful option for most fisheries has yet to be determined, however the fact that most trepang species occur in major aggregations at least makes it more feasible than widely dispersed populations. In Western Australia, 60 % of the catch is found in just 2 grids (each 60 nm x 60 nm) and in the NT over 90 % of the catch is collected from just 12 sites. Whilst detailed survey work as carried out by Skewes *et al.* (2000) is very useful for examination of a relatively small area (Warrior Reef), such a detailed approach would not be economically feasible for a fishery distributed over a thousand nautical miles and numerous locations, as found in the NT.

Whilst monitoring effort in a trepang fishery is a useful tool, care should be taken in comparing values between sites, as fishing conditions (e.g. water visibility, currents), gear used (e.g. hookah) and a range of economic factors (e.g. distance from nearest port) can have a major impact on the productivity of divers. When the time spent fishing for trepang in one area can vary from less than a day to perhaps a few weeks, how should catch per unit effort be analysed in that location and what, if anything, does catch per unit effort mean averaged across a geographically fragmented fishery?

Trepang fishing records in the NT are currently recorded using a grid, with each square of the grid having sides of 60 nm in length. More precise information could be obtained using a 6 nm grid, as has been introduced for recording prawn trawler catches across northern Australia. The approach of using GIS statistics combined with fuzzy logic to tease out further information from catch data has proved useful in reviewing the NT trepang fishery. It has enabled more information to be extracted from data recorded than has previously been the case. Fuzzy logic, a critical component of modern engineering and expert medical systems, has yet to be used to any great extent in either natural resource management or fisheries science. Fuzzy logic, as its name suggests, is valuable in making sense of what-ifs, maybes, ands, and ors, compared to most fisheries tools which seek to explain a fishery in black and white terms, too often using data of questionable value and limited scope. Such tools as fuzzy logic and GIS can theoretically be of enormous value in making sense of extremely complicated ecosystems and assist in the development of inter-active 'expert (management) systems' for many fisheries.

To date the management of trepang in the NT has been at a gross level. Uthicke and Benzie (2001) detected separate stocks of sandfish along the Queensland coast, which indicated restricted gene flow between populations, and inferred that, as a result, consideration should be given to managing that species on a local scale. With information to be gathered from the 12 most significant trepang sites in the NT from the proposed survey, information at a finer scale will be available to assist in refining future management plans. Visualisation of trepang catches over time can assist in understanding the dynamics of a trepang fishery. Such visualisation can be considered part of a more stratified approach to fishery assessment. Production of average catches or average weights have limited use when the fishery is broken down into sites or areas, with each potentially having different factors affecting their productivity. For example in discussions with fishermen, some areas are known to have regular recruitment every year, whereas others appear to have infrequent recruitment.

Macknight's (1976) examination of the Macassan trepang industry in the NT stated that 'the very continuation of the industry (trepang) at a more or less consistent level for such a long period confirms that overfishing cannot have been a serious problem. Perhaps a limited area might be cleaned out for a season by several weeks work, but by the following year it would repay another visit...'. Examination of the way in which catches vary from different sites in the contemporary fishery (Figure 4) from year to year, may well reflect the way in which Macassan fishermen sustained a fishery over several hundred years. In the NT, a sustainable fishery is being maintained by a combination of regulation, enforcement and economic pragmatism. Its future sustainability should be on an even firmer footing when a more detailed understanding of the fishery is gained from the proposed trepang surveys and whatever monitoring programs may be put in place in the future. It is the understanding of the authors that under Australian economic conditions, where catch per unit effort for trepang is too low, fishermen cannot afford to continue to fish, and so move on to try other sites. In the NT where one company currently owns all licences, overfishing would be against the long-term best interests of the licensee. In a more competitive fishery, the desire to fish as much as you can before your competitor does is more likely to lead to overfishing. Where catches vary so much from one year to the next and from site to site within a fishery, as they appear to do in the NT trepang fishery, management strategies sensitive to the overall dynamics and economics of the fishery need to be carefully considered.

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Density of *Holothuria nobilis* and distribution patterns of common holothurians on coral reefs of Northwestern Australia

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Abstract

Broad-scale distribution and density data of sea cucumber inhabiting Ningaloo Reef, Western Australia (WA), are compared with published data from Ashmore Reef, Cartier Reef and Rowley Shoals, northern WA. Results are presented particularly of the black teatfish, *Holothuria* (*Microthele*) *nobilis*. Heavy fishing pressure has affected numbers of *H. nobilis* on both Ashmore and Cartier Reefs, where population densities of less than 1.0 ind ha^{-1} have been recorded. Rowley Shoals and Ningaloo Reef, areas that are unlikely to have experienced significant fishing pressure, support black teatfish densities of 9.1 and 19.3-27.2 ind ha^{-1}, respectively. Densities of black teatfish recorded at Coral Bay are approximately equal to or exceed those reported on reefs that are closed to fishing on the Great Barrier Reef.

The distribution patterns of *H. nobilis*, *H. atra* and *Stichopus chloronotus* were examined on Ningaloo Reef using a novel method integrating both Global Positioning System (GPS) and Geographic Information Software (GIS). Differences in patterns of distribution between *H. nobilis* and *S. chloronotus* were identified. *H. nobilis* preferred habitats closer to the reef crest, whilst *S. chloronotus* were distributed among coral rubble within the inner-reef lagoon. *H. atra* showed little or no recognisable pattern of distribution. Studies utilising GIS are currently determining the relationship between species distribution and physical habitat characteristics. This process ultimately will help clarify the micro-habitat characteristics of coral reef holothurians. Methods associated with this technique are described.

Management of a potential Western Australian *H. nobilis* fishery should be approached with caution. Research investigating sources of recruitment and population recovery following fishing should be undertaken as a minimum prerequisite to the adoption of policy concerning beche-de-mer fishery management in WA.

Keywords: Holothurian, GIS, GPS, micro-habitat, fishery, management

澳大利亚西北部珊瑚礁中的常见海参的分布模式和黑乳参（*H.nobilis*）的密度

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摘要

西澳大利亚的Ningaloo礁区栖息的海参，其广泛的分布数据和密度资料与已经公布的西澳大利亚北部的Ashmore 礁, Cartier 礁 和 Rowley 浅滩的数据进行了对比。结果显示，黑乳参是很特别的。在Ashmore 和 Cartier 礁，沉重的捕捞压力已经影响到黑乳参的资源 ，有记录显示其资源密度已经不足1.0 头/公顷。Rowley 浅滩和Ningaloo 礁没有明显的捕捞压力，密度分别为 9.1头 和19.3 – 27.2头/公顷。在珊瑚礁湾所记录的黑乳参密度等于或超过那些靠近大堡礁渔场的数据。

在Ningaloo 礁，使用了全新的全球定位系统（GPS）和地理信息软件（GIS）相结合的方法检查了黑乳参，黑海参（*H. atra*）和绿刺参（*Stichopus chloronotus*）的分布模式。 鉴别了黑乳参和绿刺参之间不同的分布模式。黑乳参 更喜欢栖息在靠近礁顶的地方，而 绿刺参则分布在内礁的珊瑚碎石堆中。黑海参的分布模式难以辨别。当前正在利用GIS来研究和确定种群分布和自然生活习性之间的关系。该研究最终将有助于将珊瑚礁海参的微栖息环境特性予以分类处理。本文描述了与此技术相关的研究方法。

西澳大利亚潜在的黑乳参渔场的管理应谨慎行事。研究表明，在西澳大利亚应当将捕捞后的资源补充量和资源量的恢复作为海参捕捞业决策的最起码的先决条件。

关键词：海参、地理信息系统、全球定位系统、微生境、渔业、管理。

Introduction

Summary of sea cucumber fishing in Western Australia

Sea cucumber fishing in Western Australia (WA) operates on a smaller scale to that conducted in other Australian states. The Department of Fisheries, WA, currently supports six commercial fishing 'authorisations', all of which concentrate exclusively on sandfish, *Holothuria scabra*. Catch data relevant to holothurians are limited to the last eight years and the extent of fishing prior to the introduction of official monitoring is largely unknown. In the last five years, annual reported catch rates of sea cucumber in WA have fluctuated between 30 and 400 tonnes wet-weight (all figures refer to the weight of sandfish measured prior to evisceration) (information provided by David Harvey, The Department of Fisheries, WA).

Fishing of H. nobilis in Western Australia

The limited history of government-sanctioned sea cucumber fishing in WA, combined with the relative isolation of northwestern Australian coral reef-habitats, have precluded *H. nobilis* from large-scale harvesting by Australian nationals. Most, if not all beche-de-mer fishing in WA has concentrated on sandfish. Black teatfish, however, have been the focus of much international interest and coral reefs of northern WA traditionally have been subjected to fishing pressure by Indonesians (MacKnight, 1976). Foreign visitors to northwestern Australia have, for a number of reasons, exploited *H. nobilis* commercially: they are readily accessible on remote island reefs; they inhabit clear, relatively shallow water; and as a beche-de-mer product, they fetch some of the highest market prices available.

The significant commercial value of black teatfish on the Great Barrier Reef led to over-exploitation of this species resulting in the total closure of the fishery in 1999 (Uthicke and Benzie, 2000b). Stringent management of black teatfish stocks is clearly necessary, however, knowledge of its biology is limited to a few studies only: reproduction (Conand, 1981), larvae culture (Martinez and Richmond, 1998), feeding selectivity (Uthicke and Karez, 1999), population genetics (Uthicke and Benzie, 2000a) and impacts of fishing (Uthicke and Benzie, 2000b).

This report presents distribution and density data of the black teatfish, *Holothuria nobilis*, from Coral Bay, Ningaloo Reef. Results from Coral Bay are compared with published data from Ashmore and Cartier Reefs (Smith *et al*., 2001; Smith *et al*., 2002), and Rowley Shoals (Rees *et al*., 2003), all of which are off shore coral reefs to the northeast of Coral Bay (Figure 1). Each of these reefs, including Ningaloo, are currently closed to beche-de-mer fishing, however, illegal fishing has, and continues to affect Ashmore and Cartier Reefs, and to a lesser extent, Rowley Shoals. This report, in addition, describes a novel method integrating Global Positioning System (GPS) and Geographic Information Software (GIS) aiming to determine the micro-habitat preferences of dominant holothurian species from Coral Bay. Initial results and the potential applications of this method are presented and described, respectively.

Materials and Methods

Rapid quantitative assessment surveys recorded the density and broad-scale distribution patterns of *H. nobilis* on major coral reefs of WA, namely, Ashmore and Cartier Reefs (Smith *et al*., 2001; Smith *et al*., 2002), Rowley Shoals (specifically Mermaid Reef) (Rees *et al*., 2003), and Coral Bay, Ningaloo Reef. The mean number of *H. nobilis* (ind ha^{-1}) distributed among broadly defined habitats on each of these reefs were calculated and plotted as a histogram.

Micro-habitat determination: the application of GPS and GIS technology

Micro-habitat preferences of dominant holothurian species at Coral Bay were determined using a modification of the manta tow as described by English *et al*. (1997). Manta tows were conducted in the traditional sense, however, instead

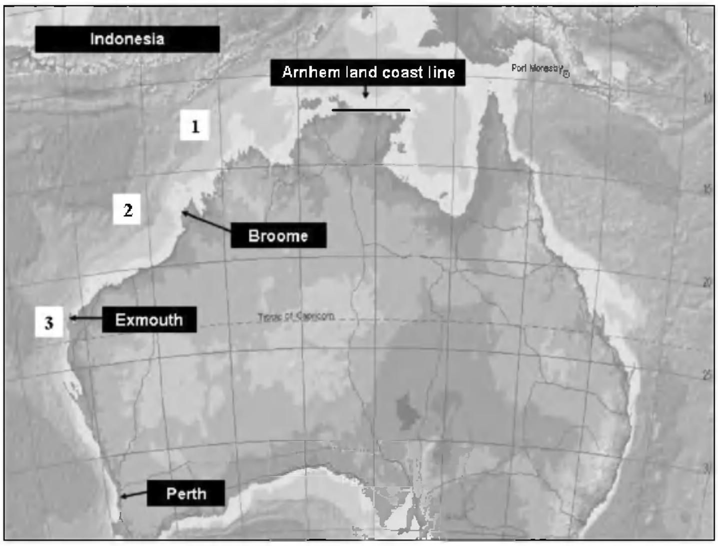

Figure 1. Partial map of Australia showing locations of density and distribution survey sites. 1. Ashmore and Cartier reefs; 2. Rowley shoals; 3. Ningaloo reef.

of counting individual holothurians, the position of each was recorded as a single GPS way-point and plotted on an aerial photograph using GIS. In situations where animals were too numerous to record individually, a single GPS co-ordinate was recorded and the observer estimated the abundance according to the following criteria: <10; <20 or <30 animals.

Standardised signals were developed to ensure the observer relayed accurate information to the GPS operators, for example different coloured gloves, representing individual species. Only two species could be surveyed per manta tow, so it was necessary to repeat tows to incorporate the three species under investigation.

All manta tow transects were conducted in the afternoons (≥ mid-day) when *H. nobilis* were known to be feeding and more likely to be visible (Shiell, in prep). Each parallel transect was separated by a lateral distance of approximately 50 m. The survey incorporated all sections of inner-reef, including broadly defined habitats such as the lagoon (including open sand), the back-reef, the reef-flat and where possible, the reef-crest. Surveys incorporated the inner-reef between Lotties lagoon, south of Coral Bay, and Point Maud, north of Coral Bay, a total area greater than 700 ha.

Results presented in this report are restricted to examples of distribution patterns obtained through this technique only.

Results and Discussion

The data presented in this paper are two-fold. Firstly, the report investigates broad-scale distribution and density patterns of *H. nobilis* obtained using traditional random transect techniques on reefs both un-impacted and impacted by fishing. Secondly, it presents initial results from a study using a GIS-based technique to determine micro-habitat preferences or fine scale distribution patterns of holothurians at Coral Bay.

Density and broad-scale distribution patterns of H. nobilis on major reefs of Western Australia

Densities of *H. nobilis* at Coral Bay differed considerably when compared with published data obtained at Ashmore Reef, Cartier Reef (Smith *et al.*, 2001; Smith *et al.*, 2002) and Mermaid Reef (Rees *et al.*, 2003) (Figure 2). Lower densities of *H. nobilis* on both Ashmore and Cartier are probably indicative of heavy fishing pressure applied both historically and in recent times by Indonesian fishermen. At these reefs, especially Cartier, populations of *H. nobilis* have been harvested to the point of near total denudation. Similarly, only small numbers of animals have been observed at the significantly larger Ashmore Reef; 13 in total after 69 transects totalling approximately 8 ha^{-1} (Smith *et al.*, 2001). Average densities of *H. nobilis* at both Ashmore and Cartier Reefs were found to be less than 1.0 animal ha^{-1}, a figure approximately 20 times lower than average densities reported on reefs closed to fishing on the Great Barrier Reef (Uthicke and Benzie, 2000b).

In contrast, populations of *H. nobilis* at both Mermaid Reef and Coral Bay were substantially greater than on those reefs described above, at 9.3 and 19.3 to 27.2 ind ha^{-1}, respectively (Figure 2). In the case of Coral Bay, these figures represent abundances that are at least equal to, or greater than, those described on reefs closed to fishing on the Great Barrier Reef (Uthicke and Benzie, 2000b). Surveys at Mermaid Reef recorded densities slightly lower than this suggesting that fishing has been conducted at some time in the past (Anon, 1973), although probably not to the same degree as that conducted at Ashmore and Cartier Reefs.

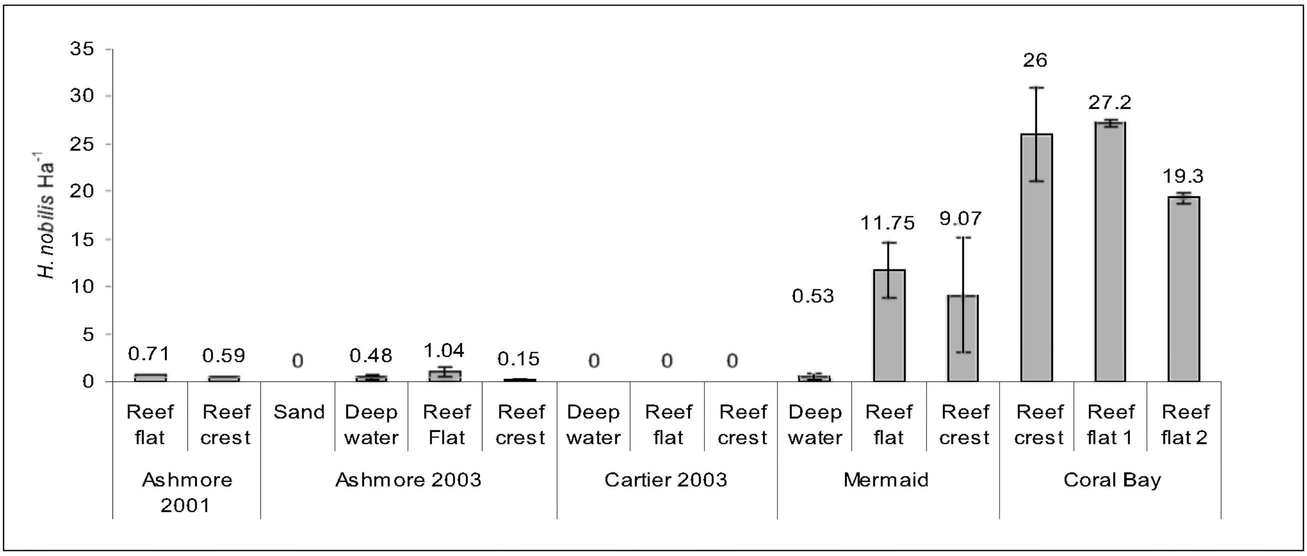

Figure 2. *Mean density of* H. nobilis *within each of the identified surveyed habitats: note the differences between heavily impacted reefs, Ashmore and Cartier (representing heavily fished reefs); and relatively un-impacted reefs, Mermaid and Coral Bay. Density and distribution results relevant to Ashmore, Cartier and Mermaid are compiled from Smith et al. (2001), Smith et al. (2002) and Rees et al. (2003).*

Broad-scale distribution patterns

Populations of *H. nobilis* on Ashmore Reef, Cartier Reef, Mermaid Reef and Ningaloo Reef showed distinct preferences for outer-reef zones, specifically, the reef-flat and reef-crest. Although average densities were greatest on reef-flats, substantial densities were also observed upon the shallower and more exposed reef-crests. For example, certain sections of the reef-crests contained densities of up to 108 ind ha^{-1}, however, the average values presented in Figure 2 were deflated because of the patchiness of suitable habitats (i.e. appropriate sand patches) within the crest itself. Large error bars present on the histograms representing reef-crests at both Mermaid and Coral Bay reflect this trend.

Micro-habitat determinations: The application of GPS and GIS technology

GPS-derived data obtained in Coral Bay provide some of the clearest illustrations of holothurian distribution patterns to date (Figures 3 and 4). Clear preferences for distinct zones within the reef are obvious in the case of *H. nobilis* and *S. chloronotus*, but, conversely, are random in the case of *H. atra*. Although apparently random distributions of *H. atra* have been documented, for example in Baker (1929) and Massin and Doumen (1986), patterns of distribution between size classes of *H. atra* have received little attention. Anecdotal observations made at Coral Bay found concentrations of smaller specimens of *H. atra* on areas of sand and coral rubble adjacent to the shoreline within the reef-lagoon. This observation may be indicative of asexual reproduction, a process reported to result in congregations of smaller sea cucumber in areas closer to the shoreline. This phenomenon has been reported previously by Conand (1996) and Uthicke (1997) on La Réunion and the Great Barrier Reef, respectively, however, further work is required to determine whether this process is important to the patterns observed at Coral Bay.

Individuals of *H. nobilis* appeared to be concentrated on sand patches either on, or near, the reef-flat and reef-crest zones. Other habitats within the area surveyed, for example, patches of sand in the central lagoon region of the bay, also contained *H. nobilis*, but in lower concentrations. These habitats were observed at considerable distances away from the preferred habitat zones described in the literature (Conand, 1981; Uthicke and Benzie, 2000b; Benzie and Uthicke, 2003), e.g. the reef-flat and back-reef slope. Further work is being conducted to isolate and identify the environmental factors consistent to these areas where individuals of *H. nobilis* were observed in an effort to clarify the micro-habitat characteristics of this species.

Individuals of *S. chloronotus* were concentrated on patches of sand among coral rubble, with the majority of animals positioned in either the central lagoon region of the bay or closer to the shore. Particularly dense congregations of this species were observed in sheltered areas of coral rubble northwest of Monks Head (Figure 3). Similar to *H. atra*, the average size of the observed specimens and the elevated densities of *S. chloronotus* at this location suggest that asexual reproduction may be causing this pattern. As with *H. nobilis*, congregations of *S. chloronotus* were not restricted to the areas described above. Transects run along some of the shallowest, high-energy sections of the reef-crest, consistently found numerous *S. chloronotus* clinging to the limestone platform.

Figure 3 shows clearly the contrasting patterns of distribution between *S. chloronotus* and *H. nobilis*. The pattern in this figure is supported by previous observations on the distribution of these species (Baker, 1929; Conand, 1981; Uthicke and Benzie, 2000b).

Very few animals of any of the surveyed species were present on open sand away from reef habitat or upon habitats containing ripple marks on the sand surface. This finding is consistent with at least two observations made of holothurian distribution (Moriarty, 1982; Massin and Doumen, 1986).

Preliminary application of this new technique has succeeded in highlighting clear differences in the distribution of the 3 surveyed species, *H. nobilis*, *H. atra* and *S. chloronotus*. Further work will investigate relationships between physical habitat characteristics and the GPS derived distribution patterns of these holothurians. Physical habitat parameters investigated include: sediment grain size, sediment type (geology), sediment nutrient content, water temperature, hydrodynamics and bathymetry. These data have been collected at points along five strategically placed transects. Ultimately, through the application of GIS software, the study aims to determine the environmental characteristics of each habitat containing individual species to help clarify the micro-habitat preferences of coral reef holothurians. Further use of GIS may lead to calculation of distances between individuals to investigate fertilisation kinetics of these broadcast spawners. The application of this technique to determining more accurately species specific density estimates may also be investigated.

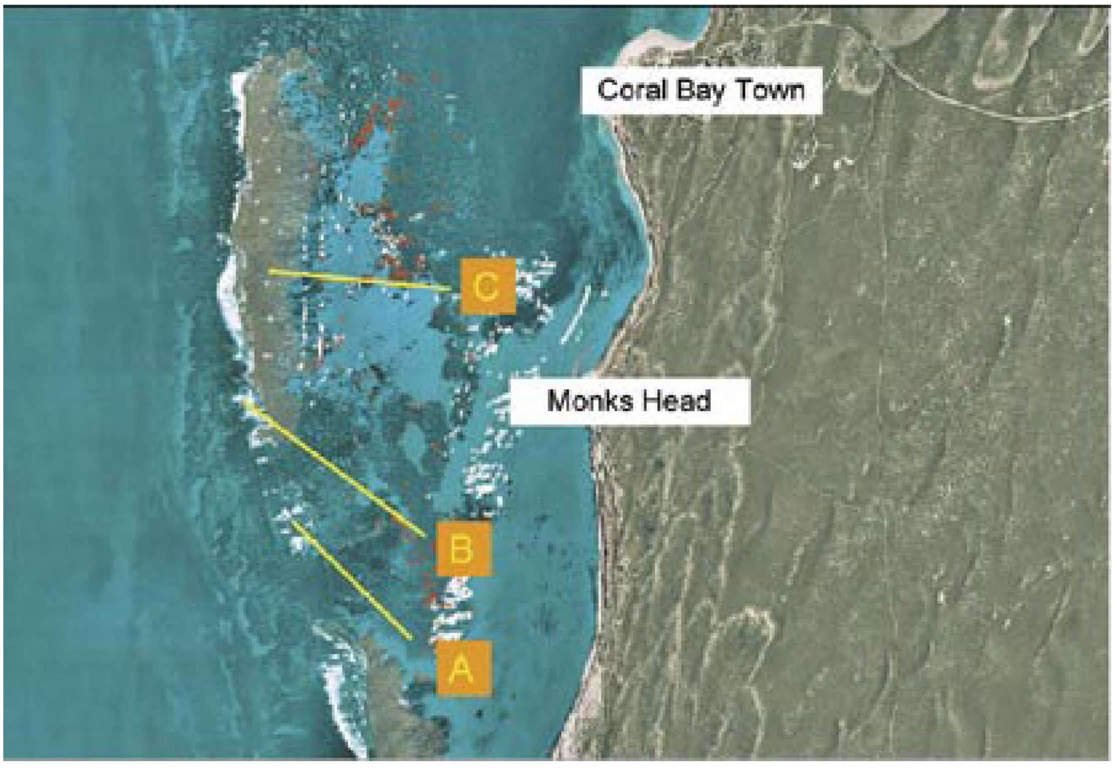

Figure 3. *Distribution of* H. nobilis *(red points) and* S. chloronotus *(white points), Coral Bay, Western Australia. Locations of selected transects* ***A****, B and* ***C****, through distinct holothurian distribution groups. Water temperature, bathymetry and sediment characteristics were recorded at measured intervals along each transect.*

Figure 4. *Distribution of* H. atra, *Coral Bay, Western Australia.*

Recommendations for management of *H. nobilis* populations in Western Australia

Management of a potential WA *H. nobilis* beche-de-mer fishery would currently be difficult given major limitations in information concerning the ecology and biology of endemic holothurian populations. In contrast to WA, a study of *H. nobilis* stocks on coral reefs in Queensland provided excellent baseline knowledge of this species (Benzie and Uthicke, 2003). Major components of this study examined stock size, gene flow, recruitment patterns, and stock recovery following fishing. Although this study provided excellent management information pertinent to the Great Barrier Reef fishery, many of the processes described by it may not be relevant to WA. For example, there are currently no data about the degree of gene flow or possible sources of recruitment between WA *H. nobilis* populations; biological processes that may be distinctly different relative to those of Queensland.

Although there are biological similarities between eastern and western Australian populations of *H. nobilis*, for example, in the timing of their spawning events (Shiell, unpublished data), sources of population recruitment are fewer in WA when compared to recruitment sources on the Great Barrier Reef, Queensland. Appropriate coral reef habitats are relatively sparse in northern WA and combined with the denuded nature of at least two of these, i.e. Ashmore and Cartier Reefs, recruitment of *H. nobilis* larvae to Mermaid Reef and, potentially, Ningaloo Reef may already be impeded.

Hence, management of a potential WA *H. nobilis* fishery should be approached with absolute caution. As a minimum prerequisite a study of the genetic similarity and the degree of gene flow between *H. nobilis* populations should be conducted before changes to current management policy are considered.

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Management of the Seychelles sea cucumber fishery: status and prospects

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Abstract

For a long period, the sea cucumber resources in Seychelles have been exploited by an open-access fishery with no management measures in place. Following its development in the 1950s, the fishery remained of minor importance until recent years, when a rapid development occurred 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 characteristics, as well as the stocks of sea cucumbers. Six species are currently exploited, mainly for the export market: *Holothuria nobilis*, *H. fuscogilva*, *H. scabra*, *Thelenota ananas*, *Actinopyga mauritiana* and *A. lecanora.* 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 become evident during the past four years, as fishers have had to dive deeper sometimes using SCUBA. In order to avoid further depletion of the 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 underreported. This led to more stringent regulations whereby catch and effort reporting became mandatory and a more conservative limit was imposed on the number of fishing licenses. Despite these measures, signs of localised overexploitation were still apparent 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 Food and Agriculture Organization of the United Nations (FAO) was approached to fund a stock assessment and management programme. The project, expected to start in late 2003, comprises two major outputs and associated capacity building. The first output is expected to produce a comprehensive and sustainable programme to assess the sea cucumber resources and monitor the development of the fishery. The second output comprises 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 the fishers in the drafting of the management plan is designed to impart 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.

Keywords: Beche-de-mer, stock assessment, management plan, stakeholder participation

塞舌尔的海参渔业：现状和展望

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摘要

长期以来，塞舌尔对海参渔业资源开发利用一直是实行开放准入制度，没有任何管理措施。从50年代到现在，该项渔业在整个渔业中始终是无足轻重的。但是，由于国际市场对海参需求的增长，塞舌尔的海参渔

业也在发展。由于缺少必要的资料，难以确定该渔业的特点以及海参的资源状况。目前被开发的海参有六种，即黑乳参（*Holothuria nobilis*）、黄乳参（*H. fuscogilva*）、糙海参（*H. scabra*）、梅花参（*Thelenota ananas*）、白底辐肛参（Actinopyga mauritiana）和子安辐肛参（*A. lecanora*）。作业渔场主要位于塞舌尔主岛周围的马和海底高地和向南的阿米然特思海底高地。2002的产量大约33 000千克。

在过去的4年里，海参资源量有明显下降的迹象，作业渔场渐渐向较深海区延伸，有时必需使用轻潜水设备。为了防止海参渔业资源的进一步衰退，塞舌尔渔业当局正在采取应对措施。其中之一是发放捕捞证和加工许可证，但是这一措施并不能及时地得到海参的渔业资料。在有效地控制海参渔业中存在的主要问题是人力和财力不足。呈报的海参捕捞数据不够准确，低报捕捞量很普遍。为此，对拥有捕捞许可证的从业人员实行了强制性措施。尽管有了这些措施，过度捕捞的迹象依然存在。负责进行资源评估的塞舌尔渔业当局，正在制定一项合理的海参渔业管理计划。

由于国内缺少有关专家，世界粮农组织（FAO）已经着手资助塞舌尔海参资源评估和资源管理项目。该项目指望于2003年底开始，预计将取得两项结果和有关生产建设事项。第一项成果将是根据资源评估结果制定出海参渔业可持续发展的计划和监控海参渔业的发展；第二项成果将把发展和管理计划的执行结合起来，包括修订和完善许可证制度，报告和强制执行机制，设立一个改善渔民和相关人员全方位参与海参渔业资源管理的框架，以及在海参渔业资源评估和渔业规章制定之间的强有力的联系。在起草管理计划时要求渔民参与是为了增强渔民的责任感。作为一项长期的战略措施，本项目也计划以海参增殖为目的，开展海参养殖。

关键词：海参、资源评估、管理计划、全方位参与

Introduction

Seychelles is an archipelago in the western Indian Ocean comprised of 115 islands lying between latitudes 4 °S to 10 °S, and longitudes 53 °E to 55 °E. The Exclusive Economic Zone (EEZ) of the Seychelles is around 1.4 million km^2 whilst the land mass is only 455 km^2. The fisheries sector in the Seychelles plays a very important economic role, as it accounts for around 52 % of the foreign exchange revenues of the country. It can be separated into an artisanal fishery, a semi-industrial fishery targeting mainly swordfish and tuna and, an industrial fishery targeting tuna. Whilst the industrial fishery is the most important in economic terms, the artisanal fishery is the most complex, as it comprises a multi-species resource base targeted by a diverse array of boat-gear combinations.

The sea cucumber fishery in the Seychelles is classified as part of the artisanal sector and has for a long time been a relatively unimportant fishery. It is a collector-type fishery, whereby some fishermen are harvesting sea cucumbers either by foot in shallow areas or by using SCUBA/snorkel apparatus. Once dried by local processors, sea cucumbers are then exported to the Southeast Asian markets. Because of the low importance attributed to the fishery, it was unregulated with open access, and no data on harvests were collected.

In recent years, with the increased demand of beche-de-mer on the international market and higher prices offered for the product, there has been an incentive to develop the fishery. More fishers entered the fishery and by 1999 there were already signs of stock depletion. The national fisheries authority (Seychelles Fishing Authority - SFA) implemented limited management measures in 1999, but due to a lack of data and low financial and human resources it was not feasible to attempt stock assessments that would produce a more comprehensive management plan.

In recognition of the data deficiencies for this fishery and the strong incentives for rapid over-exploitation, the SFA has gained support from FAO for a research and management programme directed at the sea cucumber resources in Seychelles. The project, to start in late 2003, will give the local authorities the necessary tools to prepare and implement a management plan with the participation of all stakeholders.

Status of the fishery

Legislative Framework

The Fisheries Act (1986) regulates the whole of the fishing sector in Seychelles. It is the core piece of legislation that makes provision for the Minister of Agriculture and Marine Resources to regulate the fisheries. The Fisheries Act does not specifically address the sea cucumber fishery. This, in effect, reduces it to an open-access fishery without any control or limitations on catch, gear, fishing zones or reporting of catches.

With the rapid development of the fishery over the past few years, it was considered necessary to develop regulatory measures. This was achieved through the Fisheries (Amendment) Regulations (1999). This regulation makes provision for the licensing of fishing and processing of sea cucumbers, and for the holder of a license to provide such information relating to fishing or processing carried out under the license as the competent authority (SFA) may require. The SFA is a parastatal body, whose parent ministry is the Ministry of Agriculture and Marine Resources. SFA is the executive arm of the Government in all fisheries related matters: research, development and management.

Overview of the fishery

Traditionally sea cucumbers have been harvested by a small number of fishers. The fishing grounds were located close to shore around the main granitic islands of the archipelago and sea cucumbers were caught in shallow waters using snorkelling gear or by handpicking on the reef flats. Of all the species of sea cucumbers found in local waters, only six are commercially exploited, namely *Holothuria nobilis*, *H. fuscogilva*, *H. scabra*, *Thelenota ananas*, *Actinopyga mauritiana* and *A. lecanora*.

The fresh sea cucumbers are usually bought by middlemen who process them into beche-de-mer. Although a very small amount is sold locally to the Chinese community, the bulk of the production of beche-de-mer is exported to Southeast Asian markets, namely Singapore and Hong-Kong SAR (China), and to a lesser extent to Malaysia.

Due to the low number of fishers involved, and the low biomass removed, the fishery remained uncontrolled and unmanaged until 1999. Catch and effort data were not collected. SFA did not have the necessary human and financial resources for the monitoring of the sea cucumber fishery preferring to concentrate its efforts on more important commercial fisheries. Exports of beche-de-mer were not individually accounted for but were grouped with dried shark fins by the customs officials. This situation made it impossible to estimate catches and exports before 1999. Exports have increased significantly over the last 3 years (Table 1) with around 33 000 kg of beche-de-mer exported in 2002 (SFA Annual Report 2002, in print).

Table 1. *Quantity and value of beche-de-mer exported (Source: Seychelles Customs).*

	2001		2002		2003(1)	
	Qty (kg)	Value (SR)(2)	Qty (kg)	Value (SR)	Qty (kg)	Value (SR)
Hong Kong	4 662	144 125	22 805	869 656	30 446	878 445
Singapore	1729	26 456	2 170	114 820	1 075	61 136
Malaysia	2387	76 813	8 995	394 071	13 085	540 764
Unknown	-	-	2 625	113 617	-	-
Total	8 778	247 394	36 595	1 492 164	44 606	1 480 345

(1): Data valid up to June 2003.

(2): SR: Seychelles Rupees. 1 US$ = 5.6 SR.

It is interesting to note that the amount of beche-de-mer exported to Hong Kong SAR (China) in 2001 (4 662 kg) differs from the amount reported to have been imported into this autonomous region by the Hong Kong SAR statistics authorities (7 120 kg) (Bruckner *et al.*, 2003). This discrepancy implies that accurate reporting is a problem in trade and that caution should be exercised when using published estimates.

Over the last six years, the trade in beche-de-mer has changed dramatically. Demand for beche-de-mer has been increasing on the traditional markets, while production has severely declined in most of the countries where sea cucumbers are harvested. This situation has led to a sharp increase in prices, which has renewed interest in the fishery in Seychelles. New fishers have entered the fishery and the fishing power has also increased with the use of equipment like SCUBA. Some of the fishers and processors have recently invested in new equipment (boats, SCUBA gear, air compressors, and drying facilities) for their operations.

Management issues

Introduction of management measures

Signs of stock reduction have been apparent during the past four years and fishers have found it necessary to dive deeper to find sea cucumbers in viable numbers, with some resorting to the use of SCUBA equipment. The SFA has thus found it necessary to put in place some management measures regarding this fishery. Some management measures were introduced in 1999 to regulate access to the fishery as proposed by Mees *et al.* (1998).

The Fisheries Act (1986) was amended through Statutory Instrument 25 (1999), where it became illegal to fish, catch or process sea cucumbers without a license. This makes sea cucumbers only the third marine group, after turtles and lobsters, to become a licensable fishing activity. Fishers and processors were expected, as part of the license conditions, to report their fishing and processing data to the SFA. However, anecdotal reports indicated that in spite of these measures, the level of illegal and licensed fishing of this resource continued to increase. Due to fears of overexploitation, the Government imposed a temporary ban on sea cucumber fishing in May 2001. This was, however, reconsidered in June 2001, when the Government made the following recommendations:

- Licensees who have not provided information (e.g. catch data, processing data) to the SFA will have their licenses revoked;
- No new licenses will be issued and existing licenses will not be renewed;
- A study to assess the sea cucumber resource will be undertaken by the SFA.

As a result of these recommendations, by November 2001, 22 licensees had either stopped fishing or their licenses expired out of the original 31 licensees. This left the remaining nine licensees to operate. At this time a request was made to the FAO for assistance in conducting an assessment of the sea cucumber resource in the Seychelles.

Following protests by the fishers and processors who had made substantial investments, the Government reconsidered its decision and a new set of recommendations were made at the end of November 2001:

- New licenses will be issued with new conditions of license (including completion of a catch and effort form mandatory for all fishing operators);
- Limit entry into the fishery, with the number of fishing licenses capped at 25;
- Fishing and processing licenses issued separately;
- Carry our stock assessment (research and fishery based data);
- Regulate the fishery in the outer islands through the Fisheries (Reserves) Regulations.

As a result of these recommendations, catch reporting by license holders increased by almost a hundred percent compared to the period prior to November 2001. On average 95 % of licensees report their catch, providing useful data for future fishery based stock assessment. As of October 2003, there are 12 fishing licenses and 3 processing licenses that have been issued (Table 2). Each fishing license gives the right to the licensee to use a maximum of 4 fishers. License holders are now required to report to the SFA on a monthly basis.

Table 2. *Number of licenses issued for fishing, processing and fishing & processing sea cucumbers.*

Year	Fishing (only)	Processing (only)	Fishing & Processing	Total
1999	10	2	2	14
2000	14	1	10	25
2001	12	-	3	15
2002	18	3	-	21
2003	12	3	-	15

The SFA also monitors the amount of beche-de-mer exported through data provided by the Ministry of Finance (Import and Export Section).

Concerns were also raised regarding an increase in diving accidents related to the fishery. Of all the fishers engaged in diving with compressed air, only a handful has a valid or recognized diving certificate. As a precautionary measure, the SFA proposed a series of recommendations with respect to diver safety.

However, these recommendations were not fully implemented due to the high costs involved in training divers and procuring safety equipment and diving operations within the fishery continue without complete control. It is to be noted that the fishing operators have made an effort in training their divers to a minimum acceptable certification in diving and today all the divers registered on the licenses have at least the PADI Open Water Diver certification. No new licenses are issued if divers do not have a PADI Open Water Diver Certificate.

Management constraints

One of the main constraints in implementing the management measures is the lack of the necessary financial and human resources. SFA is totally reliant on the fishery dependent data supplied by the licensees, both for catch, catch per unit effort (CPUE) or processing data. SFA does not currently have the means to post technicians at landing sites or to have observers on board fishing vessels to check on the accuracy of the data supplied. As a result there is uncertainty regarding the accuracy of the data and catches may be underreported. The problem of poaching also compromises management efforts. Even if poaching is not conducted on a large scale, the amount of sea cucumbers illegally harvested will have an impact on the stocks, making it difficult to assess whether or not the management measures put in place are having a positive impact on the fishery.

Some alleviation in the fishery can be expected, at least for the outer islands, once the Fisheries (Reserves) Regulation comes into force. This regulation proposes to create fisheries reserves around 16 of the outer islands whereby access to certain habitats will be controlled. Fishers will need a specific license to enter the reserves, will have to inform the island manager whenever they enter or leave the reserve and will be required to comply with reporting procedures. Poaching will therefore be more easily controlled.

With respect to those measures implemented since 1999, in particular the fact that catches reporting is a condition of the fishing license, the amount of data collected on the fishery has increased considerably. However, it is felt that there are still too many gaps in the data to use it to conduct a reliable stock assessment of the fishery. It was thus proposed to conduct a field survey of the resource in order to complement the data and produce a more comprehensive stock assessment.

FAO project

As mentioned earlier, the FAO was approached to fund a stock assessment and management programme. The programme was approved at the end of September 2003 and fieldwork is expected to begin in November 2003.

The 20-month long project will provide capacity building in the resource assessment and management of the Seychelles sea cucumber fishery in keeping with the Code of Conduct for Responsible Fisheries (CCRF). The project has several objectives, in the short, medium and long term.

Objectives of the project

The immediate objectives are:

- To prepare and implement a pilot management plan, with stakeholders` participation, based on the assessment of the resource, incorporating a comprehensive data collection and monitoring scheme and provisions for effective management
- To strengthen the capacity within the SFA and concerned national institutions for operating an effective, annually reviewed and updated, management system for the holothurian fishery.

The medium term objective is to create a sustainable basis for the operation of a management system for the holothurian fishery that will contribute to the optimum utilisation of the resources.

The long term objective is to contribute to the maintenance of the Seychelles income generating holothurian fishery through sustainable and responsible fisheries management.

Outputs of the project

The project is expected to have two major outputs with associated capacity building.

The first output is a comprehensive and sustainable model to assess the holothurian resources and monitor the development of the fishery. It will comprise the following:

- Methodology for surveys and monitoring programme to be developed to estimate the extent of the holothurian resource and to assess the impact of the fishery on the abundance of holothurians in selected fishing areas;
- An improved licensing system for the collection of quantitative and spatial fishery dependant data (catch, effort, cost of production, revenue);
- The statistical and geo-spatial analysis of fishery data (dependent and independent) in combination with available and acquired biological information to provide scientific advice for a sustainable harvesting regime.

The second output is the development and implementation of a management plan for the holothurian fishery, which will include the following:

- A revised and improved licensing, reporting and enforcement mechanism;
- A framework for improved fishers' and other stakeholders' participation in the management of the holothurian resource through formal as well as informal arrangements;
- A communication strategy for the SFA;
- A strong link between the scientific assessment of the resources and the regulation of the fishery to ensure sustainable utilisation.

Capacity building

The project will produce a trained core of SFA officers and research assistants that are capable of undertaking resource assessments of benthic marine animals and, in particular, holothurians. The national Fishing Authority will have the in-house skills to analyse and present this data in reports or resource maps and will be in a position also to produce specialized statistical and GIS-mediated analyses of the resource.

The project will provide, through example and experience, the capacity for resource managers to set up a management plan with stakeholder participation and to implement annual adjustments to the plan in response to scientific data on the resource. A model of a formal process of providing scientific advice to management with the advice of a committee (or other representation) of stakeholders will be established. This model will provide a structure upon which the management of other fisheries can be formalised.

Culture of sea cucumbers

Another long term objective of the project is to assess whether it would be feasible to culture sea cucumbers for restocking purposes. The necessity for restocking will depend on the results of the stock assessment. However, since holothurians are easily overexploited, it is suspected that stocks have already been heavily impacted during the last few years. Experience in other countries shows that, in the longer term, the fishery may need to be supported by reseeding of juvenile sea cucumbers.

Since there is a lack of expertise in the Seychelles in sea cucumber culture, the project has provided for one or more study tours to countries where sea cucumbers are cultured in order to gain experience and facilitate transfer of technology to Seychelles.

The outcomes of this project will make it possible to produce a comprehensive management plan for the holothurian fishery, involving the participation of all stakeholders.

Conclusion

The sea cucumber fishery in the Seychelles was, for long periods, an unimportant fishery in terms of catch and economic value. Only a few individuals were involved in the fishery, harvesting sea cucumbers in shallow waters and mainly using snorkelling equipment. Most of the beche-de-mer produced was exported to Southeast Asian countries. The fishery remained unregulated and uncontrolled due to its unimportance and limited financial and human resources and scarcity of fishery data.

This fishery has seen a rapid development since 1998 due to higher prices for beche-de-mer on the international market and dwindling stocks in many producing countries. In the Seychelles, there was an influx of entrants into the fishery and by 1999 there were already signs of stock depletion. Using a precautionary approach, the national fisheries authority implemented limited management measures, in particular with regards to the licensing of the activity, both for fishing and processing. These measures had to be adjusted several times in order to make the operators comply with the measures. Today there is a limit on the number of licenses (25) that can be allocated and it has become mandatory for all licensees to supply their catch and processing data to the fisheries authority.

Fishery-related data is still too scarce to help the fisheries authority assess the stocks of sea cucumbers and to prepare a management plan. Lacking the in-house expertise to carry out this task, the FAO was approached to assist in this exercise. A project to build capacity in the resource assessment and management of the Seychelles holothurian fishery was designed and recently approved for funding by the FAO. The main objectives of this project are to improve the licensing and reporting mechanisms, to carry-out surveys to estimate the extent of the holothurian resource and to assess the impact of fishery catches on the abundance of holothurians in selected fishing areas, and to develop and implement a management plan for the holothurian fishery.

A participatory approach will be taken to develop the management plan with the involvement of all stakeholders, and it is expected that the plan will be reviewed annually so that the resource can be exploited on a sustainable level.

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The application of the adaptive principle to the management and conservation of *Isostichopus fuscus* in the Galapagos Marine Reserve

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Abstract

Beche-de-mer fishing started in the Galapagos Islands in 1999 after commercial depletion of the populations in mainland Ecuador. The management of this fishing activity has evolved from top-down management to an adaptive and participatory management scheme. This scheme involves the direct participation of the local stakeholders. All decisions approved by a consensus in the local discussion forum ("*Junta*") are then set into law by the Government. The strategy is adaptive as it takes into account previous experiences to better the current management of the species. This paper presents a historical overview of the management regime since the 1990s. The authors present a conceptual framework, based on which the regulations have been passed in order to support the management of *Isostichopus fuscus* on a sustainable level. Changes in the management have been achieved due mainly to two key factors: (i) the innovative participatory system implemented by the Ecuadorian Government for the management of the Galapagos Marine Reserve (GMR), which enables the equal participation of stakeholders, i.e. science and conservation, tourism, fishing and managers, and (ii) the availability of demographic, biological and ecological information on this species, which acts as a tool for the decisions taken by the stakeholders. Stock assessments at over 60 sites in all fished islands, knowledge of the reproductive biology, the availability of 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 to the detriment of the species.

Keywords: Participatory management, consensus, scientific parameters, obstacles, sea cucumber

加拉帕戈斯对厄瓜多尔等刺参（*Isostichopus fuscus*）管理和保护的原则

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[1]加拉帕戈斯达尔文研究站；[2]加拉帕戈斯海洋公园管理处

摘要

自从1999年厄瓜多尔本土的海参资源衰退后，海参渔业转移到了加拉帕戈斯群岛。海参渔业管理涉及到一整套周密的管理办法和多方参与的管理措施。该管理办法要求当地各部门和有关人员全方位直接参与。管理计划的确立乃由当地的一个专门小组进行讨论，获得多数人赞同后所做出的，被作为当地的法律予以执行。与以前的管理经历相比，该策略是可行的。本文回顾了自90年代以来的管理措施。笔者根据过去的管理规章办法，提出了一个概念上的框架，试图将等刺参（*Isostichopus fuscus*）的管理，提高到可持续发展的水平上来。管理措施上的变化主要归因于两点关键因素：（1）厄瓜多尔政府为了加强对加拉帕戈斯海洋资源的保护执行了这一具有创新意义的参与体系，该体系使得各部门每一成员，包括科学家、环保人士、旅游业界、渔民和管理人员都有同等的参与权力；（2）资源统计学、生物学和生态学上有关等刺参的资料被作为参与者做出决定的前提。从60多个采样点所得到的资源评估资料、繁殖生物学的知识、已有的渔业统计资料和生态学方面的信息为可持续发展渔业规章的建立成为可能。最后，本文强调了执行中存在的障碍，如当地专门小组代表的改变和来自于渔民和其家庭对政府施加的社会经济压力，有可能损害到对海参资源的保护。

关键词：参与管理、舆论、科学参数、障碍、海参

Introduction

With the arrival of the sea cucumber fishery to the Galapagos Islands in 1991, after commercial depletion in mainland Ecuador (Camhi, 1995), fishing activity as a whole changed direction. Originally, this fishing activity was concentrated in the in the Bolívar Channel (Figure 1), focusing entirely on *Isostichopus fuscus* as the commercially important species (Figure 2). When the fishery was reopened in 1999 after the official closing in 1994, the fishing grounds were extended to Floreana, Española, Fernandina, Isabela, San Cristóbal and Santa Cruz with potential expansion to the rest of the archipelago.

Isostichopus fuscus is collected from the bottom of the sea floor by divers on a hookah, at depths ranging from 1 to 30 m. A total of 845 fishers and 313 fishing vessels were active in the 2003 season (Murillo *et al*., 2003), numbers that have remained fairly constant since the approval of the Fishing Registry in 2002. However, De Miras *et al.* (1996) reported only approximately 400 fishers during the first legal fishing season in 1994. Despite being an activity intended only for locals, the sea cucumber fishery has enticed fishermen from mainland Ecuador to fish illegally (Powell and Gibbs, 1996) and there is a constant introduction of new fishers.

Isostichopus fuscus can be found in the eastern Pacific, from Baja California, México to Ecuador, including Cocos Island (Costa Rica), Socorro Island (México) and the Galapagos Islands (Ecuador) (Deichman, 1958; Maluf, 1991). In the latter it can be found in all islands where there are rocky bottoms down to 39 m depth (Maluf, 1991). Fishing activity for this species has been recorded in Mexico (Castro, 1995; Reyes-Bonilla and Herrero-Perezrul, 2003), however, it was declared at risk of extinction (Secreteria de Medio Ambiente, Recursos Naturales y Pesca, 2000). In mainland Ecuador the populations are overexploited and the only viable populations are found in the Galapagos Marine Reserve (GMR) (For a complete list of acronyms see Table 1).

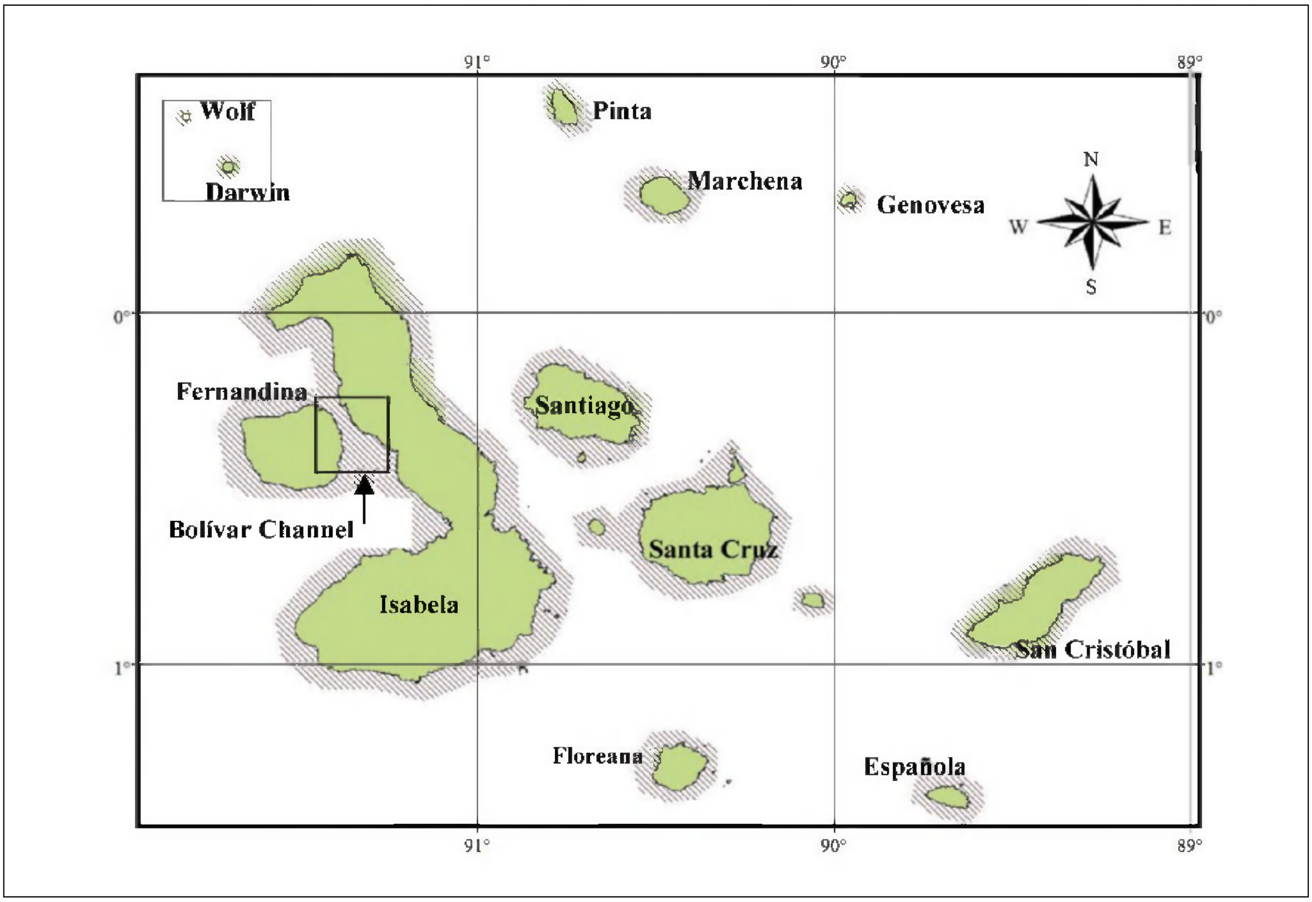

Figure 1. *Geographical distribution of* Isostichopus fuscus *in the Galapagos Islands. Shaded area show known distribution.*

The participatory approach

In 1998 the Ecuadorian Government passed the Special Law for Galapagos (SLG) aiming for a better management and conservation of the Galapagos Islands. The SLG created the GMR, comprising an area over 138 000 km^2, which included changes in the National Parks legislation, thus incorporating the first (and so far only) Ecuadorian marine reserve. The SLG grants exclusive use of the GMR to registered artisanal fishers of the Galapagos Islands, creates the coastal zoning scheme (later approved in 2000), in which approximately 18 % of the coastal zone was declared as a *No-Take Zone* (NTZ) (Heylings *et al*., 2002), and sets the participatory process within the management framework for the sustainable use of the GMR. Additionally, it places the management and control of the GMR in the hands of the Galapagos National Park Service (GNPS).

The management of the GMR is based on a two-level system, involving both local and national stakeholders. On the local level, the Participatory Management Board (PMB) or "*Junta*" includes five direct stakeholders: Artisanal Fishers Cooperatives Association, Galapagos Chamber of Tourism, Naturalist Guides, Charles Darwin Research Station (CDRS) and the Galapagos National Park Service (Figure 3). At this level, all decisions involving any activity within the GMR must be taken by consensus. Decisions are taken with regard to any activities that may influence the GMR as a whole, not just the direct ones of the stakeholders. The CDRS, the operative arm of the Charles Darwin Foundation (CDF), provides the scientific information used for informed decisions. Scientific data, such as population density, size classes and depth distribution, are collected on trips to the six islands under legal exploitation and include the active participation of the direct stakeholders of the GMR. This information is analysed and presented to the participatory forum with the direct input of all stakeholders (Toral-Granda and Martínez, 2004).

Figure 2. Isostichopus fuscus *in the Galapagos islands. Photo: Manfred Altamirano.*

Table 1. *List of acronyms used throughout the document.*

Acronym	Description	Acronym	Description
CDF	Charles Darwin Foundation	IMA	Inter-Iinstitutional Management Authority
CDRS	Charles Darwin Research Station	MMC	Merchant Monitoring Certificates
FMC	Fisheries Monitoring Certificate	NTZ	No-Take Zone
FMP	Fisheries Monitoring Programme	PMB	Participatory Management Board
GMR	Galapagos Marine Reserve	SLG	Special Law of Galapagos
GNPS	Galapagos National Park Service	TAC	Total Allowable Catch
GPS	Geographic Positioning System	TAD	Transport Authorization Docket

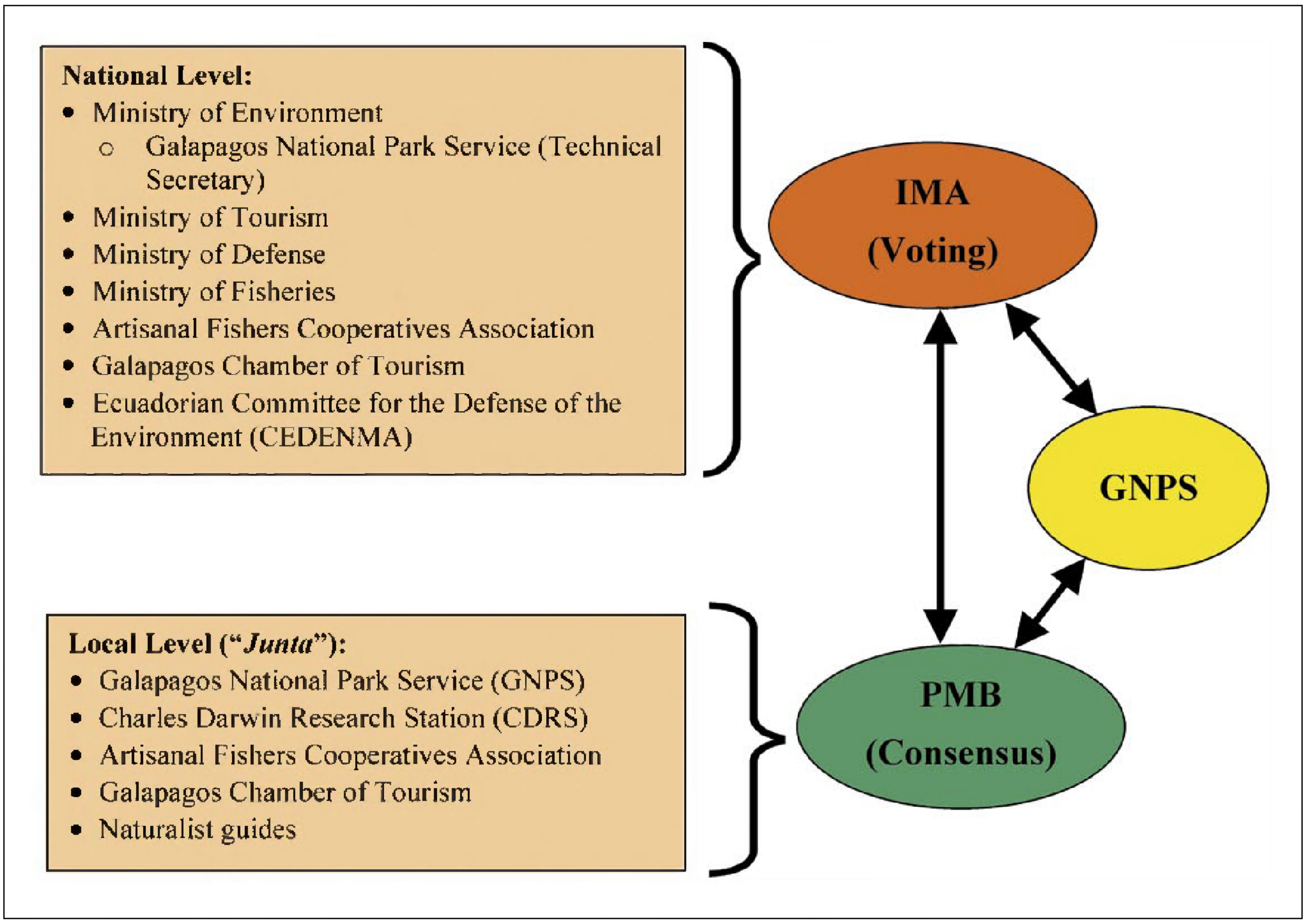

Figure 3. *Schematic presentation of the participatory management scheme for the Galapagos Marine Reserve, as approved by the Galapagos Special Law passed on 1998. (Adapted from: Heylings and Bravo, 2001; Bravo et al., in press).*

All decisions taken by the PMB are presented to the Inter-Institutional Management Authority (IMA) which comprises government authorities (Ministry of Fishing, Ministry of Tourism, Ministry of Environment, Ministry of Defence) along with Galapagos-based stakeholders (Artisanal Fishers Cooperatives Association, Galapagos Chamber of Tourism) and finally the Ecuadorian Committee for the Defence of the Environment. The CDF acts as a scientific assessor to the IMA as per agreement with the Ecuadorian Government. The GNPS serves as technical secretary during all IMA meetings. All decisions brought by the PMB are generally evaluated by the IMA that in turn makes a final resolution based on a voting system. Both the GNPS and the CDF provide guidance, opinions and criteria but cannot vote. When a resolution or a decision is taken it is the GNPS responsibility to enforce it. Most of the decisions taken by the PMB are approved by the IMA, helping to strengthen the process and to encourage the local stakeholders to continue with co-management (Heylings and Bravo, 2001).

This system has allowed the stakeholders to define and propose their own political views and management regulations, while at the same time safeguarding against the imposition of decisions made outside of the Islands and in a vertical manner (top-down decisions).

In the past six years (1998-2003) the administration system of the GMR has shown a remarkable efficiency in the management framework of the GMR. Additional to the co-management scheme, it has created tools that have maximised fishing activities within the GMR while helping sustainable development. All these tools were created in the participatory fora (PMB and IMA). These tools are:

- The Management Plan for the Conservation and Sustainable Use of the GMR: approved in 1998 it provides the guidelines for all activities (fishing, tourism, science, conservation, etc) within the GMR.

- Special Regulation for the Artisanal Fishing Activity in the GMR, which together with the Management Plan completes the regulations needed for its management and control. These constitute management's most important instruments.
- The Coastal Zoning, as approved in the Management Plan, aims to protect the GMR coastal ecosystems and biodiversity, and to set guidelines for human activities and uses, so as to avoid conflict between multiple users.
- A five-year fishing calendar (2002-2006) establishes the framework in which extractive activities will take place within the GMR. This tool includes major points that regulate the sea cucumber fishing seasons (Table 2).
- The Fishing Registry establishes the total number of fishing vessels and fishers, thus limiting the fishing effort. These numbers are controlled by the GNPS.

Table 2. *Main scientific criteria used for the management of the Galapagos sea cucumber (*Isostichopus fuscus*) fishery in the five-year fishing calendar (2002-2006).*

Season: According to the results from the population density participatory studies it will be decided whether a fishery will be opened each year. If a fishery were to happen, it should take place between March and May each year for 60 days.
Population density participatory studies: Every year, prior and after each fishing season, a participatory study on population density will be undertaken. All direct users of the GMR must take part in the study.
Criteria needed for a fishing season: In 2002, a minimum population density of 0.4 ind./-m^{-2} of individuals greater than 22 cm total length should be found in all fishing zones in order to open a fishing season. As from 2003, additional to the population density values, a comprehensive analysis of Catch per Unit of Effort (CPUE) will be carried out to indicate the trends for all the fishing zones. If CPUE values are lower every year, the fishing zone under analysis will be closed for fishing activities. If ¾ of the total of the fishing zones show diminishing values, the fishery will be closed in the entire archipelago.
Minimum Landing Size: 20 cm total length (fresh product).
Closure of nursery grounds: Bolívar Channel will be closed to fishing activities due to high levels of recruits.

The use of scientific information in the adaptive and participatory approach to management of the GMR

Until 1998, the only management strategy for the sustainable use of *I. fuscus* in the GMR was the complete ban on fishing activities; however, this was not completely enforced and illegal fishing activities were registered (Piu, 1998, 2000). In 1999 and 2000, several measures were established for the fishery: (i) fishing season; (ii) Total Allowable Catch (TAC); (iii) population density studies; and (iv) continuous monitoring of all fishing activities (Table 3).

During 2001, the fishing season also had a minimum landing size, TAC per registered fisher (the TAC was equally divided among all registered fishers), No-Take Zones, and the closure of nursery grounds after the juveniles were found in Bolívar Channel (Toral-Granda and Martínez, 2004) (Table 3). The individual TAC was present only during this year due to major complaints by the fishing sector; however, it was beneficial for both the management and conservation. In that year only 2.7 million sea cucumbers were caught (Murillo *et al.*, 2003).

From 2002, with the approval of the five-year fishing calendar, a set of both biological and fishing indicators were established as key elements for overseeing this activity in the GMR. A minimum threshold value was accepted, and although based on precautionary principles, the idea has been widely accepted by all stakeholders. Moreover, permanent monitoring of the CPUE[1] in all fishing zones will help to close a fishing zone if the value drops substantially.

In the 2003 season, nine criteria were used to manage the fishing activities for *I. fuscus* in the GMR in comparison to only four used in 1999 (Table 3). From all these criteria, the TAC has been the hardest to keep as a management tool, despite its widespread use. Galápagos artisanal fishers blame diving accidents (some fatal) and inequity of earnings on the TAC. Total income from the fishery relies on the quality of the fishing vessels used, proximity to fishing location and time underwater. The TAC promotes higher competition amongst fishers, yielding longer diving times in

[1] *CPUE= catch per unit of effort - Individuals/diver/day*

order to catch as much as possible before other fishers arrive or the TAC is achieved. This management tool has not had the consensus at the PMB level, which has led to further discussions at the National level (IMA). Socio-economic and political pressure along with hastiness at the meeting led to the absence of a TAC and resulted in a catch of 8.3 million individuals in 2002, which is likely to be unsustainable.

Table 3. *Technical criteria used for the management of the sea cucumber (*Isostichopus fuscus*) fishery in the Galapagos Marine Reserve since 1999.*

Technical Criteria	*Fishing Season* 1999	2000	2001	2002	2003
Two-Month season	✔	✔	✔	✔	✔
Total Allowable Catch (TAC)	✔	✔	✔	–	✔
Individual TAC	–	–	✔	–	–
Fisheries Monitoring	✔	✔	✔	✔	✔
Minimum Landing Size	–	–	✔	✔	✔
Coastal Zoning	–	–	✔	✔	✔
Closure of nursery grounds	–	–	✔	✔	✔
Closure of islands	–	–	–	✔	✔
Population density evaluation	✔	✔	✔	✔	✔
Catch Per Unit of Effort (CPUE)	–	–	–	–	✔
Total number of criteria used	**4**	**4**	**8**	**7**	**9**

All these regulations would not have been placed and used without the constant support of scientific information. The CDRS is in charge of providing this information to the PMB and the IMA and to any other interested parties upon request. Figure 4 illustrates the use of science towards the management of *I. fuscus* fishery in the GMR. The CDRS has focused its work on:

- *Basic biology*: taxonomy, habitat characterisation, size at maturity, reproductive season, fecundity, growth and vertical distribution.
- *Stock assessment*: From 1993 to 1998, estimates of stock density were concentrated on the Bolívar Channel region. From 1999, a total of 69 sites have been regularly monitored at the larger islands: Santa Cruz, San Cristóbal, Española, Floreana, Isabela and Fernandina (Toral-Granda and Martínez, 2004).
- *Fishing parameters*: With the establishment of the Fisheries Monitoring Program (FMP) in 1997, information such as TAC, landing size, CPUE, were gathered for all exploited species in the GMR (spiny lobster, sea cucumbers and finfish).
- *Socio-economic indicators*: In 1999, the FMP started gathering information on the socio-economic value of the sea cucumber fishery. Among the indicators are income per capita, price, market value and expenditure level.
- *Maximum Sustainable Yield and other modelling*: Based on the information gathered in the population surveys, fisheries monitoring system and basic biology studies, mathematical models are under construction to help the sustainable use of this species in the GMR. The TAC for the 2000 fishing season was obtained with a Leslie depletion model, which was used as the base for future TACs.

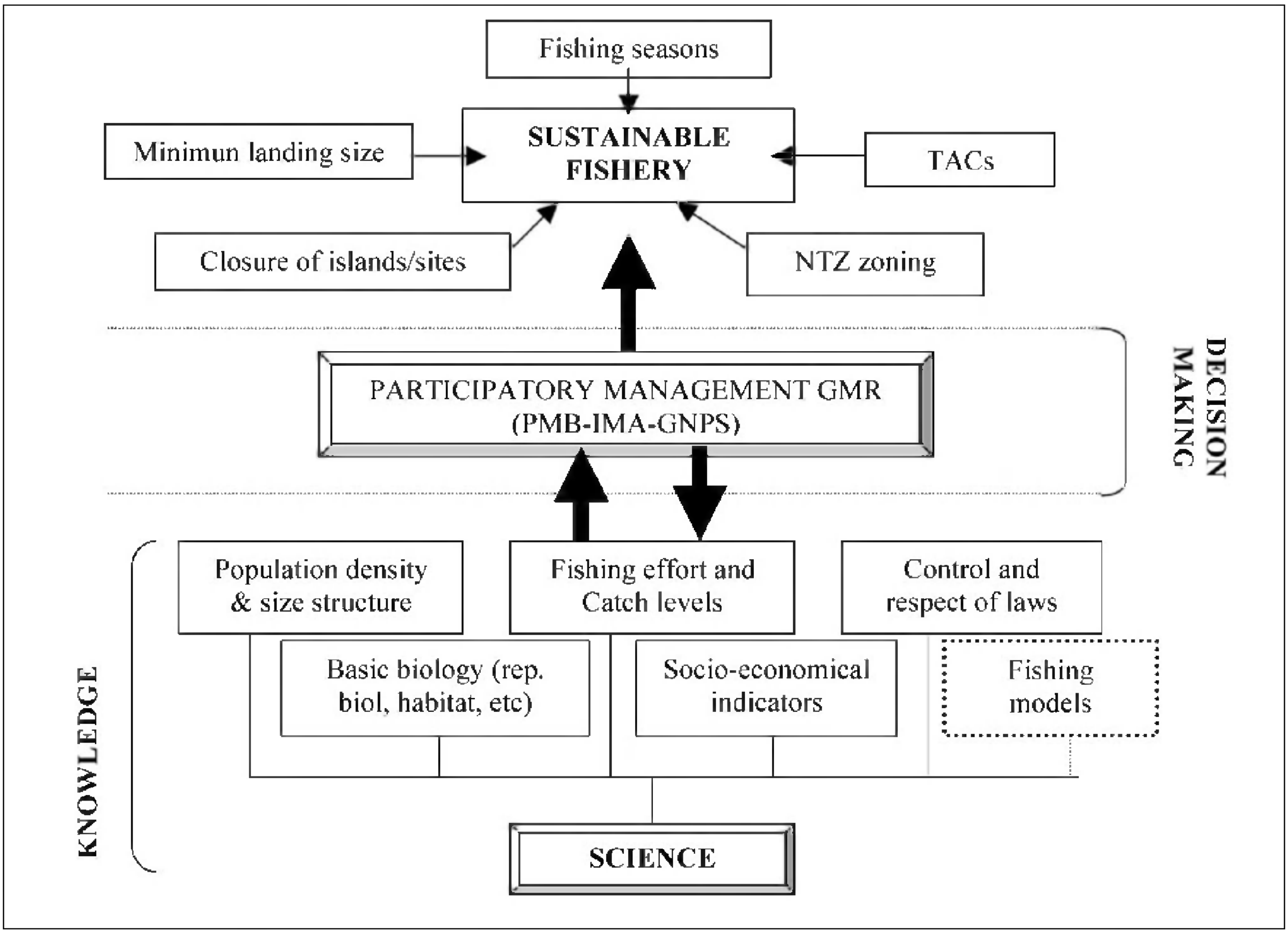

Figure 4. *Schematic presentation of the influence of scientific information for the better management of* I. fuscus *in the Galapagos Islands. The box in dotted lines is work in progress.*

Monitoring of fishing activity as a tool for scientific information and management

The FMP was established in 1997 to collect information on fishing sites, fishing effort, total catch, fishing methods, etc. This is intended to provide basic information for the proper understanding of the extractive activities within the GMR. This information is gathered for all species extracted from the GMR. The fishery database for *I. fuscus* and spiny lobsters (*Panulirus penicillatus* and *P. gracilis*) is the best available in the CDRS as they are the first and second most important products harvested from the Galapagos (Murillo *et al.*, 2003).

During each fishing season, GNPS vessels with at least one Ecuadorian Navy Officer patrol current fishing grounds. During the patrolling they will verify the fishing permits and check for illegal catch.

The FMP tries to collect information from the start of the extraction process through the use of fishing observers, landing monitors, park wardens and marine resource officers. The whole process is known as "*Cadena de custodia*" or Chain of Custody. This chain aims to follow the product from the extraction point to the exporter in mainland Ecuador. With the SLG, it is mandatory for the artisanal fishing sector of Galapagos to comply with FMP requests and activities. The Chain of Custody has the following steps:

1. A CDRS fishing observer travels on board a fishing vessel and collects information on fishing sites (GPS position), fishing method used, total catch per site, size structure of the landed product, biological information, etc.

2. For fishing vessels without a fishing observer, information is recorded in the captain's logbook.
3. Upon arrival to one of the ports: (i) CDRS personnel will record catch information, fishing sites, biological information, and (ii) GNPS will verify compliance to fishery regulations, any catch not complying to these is impounded. Vessels with a fishing observer on board must only comply with the GNPS provision. A Fishing Monitoring Certificate (FMC) is issued to the owner of the catch. This certificate verifies the amount harvested and state of the produce (i.e. fresh, in brine, dry for *I. fuscus*)
4. The owner of the catch must present the FMCs to the sea cucumber merchant, who will present all FMCs to GNPS personnel upon inspection. The total amount presented by the dealer must be equal to the sum of FMCs. The merchant is then issued a Merchant Monitoring Certificate (MMC).
5. Once the sea cucumber merchant has gathered enough product to send to mainland Ecuador, he/she will present all MMCs to the GNPS in order to obtain authorization to send the product out of the Islands. The GNPS will issue a Transport Authorization Docket (TAD) and a CITES official export permit. *Isostichopus fuscus* was included in Appendix III of CITES on August 15, 2003.
6. The sea cucumber merchant must present all TADs and CITES official export permits in the airport or cargo pier in the Galapagos Islands. Upon arrival in mainland Ecuador, all cargo will be presented to the Undersecretary of Fishing, in mainland Ecuador, who in turn will verify the amount intended to be exported from the amount stated in the certificates and permits. Then the cargo can be exported internationally.

Commercial value of *I. fuscus*

- To date, sea cucumber fishery is the most lucrative fishing activity in the GMR (Murillo *et al.*, 2003). From 1999 to 2003, a total of 25 327 972 sea cucumbers were harvested. This equals 6 856.41 tonnes fresh weight whole. After processing, this species losses approximately 90 % of its weight, giving approximately 671.2 tonnes dry weight.
- This fishing activity has yielded a gross income of US$ 14 436 589 to the local artisanal fishing sector.
- The market price per kg of individuals in brine in Galapagos was US$ 22.88 in 1999, US$ 24.1 in 2000, US$ 12.32 in 2001, US$ 14.96 in 2002 and US$ 22.88 in 2003 (Murillo *et al.*, 2003).
- According to Ecuadorian Export Statistics, Taiwan (Province of China) is the most important importer (73 % of the total), followed by USA and Hong Kong SAR (China).

Weaknesses of the participatory management system

Despite the great effort by all users, managers and scientists to preserve *I. fuscus* population at sustainable levels, this fishing activity is under threat of collapse due to a number of factors:

1. Illegal fishing activities are still present within the GMR. According to GNPS data, over 500 000 sea cucumbers have been illegally impounded between 1996 and 2003, the quantity that was not detected is unknown.
2. The minimum landing size is not respected. In 2003, 37 % of the total catch was undersized (Murillo *et al.*, 2003), compared to less than 10 % in 1999 (Murillo *et al.*, 2002).
3. Stocks on four of the six islands under fishing pressure show clear evidence of overfishing. Both CPUE values (Murillo *et al.*, 2003) and stock assessments (Toral-Granda and Martínez, 2004; Toral-Granda *et al.*, 2003) clearly show a rapid decrease of *I. fuscus* populations over time and there is no evidence of significant recruitment (Toral-Granda and Martínez, 2004; Toral-Granda *et al.*, 2003).
4. The average size at landing has decreased with time, suggesting that despite a relatively high total catch being maintained, total biomass has reduced (Murillo *et al.*, 2003).

5. The provisional zoning scheme has yet to prove its benefits to *I. fuscus* populations within the GMR. Stock abundance is highly variable over time (Toral-Granda and Martínez, 2004; Toral-Granda *et al*., 2003); however, the zoning has been effective during some fishing seasons (Toral-Granda *et al*., 2003) probably due to better patrolling by the GNPS. According to Altamirano and Aguiñaga (2002), NTZs have the highest percentage of all illegal fishing activity.

Moreover, the participatory management in the GMR has not achieved the aims and expectations envisioned. All users complain at some time about the system, but there is still the wide opinion that the process is just starting and more changes will be observed in time. Nonetheless, it is worth pointing out some deficiencies to help other possible users to overcome such problems.

- All regulations discussed and accepted by the Artisanal Fishers Cooperatives Association during PMB and IMA meeting do not reflect the sector`s opinions. The representatives to the fora usually present their group`s interests rather than those of the sector. Additionally, their opinion also changes every time the representative is voted out or replaced, leading to an unrealistic compromise by the sector to follow up and respect laws and regulations.
- Due to its adaptive nature, all regulations from the participatory management fora have developed too fast to be well understood by the stakeholders.
- All regulations passed by the PMB and IMA require GNPS and Ecuadorian Navy constant supervision and control. Due to financial constraints, patrolling activities are restricted during fishing seasons, which presents an opportunity for illegal fishing outside seasons and in the NTZs.
- Despite the vast array of scientific information, most decisions to open each fishing season have been based on: (i) a tendency to avoid social conflicts between managers and fishers; (ii) a lack of alternatives for the artisanal fishing sector of Galapagos; (iii) GNPS limited capacity to enforce the laws and regulations; and (iv) social and political influence.

Conclusions

All fishing activities within the GMR have a well established co-management scheme, which includes all major stakeholders in the decision-making process. The process itself promotes bottom-up decisions based on scientific information. For the management of *I. fuscus*, there is enough scientific information to guide the process towards sustainability, and both the local and national forum understand the present situation of this species within the GMR. Despite all efforts to manage this species within sustainable levels, the fishery is under serious peril due to overexploitation and illegal fishing. The co-management scheme is still young and undergoing changes and revisions that will yield beneficial impacts in the management and future of the GMR and for *I. fuscus*.

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Note from the Editors:

Due to a series of logistical problems the lead author of this paper was unable to attend the ASCAM workshop in Dalian, China, and to submit the final paper for inclusion in these technical proceedings. The abstract of the paper and its Chinese translation are nevertheless included to update the interested community at large on the status of the sea cucumber fishery in Solomon Islands (Pacific) and plans for a new framework for management of the resource. As in numerous other countries across the globe, national export data from Solomon Islands show decreased landings of sea cucumbers. The author proposes to spearhead a project that would promote an improved management approach, by involving the participation of the fishing communities in order to create a feeling of ownership. Customary Marine Tenure is seen as a suitable model to manage the fishery resource along with the enforcement of specific regulations derived from sound and available scientific information. The author has informed the organizers that he will prepare the paper and submit it to the SPC Beche-de-mer Bulletin some time later in the year.

CUSTOMARY MARINE TENURE IN SOLOMON ISLANDS: A SHIFTING PARADIGM FOR MANAGEMENT OF SEA CUCUMBERS IN ARTISANAL FISHERIES

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Abstract

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 tonnes (dried) in 1991 to 240 tonnes (dried) in 2001, with > 75 % of the 2001 landings derived from species of medium- and low-commercial value. The resources appear to be over-exploited because 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 of civil war (1998-2000) 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 coordinating 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.

Keywords: Beche-de-mer, Community-based Management, Resources, Overfishing, Exploitation, Conservation

所罗门群岛传统的海域使用权：海参渔业管理的范例

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摘要

由于西方渔业资源管理模式在本地区不甚成功，而采用所罗门群岛传统的海域占用模式（CMT）来管理海参资源反而是更为有效。1991-2001年间的海参出口资料分析表明，海参的上岸量从1991年的622吨（干品）下降到了2001年的240吨，同时，2001年的海参中有75%为中下等级质量的海参。这一结果说明，资源量下降是捕捞过度所致，在过去的10年内，非传统渔区作业面的迅速扩大，渔民人数也呈现快速增加。

1998-2000年间的国内战争，以及因战争所造成的经济困难，海参资源再次遭受劫难。问题出在政府未能制定和执行一套必要的保护海参资源的政策，如可捕个体的规格、捕捞用网袋的规格、捕捞工具的限制，和禁渔期等。未能奏效的原因，一是人手不足，二是财力和技术资源匮乏。由于集中管理的失败，CMT模式可能是管理海参资源的一个好的工具。因为CMT是以社区为基础，近海海域的资源是在社区的管辖权内，渔区和资源所有者的积极参与，在社区水平上形成的管理策略是这一模式的基本原则。 这些资源的管理必须转移给社区，必须有一套强制性的规章制度，如捕捞用的网袋规格、捕捞工具的限制、禁渔期、轮捕，和作业渔区的限制等。把这些规章与当地的CMT系统协调地结合起来。在管理模式上的这一转变将给所有者一个感觉，海参资源是掌握在社区手中，为社区提供了制定计划和采取何种管理方式等的决策权，适合当地的境况和需要。而政府应该采取支持和协调的作用，制定政策和协调框架。随着管理模式的转变，应该减少海参的捕捞量，暂停目前的过度捕捞现状，并为太平洋沿岸手工作业的小型渔业社区寻找其他谋生之路。

关键词：海参、社区为基础的管理、资源、过度捕捞、资源开发、资源保护

Fishery and resource management of tropical sea cucumbers in the islands of the South China Sea

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Abstract

Dongsha Islands, Nansha Islands, Xisha Islands and Zhongsha Islands in the South China Sea, located in the subtropics, are rich in sea cucumber resources. There are eighteen species of sea cucumbers in the area: *Actinopyga echinites, 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 variegatus, S. chloronotus* and *Thelenota ananas.* These species mainly inhabit the sea bed of coral reefs and are found as deep as 70 m, feeding on organic matter and microorganisms in the sand. For more than 400 years, fishers in eastern Hainan Island have visited Xisha and Nansha Islands to collect sea cucumbers using a specially designed tool known as the "sea cucumber fork". Processing of sea cucumbers includes three steps: removal of the viscera, cooking and drying. During the initial sea cucumber processing considerable care is required during the boiling phase and the intensity of the fire is regulated based on the colour changes of the specimens being cooked. Sea cucumbers are rich in protein and are used in China as a traditional medicine. They are also a highly sought after food item. Excessive fishing has caused the resources of sea cucumbers in these four island groups to gradually decline. To promote the sustainable utilization of these resources, a plan to protect some areas from fishing should be considered. 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 to maintain an ecologically stable resource by transferring emphasis from capture fisheries to aquaculture.

Keywords: South China Sea, sea cucumber, resource, fishery, management, holothurians

中国南海诸岛热带海参渔业和资源管理

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摘要

位于中国南海的东沙、南沙、西沙和中沙群岛周围海域有着丰富的热带和亚热带海参资源。大约有18种具有较高的经济价值。它们是： 棘辐肛参（*Actinopyga echinites*）、 子安辐肛参（*A. lecanora*）、白底辐肛参（*A. mauritiana*）、乌皱辐肛参（*A. miliaris*）、 蛇目白尼参（*Bohadschia argus*）、图纹白尼参（*B. marmorata*）、黑海参（*Holothuria atra*）、黑赤星海参（*H. cinerascens*）、红腹海参（*H. edulis*）、 甘海参（*H. impatiens*）、 玉足海参（*H. leucospilota*）、 黑乳参（*H. nobilis*）、虎纹海参（*H. pervicax*）、 糙海参（*H. scabra*）、 花刺参（*Stichopus variegatus*）、 绿刺参（*S. chloronotus*）和 梅花参（*Thelenota ananas*）等。 这些海参栖息于水深70米以内的珊瑚礁区，以有机碎屑和生活在珊瑚礁内的微生物为食。400多年前居住在海南岛东部的渔民经常到西沙和南沙诸岛，用一种称之为“海参叉”的专用工具捕捞海参。海参的加工包括三个步骤：清除内脏，水煮和干燥。在水煮和干燥时，要点是掌握火候和时间，依据海参的体色变化来判断。海参的蛋白质含量很高，不仅是名贵的食品，还是传统的中药。过度捕捞已经使得海参资源不断下降。为了合理利用和持续开发海参资源，计划划出一定的海参资源比较丰富的海域作为保护区。同时，限定捕捞季节和法定最小捕捞个体，以保护足够的群体资源量。进一步加强对具有重要经济价值的海参的人工繁殖研究，把海参渔业的重点由捕捞渔业向养殖渔业转移。

关键词：南中国海、海参、资源、渔业、管理、海参类

Background

Located in the tropics and subtropics, Dongsha Islands, Nansha Islands, Xisha Islands and Zhongsha Islands of the South China Sea are famous fishing grounds. Characterized by their special environment and extensive habitats, these fishing grounds are valuable for the growth and reproduction of many species of marine taxa, including echinoderms, molluscs, crustaceans, seaweeds, some reptiles and especially sea cucumber.

Status of the resources

There are a total of 18 species of sea cucumbers that live in these four island groups according to previous studies (Liao, 1997). Among these 18 species of sea cucumbers, *Thelenota ananas, Stichopus variegatus,* and *S. chloronotus* belong to the family of Stichopodidae, while all others (*Holothuria nobilis*, *H. atra, H. leucospilota, H. scabra, H. edulis, H. cinerascens, H. pervicax, H. arenicola, H. impatiens, Actinopyga lecanora, A. echinites, A. mauritiana, A. miliaris, Bohadschia marmorata* and *B. argus)* belong to the Holothuriidae family. It has been estimated that there are about 2 000 tonnes (dry weight) of exploitable of sea cucumbers in these islands off Hainan (Li, 1990). On the Qionghai coast, Hainan, the available resource was estimated at 250 tonnes (dry weight). Among these species, *T. ananas, H. atra, H. leucospilota, A. mauritiana* and *B. argus* are considered high yielding species, whereas *T. ananas, H. nobilis, B. marmorata, S. variegatus* and *A. mauritiana* are the commercially important species.

Compared with the Dongsha, Xisha and Zhongsha islands, the sea cucumber resources are most abundant in the Nansha Islands. The marine areas where sea cucumber resources are most abundant are: the southern and northern areas around the Xisha Islands; the Yuya Reef, Chang Reef, Guangxingzai Reef, South Shallow Bank, Nankang Reef, Meiji Reef and Hua Reef in the Nansha Islands; North Reef, Huaguang Reef, Yutuen Reef, Langhua Reef, Yinyupan and Zhongjian Islands in the Xisha islands group; and Paibo Reef, Meixi Reef and Huaxia Reef around the Zhongsha Islands.

Sea cucumber habits

Sea cucumbers in the four island groups are found on the coral reef flats at up to 70 m depth. Some species, such as *T. ananas*, *H. nobilis* and *B. argus,* live among coral reefs while others seek shelter in sandy bottoms and among the seaweed. Some species live in shallow waters near the sublittoral zone, such as *A. mauritiana* and *H. cinerascens*; some live in areas with an abundance of sand and seaweed, such as *A. echinites*, *H. atra, H. edulis* and *S. hermanni*; some prefer areas affected by a strong wave action, such as *A. miliaris* and *H. scabra*; while others prefer calm waters, such as *S. chloronotus*, *A. lecanora, H. nobilis* and *B. marmorata* and they are mostly found in deep waters (40-60 m). *T. ananas*, *A. lecanora*, *B. argus* and *A. mauritiana* are distributed in waters between 10 to 50 m depth. *H. atra*, *H. leucospilota* and *S. hermanni* all live in shallower waters, up to 15 m in depth.

Generally, sea cucumbers stop feeding and burrow in the sand at midnight and burrow when the water temperature is low (Li, 1990). Many species emerge from the sand at dawn and feed from noon to dusk. Sea cucumbers feed on organic matter and microorganisms, such as diatoms, foraminifera, radiolarian, small crustaceans and gastropods typically found in the sand (Li, 1990). Some species of sea cucumber, for example *T. ananas* and *B. argus*, have symbiotic fish in their cloacae. The internal organs of sea cucumber can generally regenerate if body is cut in two.

Tools and fishing methods

Fishing for sea cucumber is a traditional activity among the local fishers in Qionghai, Hainan. According to local historical records, sea cucumber fishing in Xisha, Zhongsha and Nansha islands started in 1681 and has continued from generation to generation without interruption.

Collections relied on free diving and capture of sea cucumbers by hand in the early periods, so the fishing grounds were restricted to waters with a maximum depth of 20 m. At some point, however, fishermen became unhappy with the collection efficiency as it was impossible to capture the larger specimens living in deeper waters. As a result, a tool known as the "sea cucumber fork" was designed and used in the 1920s to capture sea cucumbers. The fork was subsequently improved and nowadays it consists of a fork, a weight, a rope and a buoy (Figure 1).

The specifications of these components are as follows:

1) *Fork*: the fork is made of steel with sharp agnail ends. The pointed elements of the fork are arranged in a triangular fashion and secured at one end of a cylindrical weight. The pointed elements are 11 cm in length and 1 cm in diameter and fixed 6 cm apart from one another. The sharp ends are 3.7 cm in length and 0.8 cm in width.

2) *Weight*: The cylindrical element is a 9 kg lead weight with a diameter of 9.5 cm.

3) *Rope*: the rope is usually 80 m in length.

4) *Buoy*: the buoy is made of plastic with a buoyancy of 20 kg.

The boats used in sea cucumber fishing are generally 50-80 tonnes, in gross tonnage, fitted with a 120-250 hp engine and generally have 12-16 people onboard. Each support vessel usually carries 3 to 4 smaller boats (15-25 hp, 3-5 gross tonnage each) to enable the divers to easily move around the reefs. At the fishing grounds the collection of sea cucumbers is carried out using the smaller boats which carry a crew of 3; one in charge of steering the boat while the other two engage themselves in fishing with the use of masks or "view buckets". Upon detection of the sea cucumbers on the sea bottom the divers enter the water and swim directly above the animal. Fishing is carried out by dropping the fork on the specimen seen by the diver. One end of the fork rope is attached to the boat in order to facilitate the retrieval of the captured sea cucumber. Because of the relative seawater turbidity around the islands the fishing activity is generally restricted in waters not deeper than 60 m. Commonly 20 kg of sea cucumbers, such as *T. ananas*, are collected by each boat (or 2 000 kg/year). Furthermore, fishermen engaged in the collection of sea cucumber very often fish for other species such as sharks, molluscs, as well as collect a variety of seaweed species.

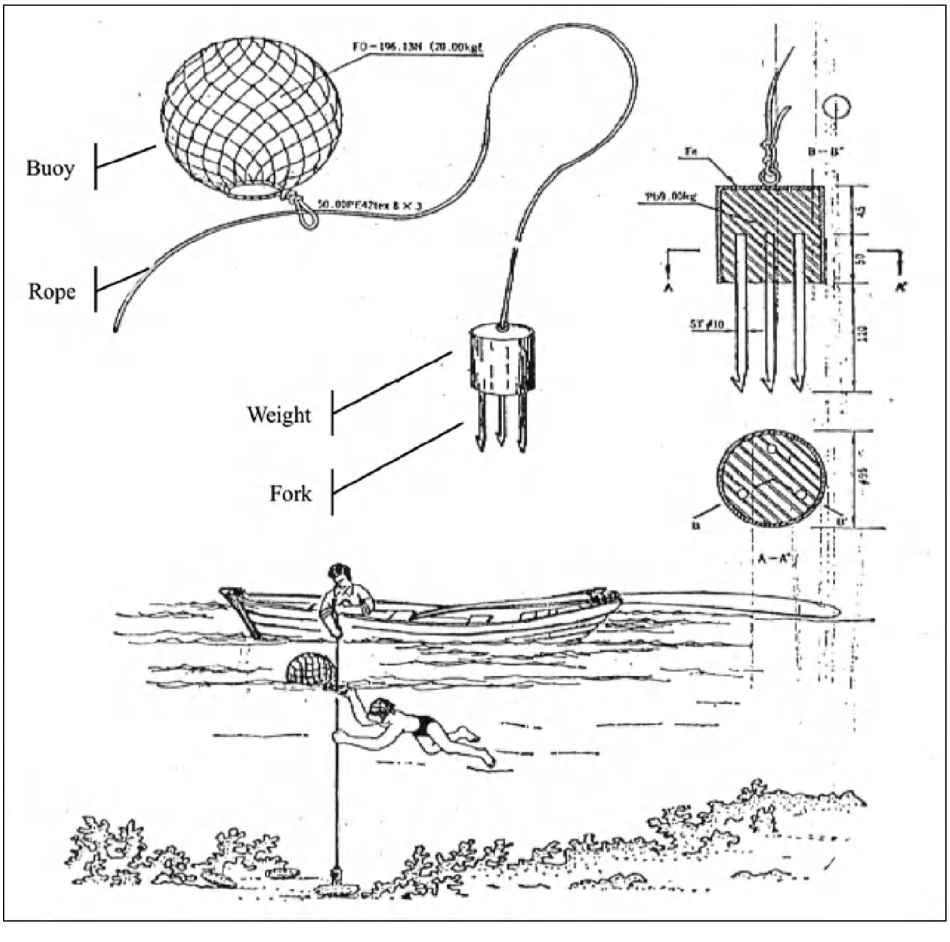

Figure 1. *The traditional tool used for fishing tropical sea cucumbers ("Drawings of Chinese Fishing Tools" published in 1989).*

Processing methods

The processing of sea cucumbers involves three steps: removal of the viscera, cooking and drying.

Prior to the evisceration process the sea cucumbers are sorted by species. In the case of *T. ananas* the incision is made on the ventral side, while it is done on the dorsal side for all other large species. In the smaller species a small incision in done beside the mouth. Following the removal of the internal organs the sea cucumbers are rinsed with seawater and then placed in a suitable boiler. Small individuals are cooked for 30 minutes, while larger individuals may require an additional 10-15 minutes. The optimal water temperature when cooking species such as *H. nobilis* and *B. marmorata* is around 90 °C. During this phase the sea cucumbers become stiff and lose 50-70 % of their body fluids, assuming a yellowish colouration in species like *T. ananas* and *S. hermanni*, and blackish colouration in most other species. The sea cucumbers are then rinsed again once they are removed from the hot water. Large species, such as *T. ananas, H. nobilis* and *B. marmorata,* are further baked over hot coals for an additional 30 minutes. The cooked product is then sun dried (small bamboo sections are used to keep the incision wide open in large individuals) while ensuring that each sea cucumber is regularly turned over every few hours. Up to 3-5 days may be required to dry the products completely.

Proper cooking and drying of sea cucumbers is essential. If not cooked completely the sea cucumber will soon start to rot and acquire an undesirable smell. Overcooking may also damage the product as a very soft sea cucumber may not be processed into a high quality product. Fishers in Qionghai have acquired considerable processing experience over the years and tend to produce a higher quality product compared to that produced in some neighbouring countries.

The ratio of dry weight to wet weight of the processed sea cucumber is 27:1 in *H. nobilis* and *H. leucospilota,* 25:1 in *T. ananas*, 20:1 in *S. hermanni* and *S. chloronotus*, 17:1 in *A. lecanora, B. argus* and *A. mauritiana* and 10:1 in *H. nobilis* and *B. marmorata.*

Nutritional value and cooking method

Sea cucumber is a nutritious seafood with a high protein and low lipid content and is rich in gluten, nitrogen, iodine and other nutritional elements (Wang, 1997). The protein content of a dried sea cucumber may be as high as 68.7 %. Considered as one of the most popular Chinese seafood dishes, sea cucumbers are also used as a traditional medicine. It is believed that the consumption of this marine organism may have beneficial effects on the kidneys and stomach as well as being a cure for some cancers. Some research findings report that sea cucumbers have helped impotent individuals as well as patients affected by other sexual conditions (Ran, 1993). In the culinary tradition, sea cucumbers are prepared and consumed in a variety of ways. Some of the most popular dishes are: sea cucumber stew, braised sea cucumber, boiled sea cucumber, lotus seed-sea cucumber and chicken-sea cucumber soups.

Management of sea cucumber resources

Sea cucumbers have been classified as a protected group according to a number of regulations issued by the Chinese Ministry of Agriculture (MoA). Furthermore the authorities are promoting the development of aquaculture activities and ensuring that adequate conservation measures are established to suit local conditions in the different geographical areas (i.e. temperate and subtropical regions).

Nevertheless, the development of a sea cucumber management plan for the Dongsha, Nansha, Xisha and Zhongsha islands has been relatively slow and the plan inadequately implemented. This has caused excessive fishing and a gradual decline of the natural resources. It is suggested that a suitable number of protected areas are established around some of the islands, a minimum catch size for the different species is set, along with the establishment of authorized fishing seasons. Moreover, applied research on the artificial reproduction of economically important species of sea cucumbers may be necessary for the long term sustainability of the sector in the islands of Hainan.

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Session III
Aquaculture advances

Pond culture of sea cucumbers, *Apostichopus japonicus*, in Dalian

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Abstract

There are more than 7 000 hectares of ponds used for the culture of *Apostichopus japonicus* and 2 000 hectares of ponds used for polyculture of *A. japonicus* and shrimp in the Dalian area. The best results are obtained in leak-proof ponds with a muddy sand bottom. The size of a pond is usually between 2-6 hectares and the water depth 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 and the water must be clean and unpolluted. The survival rate increases with the release size of the juveniles: individuals larger than 2 cm will have a survival rate of at least 20-30 %. The stocking density of sea cucumbers and shrimp is 100-150 000 and 15-30 000 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. Unwanted algae and harmful organisms should be removed from the ponds on a regular basis. The depth of the water must be maintained throughout summer and winter. After about 1.0-1.5 years, the sea cucumbers can either be harvested by divers or collected after the ponds have been adequately drained.

Keywords: China, co-culture, prawn, grow-out

大连的刺参（*Apostichopus japonicus*）池塘养殖研究

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摘要

刺参（*Apostichopus japonicus*）分布于朝鲜、日本、俄罗斯远东以及中国的近海水域。在中国，刺参是一种很受欢迎的海产品。20世纪80年代中期以来，其养殖方面的研究越来越多。特别是对刺参的幼体培育及育苗方面取得了很大的进步，推动了大连、烟台、青岛和威海等中国北部地区刺参养殖业的快速发展。上个世纪90年代由于对虾疾病的暴发使对虾养殖业遭到重创，使得许多位于潮间带的虾塘开始用于刺参养殖。并且出现了两种养殖方式，一是刺参与对虾的混养；一是单独养殖刺参，这两种养殖方式均取得了良好的经济效益。

在大连沿海刺参的池塘单养或与虾参的混养已达到相当大的规模。养殖效果最好的是泥沙底质的非渗漏池塘。池塘的大小通常为2-6公顷，水深一般为1.5-2.5米。换水可以通过潮水涨落时开闭池塘的进出水闸门来实现，养殖海水的盐度通常在25-35‰之间，养殖水要求洁净无污染。刺参养殖期间的存活率一般随放养参苗的规格增大而提高：参苗体长大于2厘米的存活率一般在20%-30%之间。虾参混养池塘的养殖密度一般是：每公顷放养刺参10-40万头，对虾3.0-6.0万尾之间。

养殖期间每天检查水质状况以及刺参与对虾的生长情况，并根据这些情况决定是否投喂饵料和投喂量，杂藻和有害生物应从池塘清除。夏季和冬季要保持池塘的水位。大约养殖1年到1.5年的时间，刺参就可以通过潜水或者排水后收获。

关键词：中国、混养、对虾，放养

Introduction

The sea cucumber, *Apostichopus japonicus* Liao, can be found along the Korean Peninsula, Japan, the eastern shores of Russia and the northern coast of China PR. It is a favourite seafood in these areas, especially in China PR. Research on its aquaculture began in the middle of the 1980s. There was great progress 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 the early 1990s, many coastal ponds traditionally used for shrimp farming were abandoned due to the emergence of diseases. Many of these ponds were restored and used for sea cucumber aquaculture also in polyculture with different marine shrimp species. Both methods proved to be financially profitable.

Pond culture of *A. japonicus* is restricted to the Liaoning and Shandong Provinces and is mainly centred in the Dalian area. Over 7 000 hectares of ponds are used for sea cucumber culture. In addition, approximately 2 000 hectares are in use for farming the holothurian in polyculture with shrimp.

Methods

Optimal culture pond conditions

Pond size and water quality - Ponds are usually located in the intertidal zone for convenience of water exchange. The salinity should be maintained above 28 all year round, however, it can drop to 24-26 over a short period in summer. Water quality should remain high and it can be renewed by opening and closing the sluice gates. The optimal pond size is usually between 2-6 hectares with a water depth maintained at 1.5-2.5 m.

Pond cleaning and sterilization - The best farming results are obtained in leak-proof ponds with a muddy sand substratum which requires sterilization prior to the rearing phase. This is done by first removing the bottom silt. At this point the pond is filled with seawater and the level adjusted to 0.2-0.3 m. Calcium oxide or bleaching powder is subsequently added. The use of the two sterilizing substances is described in Table 1.

Table 1. *Pond sterilization methods.*

Chemical	Method	Dosage	Action	Efficiency
Calcium oxide	Dissolve and distribute in the pond	750 kg/ha. Water depth: 0.05-0.1 m	1. Kills fish, crab, algae, parasites and bacteria 2. Increases pH	7-15 days
Bleaching powder	Dissolve and distribute in the pond	75-150 kg/ha. Water depth: 0.05-0.1 m	As above	4-5 days

Settlement substratum - According to the natural behaviour of the sea cucumber, the pond bottom requires a layer of an adequate substratum for larval settlement to occur. Stones, roof tiles, bricks and other suitable structures can be used. The quantity of the substrate should be in the range of 150-1 500 m^3/ha, however this can vary depending on the pond characteristics and production method employed. Stones remain the best choice, each of about 15-40 kg in weight. The settlement substratum should be added to the pond one month prior to the introduction of the sea cucumber juveniles.

Water conditioning - In order to ensure the right quantity of diatoms, the water should be inoculated at least 15 days before the juveniles are seeded. The most common fertilizer used is urea at about 30-60 kg/ha.

Juvenile rearing and growout

Time - The growout season can commence either in September/October or in March/April when the seawater temperature ranges between 10-15 °C. In a polyculture situation the shrimp postlarvae are usually introduced in May-June.

Transportation of juveniles - The juveniles are placed in temperature controlled boxes for transportation. They should not be fed for 1-2 days prior to this operation. The temperature should be maintained below 18 °C. The shrimp postlarvae are generally transported in oxygen filled plastic bags with a sufficient quantity of seawater.

Juvenile size and rearing density - The juveniles may be from the wild or hatchery produced. Juveniles usually range between 2-10 cm in length and their stocking density varies depending on the pond conditions, food supply and availability of settlement surfaces. The amount of sea cucumber juvenile released is 15-40 individuals/m^2 for individuals measuring 2-5 cm, 15-25 individuals/m^2 for individuals of 5-10 cm, and 5-8 individuals/m^2 when they are 10-15 cm in length.

There are two methods for releasing the juveniles. The first one is to place them in the sea bottom directly by hand or simply releasing them from a boat using individuals larger than 4-5 cm. The second method, used when handling individuals smaller than 3 cm, is to place the juveniles in mesh bags with an opening at one end. The mesh bags are 30×25 cm in size and each one may contain up to 500 individuals. They are placed beside the settlement substratum.

The shrimp species used for polyculture with sea cucumber are the Chinese or Japanese shrimp. The shrimp postlarvae are usually 2-3 cm in length and are seeded at a density of 3-6 individuals/m^2.

Feeding - Sea cucumber juveniles usually do not require any additional food supply. However, the addition of food is necessary to maintain a high rearing density and to favour growth during spring and autumn. Grounded pieces of *Sargassum* and *Zostera* are generally used.

Pond management - The seawater is renewed by opening and closing the sluice gates with the change of tide. About 10-60 % of the total seawater should be exchanged depending on the water quality and temperature in the ponds. In summer, the water level in ponds should be kept higher in order to maintain a lower temperature. The salinity is maintained by regular water changes. The temperature, salinity, pH and oxygen levels should be monitored daily as well as the growth, survival rate and behaviour of the sea cucumbers.

During the winter months, the following additional tasks need to be performed:

1. Maintain the water level at 2 m.
2. Removal of ice formations from the surface of the pond to keep the air-water interface free and ensure acceptable oxygen concentrations in the pond.

Harvest - The sea cucumbers are collected when they reach 150-200 g. Harvesting is done following the drainage of the ponds or with the use of SCUBA diving equipment. The shrimp are generally collected using nets placed at the sluice gates.

Production

The production levels of sea cucumber in pond culture vary between 1 500-10 000 kg/ha depending on the culture conditions, the quantity of juveniles released, their initial size and initial pond preparation (Table 2).

Growth and survival rates

The time needed to grow the sea cucumbers to a commercial size varies between 10-18 months, whereas the shrimp attain the desired size in about 4-6 months. The survival rate of sea cucumbers may vary between 10-90 %.

Table 2. Sea cucumber production along the coast of Dalian using different pond sizes, juvenile sizes and stocking densities.

Trial No	Area (ha)	Beginning of culture (year/ month)	Size of released juveniles (cm)	Number of juveniles per pond	Total duration of culture (months)	Total harvest (kg)	Weight per individual (g)
1	0.35	1994/11	2.5	170 000	17	3 500	120-140
2	0.33	1997/05	6.5	120 000	10	3 100	100-120
3	2.00	1999/04	8.6	103 000	12	8 260	130-210
4	2.00	2000/04	7.3	156 000	13	8 870	120-195

Table 3. Relationship between survival rate and size of juvenile sea cucumbers released at the start of the growout phase.

Sea cucumber length (cm)	Survival rate (%)
2-5	10-35
5-10	30-80
10-15	60-90

Financial aspect of pond culture

The net income generated by sea cucumber pond culture may fluctuate between 7 500 and 50 000 US$/ha. It is currently one of the most attractive aquaculture businesses in northern China. Numerous local farmers and entrepreneurs have become wealthy thanks to this industry. The sector is rapidly expanding.

The importance of water temperature

The growth rate of sea cucumbers is closely related to the water temperature maintained in the pond. The best growth rates are observed in spring and autumn. The body weight of an adult sea cucumber will decrease by roughly half when the water temperature is above 22-24 °C in summer. The growth rate and generally all biological activity are very low during winter months when the temperature is below 2 °C.

Conclusion

Ponds can be used for culturing sea cucumbers alone or in polyculture with different species of shrimp. The best production results are obtained in leak-proof ponds with muddy sand bottoms. Seawater is exchanged by opening and closing the sluice gates during tidal movements. The optimal cultured density of sea cucumbers is 100-150 000 per hectare. The seawater depth in the ponds must be maintained at its optimal level throughout summer and winter. After approximately 1.0-1.5 years the sea cucumbers are ready for harvesting. The industry currently yields a very good return on the initial investment.

The progress and prospects of studies on artificial propagation and culture of the sea cucumber, *Apostichopus japonicus*

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Abstract

This report summarizes the latest progress in the artificial breeding and farming of sea cucumbers, *Apostichopus japonicus* Liao, along the coast of Dalian, China. The development of specialized techniques will be discussed, emerging problems analysed and future prospects outlined. For the artificial breeding, the broodstock sea cucumbers are maintained under low temperatures (15-16 ºC) to maximize the quality, quantity and maturity of the gametes. The density of larvae is kept under 1.0 individuals/ml. The algae, *Dunaliella euchlaia, Chaetoceros gracilis, Chaetoceros muelleri, Nizschia closterium* and *Phaeodactylum tricornutum* are used as food for the larvae, whereas *Sargassum* sp. is used to feed the juveniles. High quality seawater is a basic requirement for successful larval and juvenile production.

The growout of sea cucumbers is mainly carried out in former shrimp ponds and newly built ponds in the inshore regions of Dalian. It has become an important industry after more than ten years of development. The area used for farming now exceeds 7 000 hectares. A recently developed model of culture in the open sea will be presented in this paper.

Keywords: Cultivation, technology, larvae, juvenile, diseases

刺参（*Apostichopus japonicus*）人工繁殖和养殖研究的进展和前景

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摘要

本文总结了近年来大连地区海参（*Apostichopus japonicus*）养殖与海参人工育苗的最新进展。对有关技术问题展开了讨论，对存在的问题进行了分析并展示了今后的发展趋势。著者认为，亲参应该暂养在15-16ºC的较低的水温条件下，可以确保配子的数量和质量。幼虫的密度以每毫升1个为宜。盐藻、牟氏角毛藻、新月菱形藻和三角褐指藻可用于海参幼虫的饵料，而马尾藻则可用于稚、幼参的饲料。水质是海参育苗成功的关键之一。

海参人工养殖既可利用对虾养殖池，也可在沿海地区新开挖的池塘中进行。经过十多年的发展，海参养殖业已经成为大连地区重要的海水养殖业，池塘养殖面积已经超过7 000公顷。在本文中还论及海参的增殖。

关键词：养殖、技术、幼虫、幼体、病害

Introduction

Major progress on artificial breeding of the sea cucumber *Apostichopus japonicus* was made in the mid 1980s. Since then, and particularly in the 1990s, these techniques have been improved considerably and spread widely throughout the Liaoning Province in northern China (Zhang & Liu, 1998).

In recent years, a considerable number of hatcheries have been established that produce sea cucumber juveniles for commercial purposes. The total water volume used for breeding has exceeded $2\times10^5 m^3$. The current production capacity of young sea cucumbers (body length >2 cm) is between 100-200 tonnes which is equivalent to 0.8 and 1.6 billion sea cucumbers (approx. 4 000 individuals/kg). It is estimated that the ongrowing area, including former shrimp ponds and newly built ponds, currently exceeds 7 000 hectares.

During the last two decades, the living standards of Chinese people have increased considerably, which has stimulated the consumption of sea cucumber despite sharp increases in price. On the other hand, the increased demand for this product in the Chinese market has encouraged the development of sea cucumber aquaculture.

The present report introduces the latest technology on sea cucumber breeding.

Improvement of artificial breeding techniques

Spawning induction

The condition and gonad maturity of the sea cucumber broodstock have a direct impact on the quality of the gametes. In the past, the broodstock was collected from the wild and almost immediately induced to spawn. In recent years, however, the spawners are maintained in the hatchery at a low temperature (15-16 °C) in order to allow the gonads to attain full maturity. The seawater temperature of the conditioning tanks is gradually raised to favour the maturation of the broodstock allowing the hatchery operators to produce relatively large sea cucumber juveniles early in the season. The temperature is increased daily by 0.5-1.0 °C while the tanks are kept in total darkness. Feeding rate is in the range of 5-7 % of the body weight, but it should be adjusted under different temperatures conditions. The quality and composition of the food has a direct impact on the gonad development. The ETA (effective temperature accumulation) is about 800 °C/day. Under these conditions, high numbers of spawning individuals are ensured as well as gaining an extension of the spawning season. This allows the production of sea cucumber juveniles over a longer period of time.

Gamete collection and fertilization

The natural spawning periodicity of *A. japonicus* remains poorly understood. However, technological improvements have enabled hatchery operators to induce spawning using a variety of methods that include drying, water jetting and thermal shock. Artificial spawning allows the hatchery operators to better control the concentration of spermatozoa and the stocking density of eggs. The hatching rate may exceed 90 %.

Larval rearing

Rearing the pelagic stages of *A. japonicus* requires considerable attention and constant monitoring of the culture medium.

Larval density: In order to ensure a fast growth and high metamorphosis rate, larval density should be maintained at between 3 to 4×10^5 individuals/m^3. At higher concentrations the growth rate of the larvae can dramatically decrease and the incidence of malformations is considerably higher (Sui, 1990).

Feeding: The use of different species of microalgae is crucial for the development of the larvae. *Dunaliella euchlaia, Chaetoceros gracilis, C. muelleri, Nizschia closterium* and *Phaeodactylum tricornutum* can be used to feed the larvae. The most important species are *D. euchlaia, C. gracilis* and *C. muelleri*, whereas *Dicrateria zhanjiangensis, Isochrysis galbana* and *Chlorella* sp. are usually added as a supplement and are never used alone. For a balanced diet, a mixture of 2 to 3 species is highly preferable. The microalgae are fed at a concentration ranging between 10 000 and 40 000 cells/ml. Food levels are increased gradually as the larvae develop. In order to enhance larval growth and decrease the rate of malformation of the young sea cucumbers, marine yeast and/or photosynthetic bacteria (PSB) are often supplied.

Water quality: High quality seawater in a sea cucumber hatchery is an important prerequisite. Research findings indicate that numerous physical and chemical factors (e.g. temperature, pH, salinity, ammonia, dissolved oxygen, heavy-metal concentration, turbidity, etc.) will influence the success of a culture. As these parameters tend to vary significantly from one region to another, careful monitoring of the seawater quality is essential.

Selection and use of settling bases: The traditional substrates used for the settlement of the sea cucumber juveniles are frames fitted with fine polyethylene (PE) or polypropylene (PP) cloth. In recent years, some hatcheries have started to use PE corrugated plates measuring 50×50 cm fixed together in stacks of 8-10 pieces. This latter method has been used with some success. In the traditional method, benthic diatoms need to be cultivated on the settling bases before they can be used. Currently, some hatcheries no longer cultivate benthic diatoms, but rather provide a food supply soon after the juvenile sea cucumbers have settled. This method has two advantages: no equipment is needed to rear benthic diatoms and the settling plates are easier to clean during routine hatchery operations. The settled sea cucumbers are fed with benthic diatoms that have been using mesh bags or other materials placed in the rearing tanks and with a powdered macroalgae soup typically prepared using *Sargassum* spp. such *as S. thunbergii*. The correct feeding rate is essential to ensure a high survival rate of the juveniles.

Juvenile rearing

Rearing juvenile sea cucumbers may take several months, but may require as long as 6 months if the rearing conditions are not favourable.

Food: The food must be free of contamination, of the right particle size and contain all the essential nutrients. A balanced diet not only accelerates the juvenile sea cucumbers' growth rate, but also increases their survival rate.

Transfer of the juveniles: Juvenile sea cucumbers are particularly vulnerable during the early rearing stages. High mortality rates are caused by high density, overfeeding, faeces on the settling plates and competition for space amongst themselves and other opportunistic organisms such as *Ciona intestinalis*. This species of tunicate can also secrete a toxin that can kill juvenile sea cucumbers. Therefore, juveniles should be regularly transferred to new settling plates, sorted by size and injured individuals transferred to separate tanks. Light anaesthesia is usually used to reduce stress and facilitate handling of the sea cucumbers. *Microsetella* sp. (Ectinosomatidae) is commonly found in rearing tanks and can form large colonies in a short time killing all the sea cucumber juveniles in 1-2 days when the situation gets out of control. Trichlorfon, a biocide, was formerly used to kill *Microsetella* sp., but the copepods have developed a strong resistance to the biocide and therefore have become difficult to eradicate. In 2003, a new and effective pesticide known as "Mei Zao Ling" was developed by the author. This product has little side effect on the sea cucumbers.

Nursing of juvenile sea cucumbers: As the juveniles grow, the water quality and dissolved oxygen must be maintained at the optimal level. Increasing aeration and water exchange rates becomes necessary. The oxygen level has to be maintained above 5 mg/l. It is also important to use formulated feed that can be digested and absorbed easily. Experimental results have shown that the growth rate of juveniles fed on the formulated feed is at least two times higher than that of individuals fed on traditional feed during the 20 to 30 day period. In recent years, studies on a series of formulated diets revealed that diet is a key factor for improving the survival and growth rates of juveniles in the nursing stage.

As the accumulation of excess food and faeces increase, harmful germs tend to multiply rapidly and can cause very serious disease outbreaks among the juvenile sea cucumbers, including what is known as the 'stomach ulcer'. Another disease is 'white muscle syndrome' which causes muscle tissues to turn white and rigid. More applied research is urgently required to find effective remedies to these problems.

Advances in farming technologies

The cultivation of sea cucumbers is mainly carried out in former shrimp ponds and newly built ponds along the coast of Dalian. It has become an important industry after more than ten years of development. The culture area currently exceeds 7 000 hectares.

Selection and construction of the culture ponds: The farm sites should provide suitable conditions for the growth of sea cucumbers. A supply of clean and unpolluted seawater should be easily accessible and the ponds should be constructed in such a way to ensure that the banks are leak-proof and that complete drainage can be achieved. Salinity levels should range between 25 and 35, with optimal values around 27-32. Ponds with muddy and sandy bottoms and of 2-3 hectares in size are preferred; however some operators use ponds as large as 7 hectares. If necessary, stones or other artificial materials are placed in the pond to provide an adequate substrate for sea cucumbers to aestivate and live through cold winters. Hard substrates should cover 50-70 % of the bottom. The depth of water should be between 1.5 to 2 m and the seawater temperature maintained between 0-30 °C.

Transfer of young sea cucumbers to the pond: It has been demonstrated that the release of young sea cucumbers measuring 2-3 cm in body length produce the best farming results. The survival rate can reach up to 50-70 % when the individuals are introduced at a size equivalent to 2 000-4 000 individuals/kg. These will attain commercial size after 1.5 years. For an optimal growth the culture density should not exceed 10 individuals/m^2.

Management: Sea cucumbers can be farmed with shrimp and certain species of finfish, although they are commonly reared alone. Prior to stocking the ponds with the hatchery-reared sea cucumber juveniles, it is necessary to clean and sterilize the ponds as well as inoculate the seawater with benthic diatoms. These measures will provide an appropriate culture environment and ensure high survival rates. The addition of formulated feed will also enhance growth particularly during spring and autumn. Some field tests have shown that the growth rate of sea cucumbers fed on formulated feed is as high as two times that of non-fed individuals.

Constant monitoring of several environmental and biological parameters such as the body length and weight of the sea cucumbers as well as the feeding and excretion rates is essential in order to properly adjust the food supply in the culture ponds. Furthermore, particular attention should be paid to changes in the colouration and temperature of the seawater, presence of fouling algae and predators, as well as to fluctuations in salinity, dissolved oxygen, etc. Finally, the depth of the water should be monitored closely as the appropriate levels and exchange rates must be maintained to prevent thermal stress.

Problems and outlook

A number of problems have emerged following the relatively fast development of sea cucumber aquaculture in China. The most notable of these is the shortage of good quality broodstock and, consequently, the production of poor quality fertilized oocytes. Furthermore some hatcheries are not able to provide proper feed due to the lack of appropriate equipment and techniques. Other hatcheries fail to ensure good water quality due to poor design and inappropriate selection of the farming site. The emergence of numerous diseases, such as "stomach atrophy", "stomach ulcer" and "body ulcer", are also major constraints affecting the industry. Because sea cucumber farming is a relatively new aquaculture practice, pathogens and their treatment are still poorly understood. Further research is needed.

In view of the problems mentioned above, the author deems that improving the overall design and layout of the sea cucumber hatcheries and farming facilities, effective transfer of the culture techniques to the farmers and further research on the prevention and treatment of diseases are priorities for the development of the sector. Indoor and land-based cultivation should be considered so as to shorten the cultivation period and reduce production costs. The author believes that the artificial breeding and cultivation of sea cucumbers in the inshore regions of Dalian will expand and achieve technological improvements in the future.

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Breeding and culture of the sea cucumber, *Apostichopus japonicus,* Liao

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Abstract

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 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 organisms 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.

Keywords: China, release, diseases, growth, survival rate

刺参（*Apostichopus japonicus*）的苗种培育和养殖

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摘要

刺参在中国是最重要，最具经济价值的海参。刺参的生活史经历耳状幼体、樽状幼体、五触手幼体、稚参、幼参和成参等阶段。本文重点介绍诱导刺参产卵的几种方法和养殖技术。讨论了海参在不同发育阶段的各种培养方法、理化因素的控制和病害的防治。比较了不同养殖方法的优缺点。

海参的人工养殖仍处于发展过程中，养殖规模不断扩大，问题也随之增多，故要求加强对刺参的经济问题的研究。

关键词：中国、放流、病害、生长、成活率

Introduction

The history of sea cucumber fishery dates back for more than 1 000 years. Over the last century, and especially the past 20 years, Chinese research projects have focused on the breeding, artificial culture and processing of sea cucumber.

There are over 1 000 species of sea cucumbers known worldwide. More than 100 species can be found in China, amongst which more than 20 species are considered edible. Most of them, e.g. *Thelenota ananas*, *Stichopus chloronotus*, *S. variegatus* and *Apostichopus japonicus*, are distributed in the southern sea of China.

Apostichopus japonicus belongs to Echinodermata, Holothuroidea, Aspidochirota, Stichopodidae; it is generally referred to simply as sea cucumber. It can be found in Russia, Korea Rep., in the Chinese provinces of Liaoning, Hebei and Shandong as well as in northern Japan. Because of its high nutritional value, it is considered an important seafood. In addition, more recently medical research has discovered that sea cucumbers are rich in acidic amylose, suggesting that they could possess medicinal properties.

According to several sources of information, the output of *Apostichopus japonicus* in Dalian was 906 tonnes in 1955. With the improvement of breeding technology, the quantity of farmed sea cucumbers has increased significantly. In 1999, the farming area was estimated at around 32 000 hectares and the output at 2 000 tonnes; the following year, in 2000, the farming area covered 48 000 hectares, while the output was 3 000 tonnes valued at 200 million Yuan. In 2002, the production reached 8 000 tonnes.

Developmental biology of *A. japonicus*

The development of *A. japonicus* includes six major phases: fertilized oocytes, early development (including cleavage, blastula and gastrula), auricularia (including early auricularia, middle auricularia and late auricularia), metamorphosis (including doliolaria and pentactula), juvenile, young sea cucumber and adult (Figure 1).

Kinetics of development

After the oocytes have been fertilized, they slowly sink and start their development. When the water temperature ranges from 21 to 24 °C the fertilized eggs require about 45 minutes to begin to divide themselves and finally develop into a blastula (Table 1). The blastula is ciliated and rotates actively. After about 2 to 3 h, the hatched embryo gradually elongates and moves to the surface of the water column. During this ascent the embryo begins to invaginate and gradually develops into gastrula. A fully developed gastrula appears at the surface of the culture tanks 24 to 28 h after fertilization. Twelve to twenty hours later the gastrula gradually elongates and begins to fold into the auricularia stage.

Table 1. *Development of the sea cucumber* Apostichopus japonicus[1].

Stages of Development	Time to each developmental stage			
	Marine Fisheries Research Institute, Liaoning Province	**Marine Fisheries Research Institute, Hebei Province**	**Yantai and Changdao[2]**	**Japan[2]**
First polar body	15-20min		43-48min	
Second polar body	45min		48-53min	30min
2-cell stage	1h 50min	1h 10-20min	1h 3-30min	
4-cell stage	2h15min	1h 58min to 2h 15min	1h30min-2h 15min	
8-cell stage	2h 41min	1 58min-2h 15min		
16-cell stage	3h 3min	2 30min-2h 50min		
32-cell stage	3h 25min	2h 53min		
64-cell stage	3h 50min	3h 24min		
128-cell stage	4h 10min	3h 40min		
Blastula	7h 5min	10-12h	3h40min~5h 40min	11h
Gastrula	28h 35min	24-26h	17h-20h	24h
Early auricularia	40~48h	46~48h	25h 20min-31h	45-46h
Middle auricularia	4-5d	5-7d		4-5d
Later auricularia	6-7d	7-10d		11-13d
Doliolaria	8-9d	10-16d	5-7d	13-15d
Pentactula	10-11d	13-17d	9d	15-17d
Juvenile sea cucumbers	11-13d	13-17d	13d	15-23d
Juvenile sea cucumbers (2~4 tube-feet)	30d			

1. Water temperature maintained between 21.5 and 23 °C.

2. Results obtained in research facilities in Yantai and Changdao (China) and Japan.

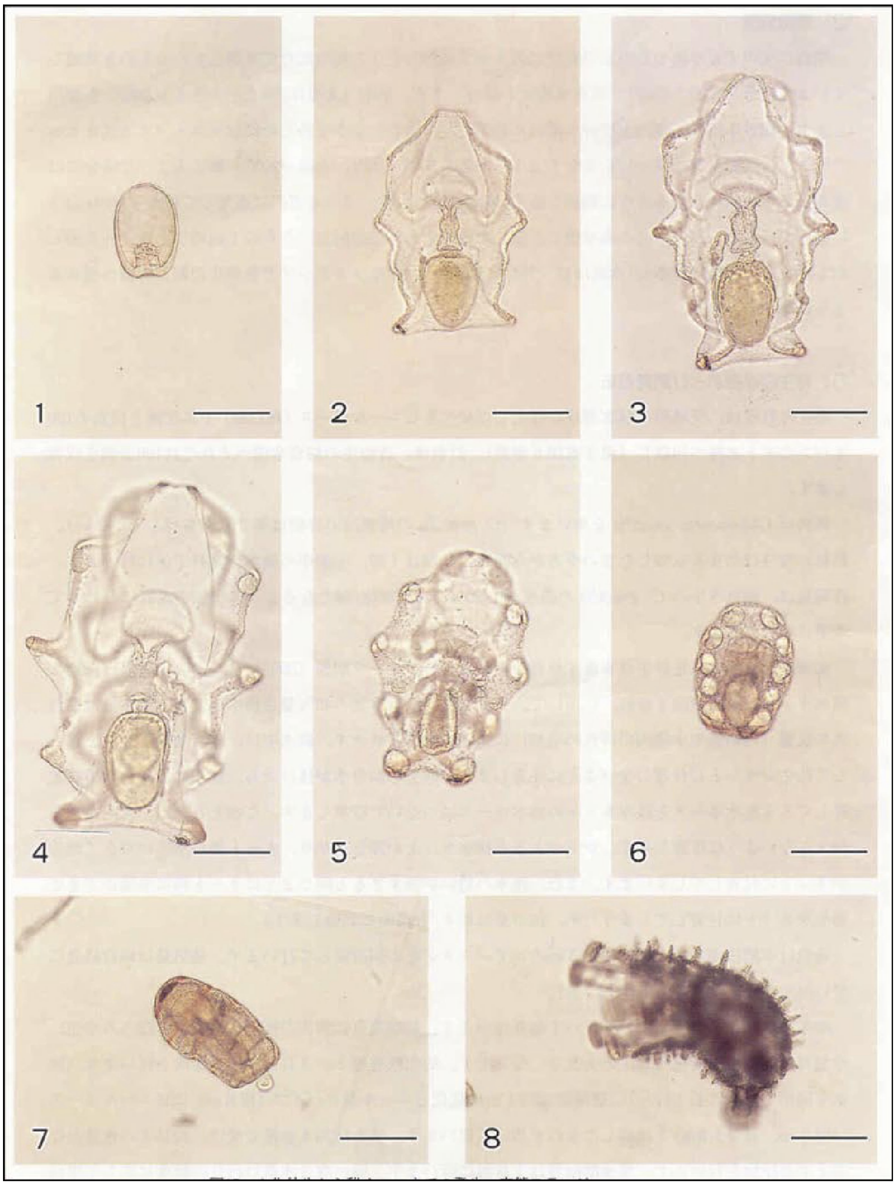

Figure 1. *The development of* A. japonicus. *1. Gastrula; 2. Early auricularia; 3. Mid auricularia; 4. Late auricularia; 5. Early doliolaria; 6. Doliolaria; 7. Early pentactula; 8. Pentactula (bar = 100 µm).*

The auricularia stage

The auricularia stage lasts from day 7 to day 10 at a water temperature ranging from 18 to 26 °C. Early auricularia larvae have a symmetrical bilateral and a length varying from 320 to 600 µm. As the larva grows, the stomach increases in size. When the auricularia reaches 600 to 750 µm, its left cavity, which adjoins the stomach and gullet, begins to grow and gradually takes on a semi circular shape. At this point, the auricularia has reached the middle phase of its development. Later, the cilia develop into five pairs of symmetrical circles. At the same time, the primary tentacles begin to develop as the larva reaches the late auricularia stage. Typically, the ball shaped body of the larva at this stage is the early sign of the upcoming doliolaria stage.

Doliolaria stage

In the late auricularia phase, the larvae begin to shrink; the five lipid spheres finally connect while the tentacles enlarge and move to the centre of the body. At this stage the auriculariae are still swimming in the water column; they move from the surface to the bottom. The settlement plates should be placed in the tanks at this time.

Pentactula

The doliolaria phase usually lasts for 1 or 2 days at the end of which five tentacles reach out of the body. At this moment, the larvae begin to creep along the bottom for an additional 1 or 2 days. The number of cilia on the body surface of the larvae progressively decreases and x-shaped ossicles gradually begin to appear. The body becomes rounder and the first tube-like foot emerges on the left posterior section of the body. The presence of podia is a significant precursor to the juvenile stage.

Juvenile sea cucumber

The primary change in the juvenile stage is the appearance of tube-like feet (which enables the organism to attach to a substrate) and the ability to ingest food. The gut, mouth and papillae become clearly visible. In the next couple of months the juvenile sea cucumbers grow to about 1 cm in length assuming the appearance of an adult individual. The body pigmentation changes gradually from a transparent whitish appearance to a red, grey or light green colouration (Figure 2). At this point the individual has reached the young sea cucumber stage.

Figure 2. *Sea cucumber juveniles (Photo: A. Lovatelli).*

Young and adult sea cucumber

There is almost no morphological difference between a young and an adult sea cucumber. In a hatchery facility the movement and feeding activity of young sea cucumbers sharply decreases when the seawater temperature exceeds 23 °C. The young specimens move from the surface of the water to the bottom of the tank. For this reason it is important to maintain an optimal temperature level in the culture tanks to ensure adequate growth and reduce the length of this relatively fragile developmental stage.

Artificial breeding techniques

Facilities

A large sea cucumber hatchery in northern China typically has the following facilities: a larvae culture volume of 2 600 m^3 divided into tanks of 10 to 20 m^3 with a depth of 1.4 m; a juvenile culture volume of 4 000 m^3 divided into tanks of 30 m^3 with a depth of 1.7 m (Figure 3); a phytoplankton production unit with a total tank volume of 500 m^3; 4 filter tanks of 200 m^3/h filtering capacity; and 5 overhead troughs of 200 m^3 each. The facility is also fitted with a high quality water supply and drainage system as well as a heater to raise the water temperature when necessary.

The devices used for larval settlement include metal frames each fitted with 5-10 polyethylene screens measuring 50 x 50 cm and used as the settlement substrate (Figure 4).

Figure 3. *Sea cucumber settlement device (Photo: A. Lovatelli).*

Figure 4. *Sea cucumber hatchery in the vicinity of Dalian, Liaoning Province. Juvenile culture tanks (Photo: A. Lovatelli).*

Physical and chemical factors

The optimum water temperature in a hatchery is between 23 and 25 °C, even though sea cucumbers can adapt to a range between 10 and 26 °C. The best salinity level is 31.6, but individuals can tolerate salinities from 26 to 33. The optimal pH is 7.8, but it can range from 7.5 to 8.2. The dissolved oxygen should be maintained at >5 mg/litre.

Apostichopus japonicus appears to be more tolerant to environmental fluctuations than many other species of sea cucumbers. However, the larval stages remain rather sensitive and less tolerant to variations in their environment.

Broodstock collection and maintenance

Broodstock harvesting. Individuals are generally collected from the 20th June to the 20th July in the Dalian area. At that time, the seawater temperature varies from 15 to 17 °C. A few individuals are usually sacrificed and dissected in order to adequately determine the maturation stage of the gonads. Specimens weighing around 300 g and measuring around 20 cm in length are generally preferred.

Considerable care is required during the collection and transportation of the sea cucumber broodstock. It is important to: 1) select each specimen individually; 2) keep the selected sea cucumber away from any source of pollution (e.g. oil spills from the boat engine); 3) avoid exposing the sea cucumbers to high temperatures or violent movements during transport; and 4) avoid simultaneous collection of the sea cucumbers and other marine organisms (e.g. bivalves) in order to avoid damaging the broodstock.

Maintaining broodstock. Following collection, the sea cucumbers should be placed in a tank filled with seawater at ambient temperature. The tanks should be clean and the individuals kept at a density of 30 individuals/m³ for 2-3 days. No feed is supplied. At this point the water temperature is gradually raised to 19 °C at a rate of 1 °C per day. After 7 to10 days the broodstock can be induced to spawn. During this phase it is necessary to maintain the quality of the water in the culture tanks. Water exchange should be carried out rapidly, when required.

Spawning induction

When the seawater temperature has been raised to 19 °C, the sea cucumber activity should be carefully monitored particularly during the night hours. The bottom of the tanks should be examined for the presence of oocytes as this is an indication that the sea cucumbers are likely to start mass release of gametes. There are two ways to induce spawning: the first method consists of drying the sea cucumber in the shade followed by a jet of violent water; the second method uses a temperature shock by raising and lowering the water temperature by several degrees.

With *A. japonicus*, spawning often occurs between 2100 h and 0200 h. It is important to maintain a quiet environment and keep the tanks in the dark. Male sea cucumbers usually are the first to spawn, which in turn induce the females to start releasing the eggs. At this point the number of spawning males should be reduced, only retaining a few strong spawners. Following the spawning activity the tanks are drained and all the sea cucumbers removed. The eggs are gently washed and the tanks refilled with clean seawater at a temperature of 22 °C.

Hatchery techniques and larval selection

The clean seawater in the tanks should be stirred gently every 30 minutes ensuring that whirlpools do not form. EDTA is added at a concentration of 3-4 ppm while the larval density is kept at about 5 larvae/ml. The hatching success may exceed 90 %.

Selection of the larvae begins before the auricularia`s tube-like foot is formed, or shortly after. An hour prior to the selection process, stirring is stopped in order to allow the auriculariae to gather at the surface of the tanks. Malformed larvae are unable to swim and will sink to the bottom of the tanks. The larvae gathered at the surface are collected from the uppermost 0.5 m of the water column with the use of a fine mesh. These are then transferred to a new tank at a density of 300 larvae/litre.

Larval rearing

Feeding

After the appearance of the mouth in the auricularia larvae, feeding should commence immediately. Early in the growth of the auricularia, the feeding regime should be in the range of 5 000 to 10 000 microalgae cells/ml. At the intermediate stage, feeding needs to be increased to about 20 000 cells/ml. Monitoring the presence of algae in the stomach of the larvae helps the adjustment of the feeding regime. *Dunaliella* is the primary algal species used and is generally mixed with diatoms and *Chaetoceros* sp. The three micro-organisms are added in a proportion of 4:1:1. The food mixture should be supplied in small quantities in order to maintain optimal water quality.

Water exchange

Rearing during the auricularia stage should be carried out in still water. Water should be added to the rearing tank at a rate of 20 cm per day until the tank is filled. This usually takes approximately 3 days. Once the tank is filled, one third to a half of the water should be exchanged daily using a siphon. As the larvae grow the water exchange rate should gradually increased. Water exchange should be carried out gently in order to avoid injuries or loss of larvae.

Control of chemical and physical factors

The culture of auricularia larvae requires the proper control of all major chemical and physical factors. Generally speaking, the pH and salinity values should remain within the range tolerated by the larvae. Stirring the water or adding new seawater will control dissolved oxygen levels. It is important to maintain the temperature at around 23 °C. If the larvae are reared in natural seawater, the temperature will rise gradually with the seasonal fluctuations. Appropriate measures must be taken to maintain it within the acceptable range.

Control of diseases and harmful organisms

During the larval culture, the primary harmful organisms are copepods; however their presence can be contained through a proper water exchange protocol and the use of EDTA (3 to 4 ppm), if necessary.

The primary symptoms of disease are a slow development rate of the larvae and the "rotten stomach" phenomenon observed in late auriculariae. This can be caused by food deficiency or sub-optimal larval densities. The use of quality feeds and maintaining low larvae densities can minimise the outbreak of diseases.

Larval settlement

After the larvae have developed for 7 to10 days, the five lipid spheres on each side of the larvae appear and the hydrocoel begins to develop. The larvae are now transforming into doliolaria. At this stage, the settlement substrates (see Figure 4) should be placed in the rearing tanks. The density of the larvae settled on substrate should be maintained between 1 to 2 individuals/cm².

Rearing of juvenile sea cucumbers

The rearing techniques at this point of the development of the sea cucumber juveniles are very important and should be carefully applied in order to ensure a high rate of survival.

Water exchange

The rearing tanks are fitted with a water flow through system. The presence of food particles and the relatively high water temperature are responsible for the proliferation of undesirable and harmful organisms, such as copepods and bacteria. The water in the tanks should be clean with a daily exchange rate of up to 200 %.

Feeding

Feeding quantity and feed quality are key parameters to the survival of the larvae. Insufficient food may not only reduce the growth of the larvae but may cause the entire sea cucumber population in a tank to perish. On the other hand, overfeeding may seriously pollute the water in the tanks. In the early developmental stage, diatoms are used as the main food source along with a soup of powdered *Sargassum thunbergic*. At a later stage, *S. thunbergic* becomes the primary food item and is complemented using artificial feed. Fresh *S. thunbergic* is used which is ground to suit the size of the juveniles that are being fed. In addition, 1 to 5 ppm of yeast is added. A mixed food diet is preferred over a single diet when rearing sea cucumber.

Sorting juveniles sea cucumber

Juvenile sea cucumbers grow at different rates and it is therefore important to sort them according to their size. This is done using sieves fitted with different mesh sizes. While sorting, care should be taken not to damage or kill the juvenile sea cucumbers.

Prevention and treatment of diseases and harmful organisms

A variety of diseases affect juvenile sea cucumbers, often causing ulcer-like lesions on their body surface. Additional problems are cause by harmful copepods that compete for the food present in the tanks. Bacteria cause decay of the body tissues, but the mechanism is still not clearly understood. Bacteria are treated with antibiotics (1-3 ppm). Furthermore high numbers of Harpacticoida can also be harmful to the juveniles. These tiny crustaceans are eliminated with the use of a pesticide (e.g. trichlorphon) at a concentration of 1-2 ppm for 8-12 hours, followed by a complete water change.

Growout techniques

Farming methods

Today, in northern China, the sea cucumber *Apostichopus japonicus* is commonly farmed in earth ponds either in an extensive or semi-intensive system. Sea rafts are sometimes used, but are not very popular.

Extensive pond farming: This farming system has developed and expanded rapidly as a result of the low investment costs involved, easy management of the ponds and remarkable revenues. Either old and abandoned shrimp ponds or new intertidal ponds are used. The sea cucumbers are stocked at a density between 30-100 individuals/m^2 depending on their initial body size. Very little or no additional food is needed when abandoned shrimp ponds are used as incoming seawater is usually rich in food particles and algae. Rocks are placed on the bottom and aerators are added to compensate for the low dissolved oxygen levels. Under these conditions the sea cucumbers can grow 1-1.5 times faster than in the wild. Finally, the introduction of pathogenic and other undesirable micro-organisms can be adequately controlled if an appropriate water supply is identified.

Raft culture. Wooden rafts are usually located in sea areas not exposed to strong winds and tidal action. The sea cucumber cages are usually hung under the rafts or placed directly on the sea floor. During the rearing period, sea cucumbers are fed with *Sargassum* sp. and other macroalgae. This farming method is not very popular due to the high costs involved.

Intensive farming: Intensive sea cucumber aquaculture has only recently developed. Large quantities of rocks or other suitable substrates (e.g. roof tiles) are placed in the culture ponds to increase the surface area for the juvenile sea cucumbers and to provide shelter from predators. A refrigeration system or underground water supply is used to lower the water temperature in the ponds in the summer months when high temperatures can reduce growth and feeding rates. These pond facilities are expensive and therefore intensive farming is only carried out by large and financially strong companies.

Selection of culture areas in the sea

The most suitable sea locations are rocky sites with an abundance of macrophytes and with muddy and sandy bottoms. Areas protected from strong winds and tidal actions are usually favoured.

Stocking method

Juveniles over 1 cm in length are used when stocking directly in the sea. The larger the initial size of the juveniles, the higher the survival rate. When stocking, the juveniles are placed in bags with a mesh size of 0.25-0.5 cm. A diver then places the bags on the sea bottom in the vicinity of existing rocks or artificially prepared rock piles. Subsequently the mesh bags are opened and the juveniles are simply left to crawl away. Larger juveniles (>5 cm) can be released into the sea directly.

Harvest

Generally, two years after stocking, the sea cucumbers have reached a marketable size and can be collected. Harvesting is often done in the spring (mid-April to early June) and autumn (October to December) (Figure 5).

Figure 5. *Sea cucumber harvested off the coast of Dalian, China (Photo: A. Lovatelli).*

Advantages and disadvantages of sea ranching

Sea ranching takes full advantage of the natural environment and this method is considered to be ecologically acceptable and therefore worth developing. However, due to a number of seasonal limitations and resource use conflict (presence of industrial activities), this growout method can only be carried out in locations which have the right conditions.

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

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Abstract

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

Keywords: Broodstock, larvae, juvenile, disease, metamorphosis, overwintering

刺参人工育苗技术及相关问题的探讨

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摘要

本文综述了我国刺参（*Apostichopus japonicus*）人工育苗技术的发展概况，从亲参的选择与蓄养、产卵与孵化、幼体培育、附着基投放、稚参培育等几个环节介绍了刺参人工育苗技术，分析了育苗过程中常见的幼体烂胃与变态率低以及稚参死亡量大等问题，并提出了相应的技术措施。

关键词：刺参、人工育苗、问题探讨

Introduction

The Chinese have been using sea cucumber as a food item and for treating illness for over a thousand years. There are about 134 species of sea cucumber distributed in China's seas. Among them, *Apostichopus japonicus* is well known as a delicacy and for its medicinal properties. According to Chinese traditional medicine, sea cucumber is a tonic food. In recent years, pharmacodynamic studies have shown that sea cucumber contains mucoitin that could retard aging and act as anti-tumour and blood coagulation agent. Hence, sea cucumber is very popular and *A. japonicus* is considered to be the most valued of the edible species.

In China, *A. japonicus* is distributed along the shore of the Yellow Sea and Bohai Sea from 34° of northern latitude, including the provinces of Liaoning, Hebei, Shandong and Jiangsu. The highest biomass is found along the shores of Dalian and Jinzhou in the Liaoning Province and off Qingdao and Yantai in the Shandong Province. The natural stocks of this species have decreased significantly, having been overfished for a long period. Therefore, the Chinese Government has been encouraging research into artificial breeding, farming and enhancement of *A. japonicus* since the early 1980s.

An outline of hatchery techniques development

Studies on *A. japonicus* hatchery techniques started in the early 1950s. By 1954, Zhang Fengying and Wu Baoling had produced a number of auriculariae and doliolariae in their laboratory. Two years later, they had managed to produce a number of juvenile sea cucumbers. During the 1960s, Chen Zongrao, who worked at the Shandong Mariculture Research Institute, used the same methods and was also able to produce juveniles. The hatchery production of the species developed rapidly during the 1970s, but it did not become a prosperous activity until the early 1980s. Since then, the Yellow Sea Fisheries Research Institute, the Liaoning Marine Fisheries Research Institute, the Shandong Mariculture Research Institute as well as the Yantai Fisheries Research Institute have successively succeeded in breeding *A. japonicus*, and have devised a series of protocols for hatcheries. This work has been supported by the Ministry of Agriculture.

As more and more commercial hatcheries emerged along the northern coastal line of China, the rearing techniques were widely adopted and improved during the 1990s, while the scale and dimensions of hatchery facilities for breeding larvae increased rapidly. Presently, a single harvest typically yields 5 000 juveniles (about 1 cm long) per m^3 of water in commercial hatcheries, although over 10 000 juveniles per m^3 can sometimes be obtained. Juvenile production of *A. japonicus* has now become a commercially stable activity.

Facilities

An ideal hatchery should be built on the coast where the seawater is clear, unpolluted and unaffected by freshwater runoff. Hatcheries for scallop can be used for sea cucumber production, either alone or in co-culture. A typical hatchery consists of a series of interrelated systems as described below.

Hatchery

The hatchery is used for conditioning broodstock and rearing larvae. The inner room should be well ventilated, sunlit, but protected against direct sunlight. The illumination should be between 500-2 000 lux.

Tanks, either for rearing larvae or for spawning the broodstock, are commonly built with bricks, blocks or reinforced concrete. They are usually rectangular or elliptical in shape with a capacity of between 10 and 30 m^3. Tanks of 15-25 m^3 are preferred. The depth of the tanks should be about 1.2 m. The total water volume in commercial hatcheries may vary between 300 and 3 000 m^3, though facilities of 500-1 000 m^3 are more common.

Microalgae culture room

A microalgae culture room generally has a fibreglass or transparent plastic film roof and is oriented in an east-to-west direction. Tanks for microalgae culture are generally rectangular, 0.7-1 m in depth and with a volume of 1 to 10 m^3. The bottom and inner wall of the tanks are lined with white ceramic tiles or white cement in order to reflect sunlight. An ideal microalgae culture facility is well exposed to sunlight. Commonly, the volume of water required for the culture of microalgae is in a ratio of 1:4 to 1:3 of the total hatchery.

Sea cucumber larvae / early juvenile tank(s)

The capacity of the larval culture and settlement tanks should be twice or three times that of the total hatchery water volume. A roof is also necessary to provide protection from rainwater and dust and to provide a dark environment for the sea cucumber larvae to settle on the bottom.

Seawater filter

Seawater must be filtered through a gravel bottom filter tank before being used for larval rearing and microalgae culture. A gravel bottom filter tank should be filled with cobble, gravel and sand in that order, from bottom to top. The top layer of fine sand (particle diameter: 500 µm) should be more than 60 cm thick. Recently, some newly established hatcheries obtain their water supply from sea wells rather than using sedimentation and filter tanks.

Broodstock

Collection season

The reproductive seasons of *A. japonicus* in different areas may vary according to the prevailing water temperatures and abundance of natural food that influence the development of the gonads. The reproductive season of this species occurs in late May in Qingdao and Rizhao, from early to mid June in northern Shandong Province, from late June to the end of July in Changdao Islands and from late June to early August in Dalian and the northern Yellow Sea. Commonly, when the seawater temperature rises to 16-17 °C (Liu *et al.*, 2002) the mature individuals will be collected for immediate use. In recent years, individuals farmed in deep water with sufficient water exchange can also be used for broodstock. These may be caught ahead of the season.

Selection

The broodstock should be over 250 g in body weight and 20 cm or more in body length with fully developed gonads. Gonadal index (gonad to body weight ratio) should be over 10 %. The broodstock must be captured with care so as to protect it from oil and avoid injuries.

Transportation

There are two methods for transporting the broodstock: dry and wet. The former is used for short distances within three hours of the destination. The sea cucumbers are packed in a single layer into a foam box, with ice bags to keep the temperature low. Wet techniques are used for long distances. A canvas tank of 50×50×80 cm^3 is filled to about a third to a half full with aerated seawater; it can hold 60-80 individuals. It is preferable to transport the broodstock in the morning or at night in order to avoid exposure to direct sunlight. The temperature inside the box or tank should be maintained below 20 °C.

Breeding programme

Most of the broodstock will not spawn on the same day after being transported to the destination. Several days of maturation are required. The broodstock should be cultured in tanks at a density of 30-50 individuals/m^3 and a water temperature of 18-20 °C.

Daily management operations - The seawater should be exchanged twice a day: a third to a half of the total volume in the morning and the total volume at night, pumping air into the water, gently but continuously, and clearing the deposits. There is no need to feed the broodstock if the breeding period is imminent, but if the sea cucumbers do not spawn after 5-6 days at 19 °C, then they must be fed with brown seaweed (*Sargassum thunbergii*), mixed feed or sea bottom mud. Daily feeding rate is 5 % of the body weight (Liu *et al.*, 2002).

Broodstock conditioning - When the sea cucumber juveniles are needed ahead of the natural reproductive season in order to maximize their growth during the same year, the broodstock are collected earlier in the season and matured by gradually raising the water temperature. This procedure will induce the animals to spawn in advance. The method is as follows: maintain the ambient seawater temperature for 2 to 3 days after the capture, and then raise it by 0.5 °C/day. When the water temperature reaches 13-15 °C, maintain it again for another 7-10 days prior to spawning and then raise it gradually to 17-18 °C for spawning. Feed the animals daily at a rate of 5-10 % of the body weight (Wang *et al.*, 2001).

Spawning, fertilization and hatching

Spawning

Three methods can be used for spawning.

1. Natural spawning - Fully matured broodstock will spawn naturally in the tanks between 1900 and 2000 hours.
2. Induced spawning through temperature shock - The water temperature is abruptly raised by 3-5 °C.
3. Induced spawning through water shock - The holding tank is drained completely and the sea cucumbers kept dry for 0.5-1 hour. Following this the individuals are shocked with a flow of seawater for 30 mins. The tank is subsequently filled with fresh seawater. Generally, the animals will spawn 1-2 hours after the shock (Figure 1).

In some cases, a combination of the last two methods is used to induce artificial spawning.

Figure 1. *A spawning* Apostichopus japonicus.

Fertilization

Artificial fertilization - As the broodstock starts to spawn, the individuals are removed from the tank as soon as possible; males and females are placed separately into fibreglass or plastic containers. While the female is spawning, a small quantity of sperm is added and the water stirred constantly to aid fertilization. Upon microscopic examination, a ratio of 3-5 spermatozoa per oocyte is considered to be suitable.

Natural fertilization in tanks - When the broodstock starts to spawn, the males are removed from the tank. When all the females have ceased spawning, they are removed and the tank is filled with fresh seawater. After about half an hour, the oocytes sink to the bottom. The uppermost half to two-thirds of the volume is gently siphoned out. After repeating this protocol two or three times, the excess spermatozoa are effectively eliminated.

Hatching

Once the oocytes are fertilized, the eggs are kept in an incubator vessel and maintained at a density of 10-20 per ml. The eggs may also be allowed to hatch directly in the spawning tank, maintaining a density of 1-2 per ml. In both methods, the water must be gently aerated or stirred every half hour. At a temperature of about 20 °C, the gastrula will begin to hatch within 24-26 hours, and the auriculariae will appear within 34 hours.

Larval rearing

Larval selection

Well developed auricularia are selected from the hatching tanks by siphoning them into a fine mesh screen (NX103) or are hand collected using a purposely designed trawl net. If the egg concentration is less than 1 egg/ml and the hatching rate of the auricularia is high, the larvae do not have to be transferred to other tanks. In this event debris, unfertilized oocytes and malformed eggs should be removed and the tank filled with fresh seawater. A rearing density of 0.5 auricularia/ml should be maintained (Zhang *et al.*, 1998).

Feeding

Feeding regime - The following microalgae species are suitable for the development of the sea cucumber larvae: *Dunaliella* sp., *Chaetoceros muelleri*, *Nitzschia closterrium*, *Phaeodactylun tricornutun*, *Isochrysis zhanjiangensis*, and *Isochrysis galbana 3011.* Diatoms and *Dunaliella* sp. can be used as the main food, supplemented with *Isochrysis* sp. Other feeds such as yeast and finely grounded and filtered *Sargassum thunbergii* can also be used.

Daily feeding rate - Microalgae should be supplied 4-8 times a day in order to maintain a concentration of $2\text{-}5\times10^4$ cell/ml in the culture tank. Observation through a microscope should clearly show that about half of the larva`s stomach is filled with food.

Water management

Water exchange - The water should be changed twice a day, either by replacing a third to a half of total volume at once, or using a siphon to gradually exchange 1-1.5 times the total volume. When exchanging the water a mesh screen (NX103) should be placed on the water outlet to avoid loosing any larvae.

Cleaning - All debris should be siphoned from the bottom of the rearing tanks every 2 to 3 days; these include uneaten food particles, faeces, dead larvae and protozoa. If the water quality has deteriorated and the larvae are growing very slowly, the water must be completely replaced, even though the larvae might be injured during this operation.

Aeration

During larval rearing, the water should be aerated continuously or gently stirred every 30 minutes.

Monitoring the physico-chemical factors of the water

The optimum water temperature ranges from 18 to 22 °C, the dissolved oxygen should be maintained above 5 mg/l, the salinity between 26.2 and 36.7, the pH value between 8.1 to 8.3, the illumination between 500 and 1 500 lux, the concentration of non-ion ammonia less than 0.02 mg/l and the turbidity should not be extremely low (Liu, 2000).

Settlement

Settlement plates

Two different setups are used for the settlement of the larvae. The first setup is made of flexible polyethylene film sheets measuring 50×60 cm. About 10 to 15 sheets are fixed on a metal frame at a distance of 5 cm from one another (Figure 2). Each cubic metre of water contains 30-40 sheets. The second setup uses corrugated polyethylene plates measuring 42×33 cm and 1 mm thick. Each holding frame supports 10-20 plates (Figure 3). Each cubic metre of water holds 60-80 plates (Figure 4).

Benthic diatoms must be inoculated on the polyethylene sheets and plates 7-10 days before larval settlement commences in order to supply the pentactulae with an adequate starter food. The settlement plates are placed into the rearing tanks when 10-20 % of the larvae have metamorphosed into doliolariae.

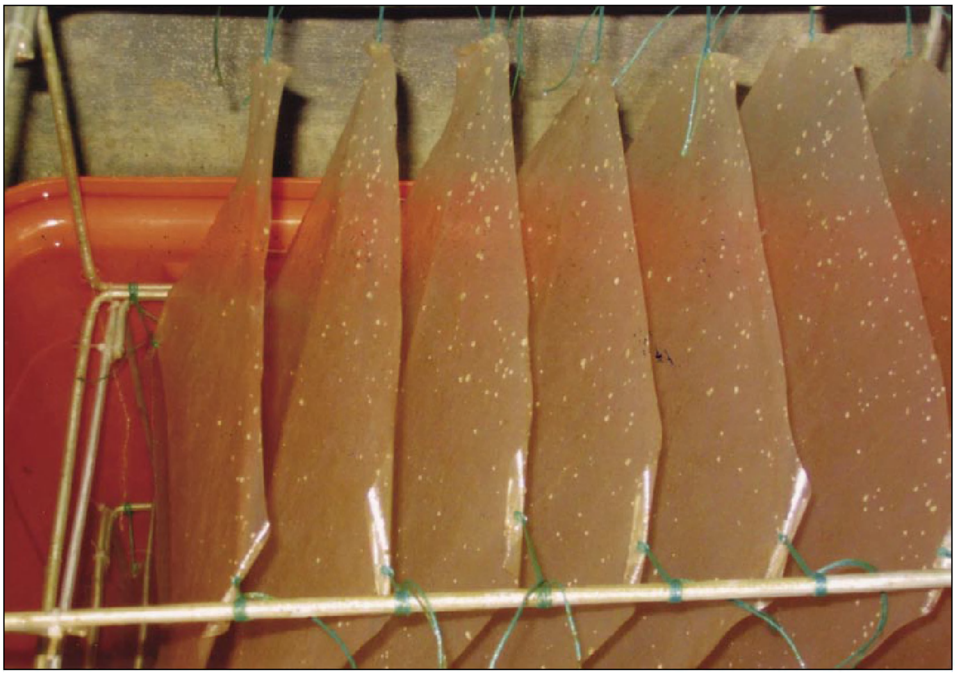

Figure 2. Polyethylene filmstrips.

Figure 3. Corrugated polyethylene plates.

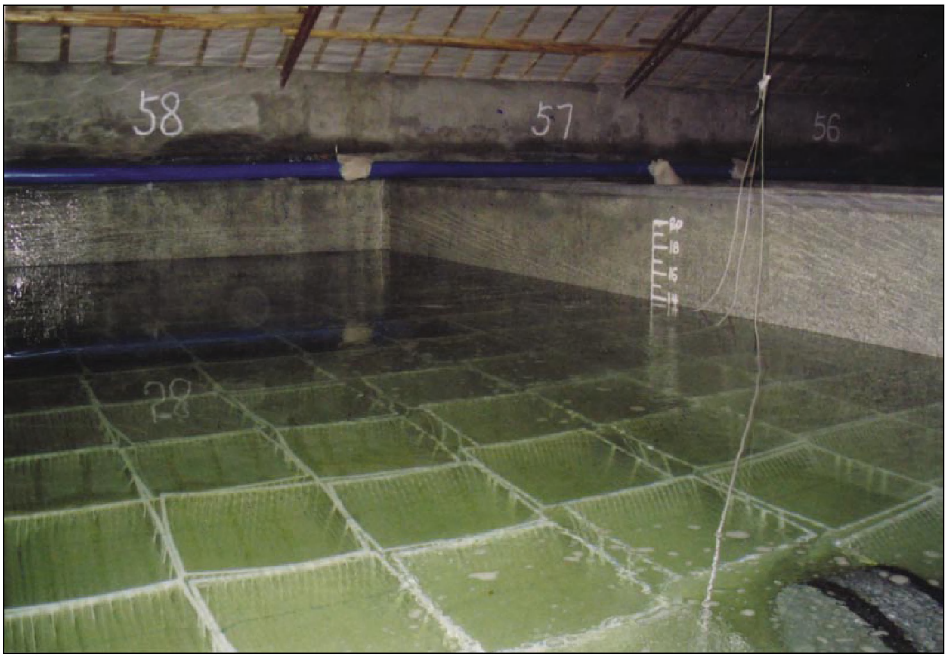

Figure 4. *Installation of settlement plates.*

Juvenile rearing

Juveniles density

An optimum density of 1-3 individuals/cm^2 should be maintained for early juvenile sea cucumbers; if the density is too high, the juveniles must be dispersed onto other plates within 10 days.

Feeding

There is no need to feed early juveniles with artificial food as they will consume the benthic diatoms present on the settlement plates. However, usually 3-5 days after settlement, it is important to supply fresh sea bottom mud and/or a mixed microalgae diet, while grounded and filtered *Sargassum thunbergii* becomes necessary as the juveniles develop. Based on the feeding rate and growth of the sea cucumber juveniles, yeast, fishmeal, sea kelp powder, as well as *Spirulina platensis* powder can be further added. Grounded and filtered *Sargassum thunbergii*, for example, can be used at an early stage, feeding 20-50 g/m^3 of water a day, and increasing the quantity to 50-100 g when the body length is 2-5 mm, and to 100-150 g as the juveniles continue to grow.

Water exchange and aeration

A rearing technique using flow through water was recently adopted. If this system is not used, then the water should be completely changed 2-4 times a day. Filtered air should be injected continuously into the water throughout the juvenile rearing period in order to maintain good levels of dissolved oxygen and optimise water quality.

Physico-chemical factors

The optimum seawater temperature range for rearing the juvenile sea cucumbers is 24-27 °C. The dissolved oxygen should be above 5 mg/l and the minimum salinity adjusted according to body length as follows: 0.4 mm individuals, salinity 20-25; 5 mm individuals, salinity 10-15; larger individuals, salinity 15-20. The pH should be kept between 7.9 and 8.4, and the light intensity under 2 000 lux.

Wintering

Both hatchery and microalgae tanks can be used for wintering. The optimal density of juveniles is shown in Table 1.

Table 1. *Stocking density of juvenile sea cucumbers.*

Juveniles (individuals/kg)	Density (individuals/m^3)
under 200	100 - 300
200 - 1 000	300 - 1 000
1 000 - 2 000	1 000 - 2 000
2 000 - 4 000	2 000 - 3 000
4 000 - 6 000	3 000 - 4 000
6 000 - 8 000	4 000 - 5 000
over 8 000	5 000 - 10 000

Feeding of juveniles

Juveniles should be fed with seaweed powder or a mixed feed twice a day, in the morning and evening, at a rate of 1-2 % of their body weight.

Water temperature and exchange

The water must be heated during the cold winter months. Some of the methods used include a water tube boiler, a deep well, and a winter house with a plastic film roof. The optimum temperature range is between 10 and 12 °C whilst the absolute lower limit is 5 °C.

Water exchange and aeration

The water should be completely replaced once or twice a day, the bottom cleaned once a week. One air-stone should be added for every 2-3 m^2 in order to gently and continuously inject air into the water column.

Common problems

"Rotten-stomach" disease of auricularia

Early symptoms show a thickened stomach wall, which becomes rough and withered as the auriculariae assume an abnormal shape. Diseased larvae display a slower growth rate than unaffected larvae. Larvae suffering from this disease also have a lower survival rate. In order to control this problem, several actions can be taken as described below.

1. *Using healthy broodstock* and conditioning them properly are the basic prerequisites to producing healthy larvae, especially in a temperature conditioned hatchery. The water temperature should remain below 20 °C during the broodstock rearing. If the temperature is too high, the gonads will degenerate and auto evisceration may occur. Even after successful spawning under sub optimal conditions the auricularia larvae do not develop properly.

2. *Feeding with high quality food without overfeeding.* A proper feeding regime should be followed, feeding small quantities frequently, rather than all at once. Old or contaminated food must be avoided.

3. *Using proper stocking density.* Overcrowding induces slow growth rates and a great variability in body length, as well as causing deformities, "rotten-stomach" and low metamorphosis rates (Liu *et al.*, 2002).

4. *Maintaining good water quality.* Among all the environmental factors that influence the growth and development of the larvae, water temperature and salinity are the two main parameters that require special attention, especially since the natural reproductive season occurs in the summer months when it is hot and rainy. Rainfall may cause a

rapid decrease of the salinity in inshore waters and the physico-chemical parameters of the seawater may become non-ideal. High water temperatures (above 23 °C) and/or rainfall can cause slow growth rates and can be responsible for the outbreak of diseases. In order to avoid any problems, deep wells located near the hatchery have been used in recent years. Well water has the advantage over open seawater of being cleaner also in terms of microbes and predators. Furthermore, gravel filters are not required for well water so water can be pumped directly into the rearing tanks.

Mortality of juvenile sea cucumbers

In recent years, many hatcheries have experienced mortality of juveniles during the early growth phase on the settlement plates, especially in individuals under 5 mm in body length. The symptoms are that the body remains contracted, adherence is lost and the body changes from translucent to milky-white. The juveniles then become whiter, start rotting, drop from the plates and eventually die. Mortality may reach 90 %. Solutions proposed include:

1. *Ensuring the quality of the broodstock.* There will be no healthy juveniles and no high survival rates without healthy broodstock.

2. *Maintaining a proper density.* Experience shows that overcrowding increases mortality. Overcrowding reduces available space and food availability, causing malnutrition, slow growth rates and size variability. Therefore, it is necessary to reduce the density as the juveniles develop to reach a proper density of 1-2 individuals/cm^2 prior to body colour change.

3. *Designing a good feeding regime.* Feeding a single variety of food for a long period should be avoided; instead, a high quality pellet feed must be used to ensure a proper nutrient balance.

4. *Maintaining a proper water temperature.* Mortality is usually observed after the juveniles have been exposed to a water temperature above 27 °C for a long period. In summer the rearing water temperature must be reduced by: (a) covering the roof and the settlement tank with straw screens to minimize the amount of sunshine, (b) ventilating efficiently and pumping water during the night, (c) increasing water exchange to at least three times a day, and (d) pumping water from a deep well (Liu *et al.*, 2002).

5. *Protecting the juveniles from predators.* The main predators are copepods, especially *Harpactorda* sp. They not only compete for food and living space with juvenile sea cucumbers, but also bite them and sometimes kill them. Copepods are particularly dangerous for juveniles under 5 mm in body length. Large numbers of *Harpactorda* may cause a rapid decrease in the number of juvenile sea cucumber. To eliminate them, crystal dipterex can be used, at a dosage of 2-5 g/m^3 of water, followed by a water exchange after 2-3 hours.

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Diseases of cultured sea cucumber, *Apostichopus japonicus*, in China

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Abstract

Ever since the artificial breeding techniques of *Apostichopus japonicus* were first introduced in the 1980s, the Chinese have been making efforts to develop and improve the rearing protocols. In recent years, sea cucumber aquaculture has developed rapidly along the northern coast of China, where 1-2 billion seeds can be produced and 90 000 tonnes of sea cucumber (live 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. A study has revealed that several new or 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 outdoor cultivation. These pathogens induced high mortality rates, occasionally reaching up to 80 %. Upon the isolation of these etiological agents, morphological, physiological, biochemical and pathological studies have been performed, and a preliminary identification of the isolated agents was conducted in the present study.

Keywords: Aquaculture, sea cucumber, disease, bacteria, fungus, parasite

中国养殖刺参的疾病现状

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摘要

自二十世纪八十年代取得刺参人工育苗的重大技术突破之后，中国进行了长期不懈的努力来发展和完善其养殖技术工艺。迈入二十一世纪，刺参的人工养殖在我国北方沿海地区迅速兴起，每年约生产苗种10～20亿头，收获鲜参90000吨以上。

随着海参大规模人工养殖的快速发展，病害问题日渐突出，造成了巨大的经济损失，成为制约该产业持续、健康发展的瓶颈之一。近年来，笔者就北方地区养殖刺参的病害进行了全面的调查研究，发现了几种国内外均未报道的疾病。流行病学研究表明：苗期幼体出现的烂边、胃溃疡和化板病主要是由细菌性病原引起的；而养成期海参出现的皮肤溃疡、腐皮、水肿则是由细菌、霉菌以及寄生虫等多种病原造成的，这些病原可引起明显病症和死亡，有时死亡率高达80%以上。在分离病原的基础上，开展了主要病原的形态学、生理生化、分子生物学及组织病理学方面的研究，并对致病原进行了初步鉴定。

关键词：水产养殖　海参　刺参　疾病　细菌　真菌　寄生虫

Introduction

Sea cucumbers belong to the phylum Echinodermata, class Holothuroidea. There are about 1 200 holothurians in the world (McElroy, 1990) and 134 species identified in China, among which about 20 species have commercial value for human consumption (Chen, 2003). The temperate species, *Apostichopus japonicus*, naturally distributed in Bohai Bay and the Yellow Sea, is the most valuable due to its nutritional and supposed medicinal properties. It has been shown, in particular, that acid mucopolysaccharides from this species have anticoagulant, antifungal and antitumour activities (Li and Lian, 1988; Nagase *et al*., 1997; Suzuki *et al*., 1991; Fan, 2001). Additionally, *S. chloronotus* is also known to promote growth, facilitate internal healing and enhance the immune system in humans (Fredalina and Ridzwan, 1999).

Since 1954, Chinese researchers have conducted studies on artificial breeding of *A. japonicus*, and the technique was successfully established in the middle of the 1980s. The first sea ranching trials were successfully carried out by Zhang Fengying, Sui Xilin and others in the provinces of Hebei, Shandong and Liaoning (Zhang and Liu, 1998). The recent economic growth in China and, consequently, the improved standards of living have increased the demand for sea cucumber products for human consumption in the national market. Sea cucumber farming has developed rapidly and has become a vigorous industry along the northern coast of China, where every year 1-2 billion juveniles and 90 000 tonnes of sea cucumber (live weight) can be produced and harvested, respectively.

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. However, the research on diseases of cultured sea cucumber in China has only recently started, so there is little information available on this aspect. This paper presents the results of an epidemiological study, during which several non-reported diseases have been discovered.

Diseases of *Apostichopus japonicus* larvae and their aetiology

Rotting edges symptom

Epidemiology and clinical signs: This is the first report on this disease. Usually, it occurs during the auricularia stages from June to July, causing a high mortality of up to 90 % in certain cases. This symptom was widely detected in commercial sea cucumber hatcheries in Shandong Province. Compared with the normal larvae (Figure 1), the clinical signs of infected animals are recognized by the darkening of the body edges (Figure 2). Diseased specimens undergo autolysis (Figures 3 and 4) and the body completely disintegrates within 2 days. If metamorphosis is achieved, the pentactulae are weak and the survival rate is rather low.

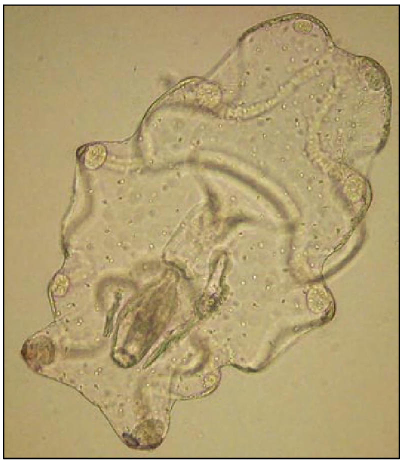

Figure 1*. Normal auricularia of* A. japonicus.

Figure 2*. Abnormal auricularia with bacterial infection and the presence of darkening edges (arrows).*

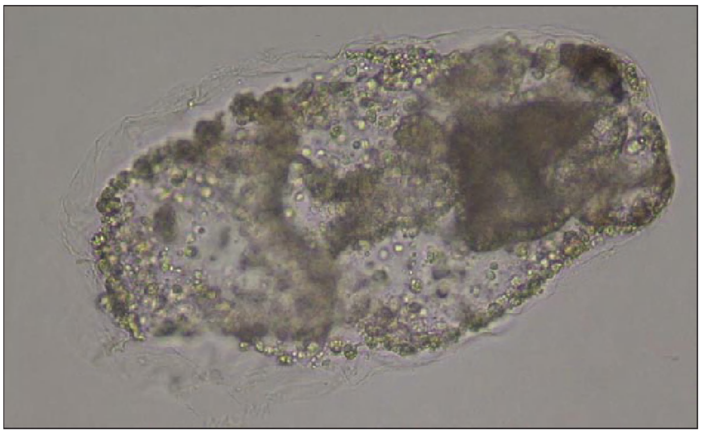

Figure 3*. An affected larva undergoing autolysis.*

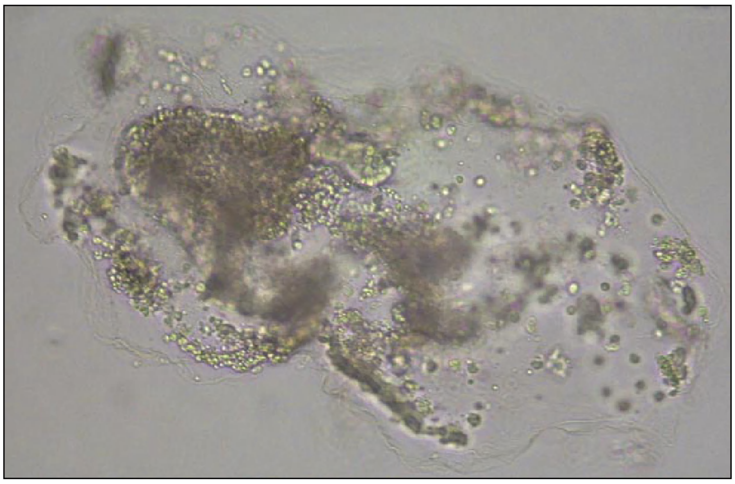

Figure 4. *An autolyzed larva with incomplete edges.*

Aetiology: Two dominant bacterial isolates (LB-1 and LB-2) are obtained from infected sea cucumber specimens. Based on the characterization of the isolated microbes and histopathological analysis, the bacteria LB-1 and LB-2 have been associated with the disease.

The colony of LB-1 was round, yellowish brown, and the surface was smooth, moist and opaque. The cells were Gram-negative, short rods with round ends or curved rods. The edge of the colony LB-2 was smooth with a yellowish dot in the centre, transparent and moist, and a blue glistening could be seen under the light. The particles were Gram-negative, thick and short rods. The morphological, physiological and biochemical characteristics of the above isolates are listed below (Table 1). According to the results, these two bacterial strains possibly belong to the *Vibrio* genus.

Table 1. *Morphological, physiological and biochemical characteristics of the bacteria nominated LB-1 and LB-2 isolated from infected sea cucumber larvae.*

Characteristic	LB-1	LB-2	Characteristic	LB-1	LB-2
Gram Stain	-	-	Indole production	+	+
Movement	+	+	H_2S production	-	-
O/129 Sensitivity (10μg)	-	+	Lysine decarboxylase	-	-
O/129 Sensitivity(150μg)	+	+	Arginine dihydrolase	+	+
Growth on TCBS	+	+	Ornithine decarboxylase	+	-
0% NaCl, growth (w/v)	-	-	Gas from glucose	-	-
3% NaCl, growth (w/v)	+	+	Arabinose	+	+
6% NaCl, growth(w/v)	+	+	Mannitol	+	-
8% NaCl, growth (w/v)	+	-	Inositol	-	-
10% NaCl, growth (w/v)	-	-	Raffinose	-	-
4°C, growth	+	+	Rhamnose	-	-
25°C, growth	+	+	Sucrose	+	+
28°C, growth	+	+	Glucose	-	+
35°C, growth	+	+	Salicin	+	+
40°C, growth	-	-	Sorbitol	-	-
45°C, growth	-	-	Gelatinase	-	-
Oxidase	+	+	Urease	-	-
Oxidation-Fermentation	F	F	ONPG	+	+
Citrate utilization	-	-	Spore stain	+	-
Vogus-Proskauer reaction	+	+	Methyl red test	-	-

Symbols: +: positive reaction; -: negative reaction; ***F****: Fermentative;* ***x% NaCl****: (10x) g NaCl was added to the liquid media consisting of 15 g tryptone, 5 g phytone and 1 litre distilled water.*

Histopathology: Infected larvae stained with Haematoxylin & Eosin (H&E) appeared with the edges in dark purple. The epithelium cells showed multiple layers, with enlarged and deeply stained nuclei (Figure 5). Affected cells became necrotic and shed off from the tissues.

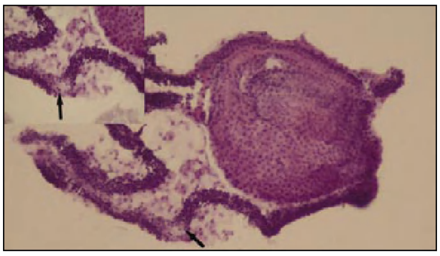

Figure 5. *H&E staining of sea cucumber larvae with the rotting edges symptom. The thick stomach wall results from the proliferation of the epithelial cells. Insert: Close-up of the edge tissues (arrow).*

Stomach ulceration symptom

Epidemiology: The disease typically occurs in summer at high temperatures. It is reported to be associated with pathogenic bacteria and is triggered by unsuitable feeds and high stocking densities (Zhang and Liu, 1998; Liu, 2000; Liu *et al.*, 2002). It appears that the auricularia is susceptible to the infection. The mortality of affected larvae may rise up to 90 % in certain cases.

Clinical signs: Under a microscope, the stomach walls of juveniles are thick, rough, and visibly atrophic in the latter stages (Liu *et al.*, 2002). The ulceration of the stomach usually results in reduced growth and a low metamorphosis rate. The disease often leads to mortality during the metamorphosis from the auricularia to the doliolaria stage.

Aetiology: According to the literature, the aetiology of the disease may be associated with two causes: (1) lack of appropriate food, e.g. feeding juveniles only with chrysophyte or *Platymonas* sp.; (2) certain bacteria induce the ulceration of the stomach (Zhang and Liu, 1998).

Treatment: Using appropriate feeds that meet the nutritive requirement of juveniles, such as marine yeast. When a microbial flora becomes dominant in the breeding tank, antibiotics such as penicillin or streptomycin, in the range of 3-5 ppm, will be effective (Zhang and Liu, 1998).

Gas bubble disease

Epidemiology: This disease has only been detected in the auricularia stage and causes relatively low mortalities (Zhang and Liu, 1998).

Clinical signs: Presence of gas bubbles inside the body of the larva, which results in anorexia. The most severe cases lead to death.

Aetiology: According to Zhang and Liu (1998), the aetiology consists of excess aeration in the rearing tanks. Under this condition, larvae can easily swallow bubbles and become affected. However, the mechanism that leads to death is still not well understood.

Treatment: Avoiding excess aeration by adjusting the air flux is effective in treating this disease. Continuous aeration should be avoided. Thirty minutes intervals every 2 hours without aeration are recommended.

Off-plate syndrome

Epidemiology: This disease was first observed about ten years ago, however, little information was recorded. It occurs in juveniles that have settled (normally on PVC plates) after the completion of metamorphosis from the doliolaria to the pentactula stage. Often mortality can reach 100 %.

Clinical signs: The affected juveniles shrink and gradually lose the ability to remain attach onto the available substrate. Meanwhile, the epidermis of infected individuals disappears; the whole body can even dissolve with the autolysing process. In such cases, the spicules can be found on the bottom of the infected tanks as they drop from the dissolved carcasses.

Aetiology and morphology: Three dominant bacterial strains, nominated HB-1, HB-2 and HB-3, have been isolated from specimens collected from different hatcheries. Based on histopathological analysis and bacterial count from infected tissues, these bacteria have been associated with the syndrome. The colony of HB-1 is small and round, with a white aureole around its edge. The cells are short or curved rods and Gram–negative (Figure 6). The colony of HB-2 is thick, moist, opaque and white. The cells are thin, straight short rods and Gram-negative. The colony of HB-3 is flat and medium in size, moist and transparent, and shows a blue lustre under the light. The cells are Gram-negative, thick and short rods about 2µm in length (Figure 7). Preliminary studies on the morphological, physiological, biochemical and molecular characteristics of the three isolates have been done (Table 2). Based on the above results, HB-1 and HB-3 appear to be *Vibrio* like, while HB-2 has not yet been defined.

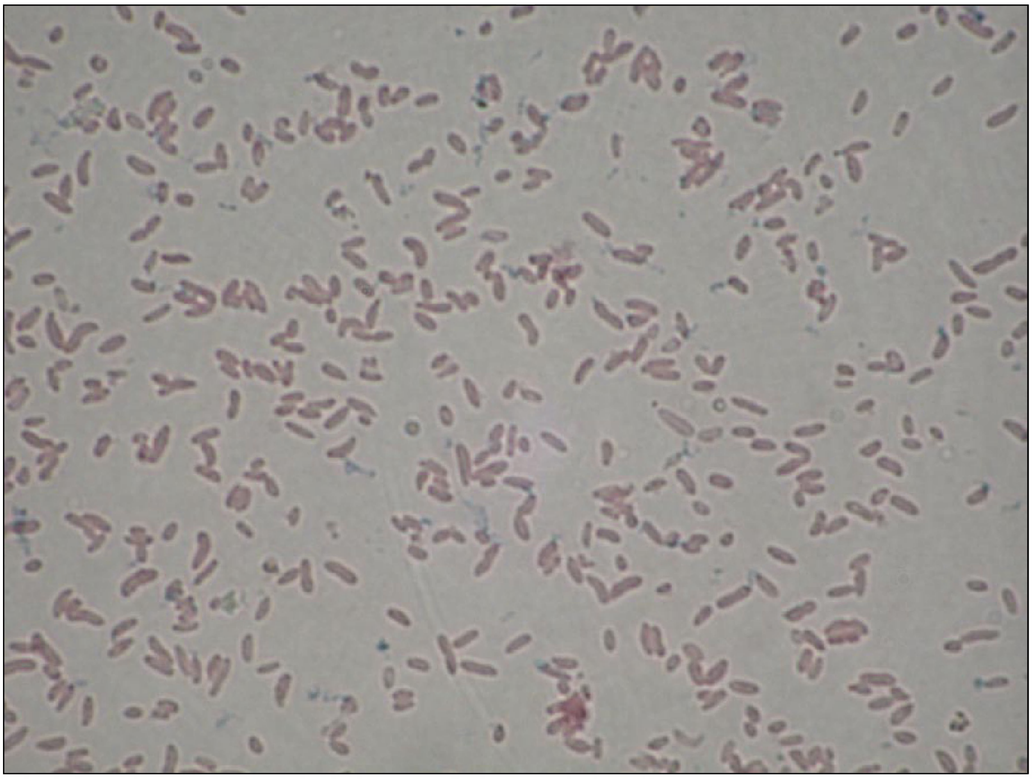

Figure 6. *Gram-negative HB-1 bacteria where the short and curved rods are visible.*

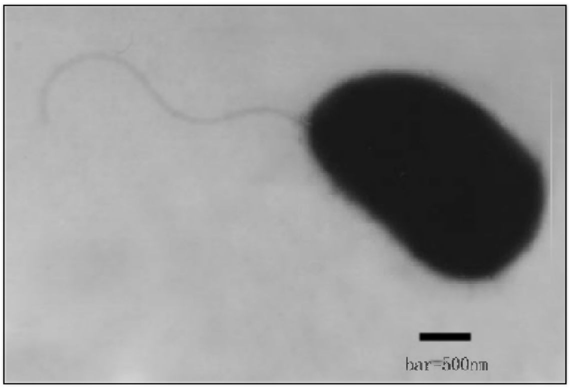

Figure 7. *Negative staining of the HB-3 bacteria show thick and short rods with a single polar flagellum under electron microscope.*

Table 2. Morphological, physiological and biochemical characteristics of the bacteria nominated HB-1, HB-2 and HB-3isolated from sea cucumber larvae.

Characteristic	HB-1	HB-2	HB-3	Characteristic	HB-1	HB-2	HB-3
Gram Stain	-	-	-	Indole production	-	-	+
Movement	+	+	+	H_2S production	-	+	-
O/129 Sensitivity (10µg)	+	-	+	Lysine decarboxylase	-	-	-
O/129 Sensitivity(150µg)	+	-	+	Arginine dihydrolase	-	-	+
Growth on TCBS	-	+	-	Ornithine decarboxylase	-	-	+
0%NaCl, growth	-	-	-	Gas from glucose	-	-	-
3%NaCl, growth	+	+	+	Arabinose	-	-	-
6%NaCl, growth	-	-	-	Mannitol	+	-	-
8%NaCl, growth	-	-	-	Inositol	-	-	-
10%NaCl, growth	-	-	-	Raffinose	-	-	-
4°C, growth	+	+	+	Rhamnose	-	-	NT
25°C, growth	+	+	+	Sucrose	+	-	-
28°C, growth	+	+	+	Glucose	-	+	+
35°C, growth	-	+	+	Salicin	+	+	+
40°C, growth	-	-	+	Sorbitol	-	-	-
45°C, growth	-	-	-	Gelatinase	-	-	-
Oxidase	+	+	+	Urease	-	-	-
Oxidation-Fermentation	F	F	F	ONPG	+	+	+
Citrate utilization	-	-	-	Spore stain	+	-	-
Laetrile	+	-	NT	Methyl red test	-	-	-
Lactose	-	-	-	Tryptophan deaminase	-	-	-
Vogus-Proskauer reaction	+	-	-	Pigmentation	-	-	-

*Symbols: +: positive reaction; -: negative reaction; **NT**: no test conducted; **F**: Fermentation; **x% NaCl**: (10x) g NaCl was added to the liquid media consisting of 15 g tryptone, 5 g phytone and 1litre distilled water.*

Diseases during aestivating stages of *Apostichopus japonicus* and their aetiology

Skin ulcer disease

Epidemiology: This infection tends to occur in juveniles during aestivation as a result of high temperatures and stocking densities. The infection rapidly transfers from the diseased individuals to healthy ones making it difficult to control. Occasionally, the whole population can be wiped out in a short time once the infection sets in.

Clinical signs: Infected individuals are weak and anorexic; their body shrinks and eventually takes a rounded shape and becomes white. The skin ulceration begins with the appearance of small white patches, which enlarge and eventually expose the underlying muscle and spicules. Dead juveniles fall from the substrates leaving clearly visible white marks.

Aetiology: A previous study associated this disease with bacteria (Zhang and Liu, 1998) that proliferate on the PVC plates appearing as red, pink or purple-red patches. The skin ulcer disease occasionally breaks out as the bacterial colonies spread over the plates. The characteristics of these bacteria have not been reported.

Treatment and prevention: Preventive measures include: (1) good hatchery management operation; (2) disinfection of tanks, plates and tools before use; (3) removal of excess food, faeces and other organic matter; and (4) provision of high quality water. The disease can be treated with antibiotics (3-5 ppm) such as terramycin, acheomycin and sulphanilamides.

Predatory copepods

Epidemiology: Summer marks the peak of copepod reproduction as the larvae of sea cucumbers develop into juvenile stages. In the presence of high numbers of copepods, the abundance of juveniles decreases acutely within 1 or 2 days. Usually, these predatory copepods will attack juveniles smaller than 5 cm, and often cause high mortalities.

Clinical signs: The juveniles have lesions on their body and become weak. Eventually, the juveniles die off, the body walls dissolve and the spicules disseminate on the bottom of the rearing tanks.

Aetiology: According to the literature, the copepod known as *Microsetella* sp. is the causative agent. Normally, the rearing conditions for juveniles are favourable for the growth and reproduction of this species. At temperatures between 15-25 °C one adult copepod can produce 90 individuals in 20 days. Generally, the mature female can produce new oocysts within a few minutes following the release of an initial batch. The copepods compete for food and space, as well as bite the young sea cucumber juveniles.

Treatment: Chlorophos is the best option to control the problem at present. A dosage from 2 to 3 ppm is effective; at this concentration all copepods can be killed in two hours without harming the sea cucumber juveniles (Zhang and Liu, 1998; Liu, 2000).

Diseases in outdoor cultivation of *Apostichopus japonicus* and their aetiology

Bacterial Ulceration Syndrome (BUS)

Epidemiology: Sea cucumber adults are susceptible to this disease during the warm season. It usually results in chronic mortalities, with cumulative rates of 30 %. Generally, the infected sea cucumbers die 15 days after the clinical signs appear.

Clinical signs: The infected sea cucumber shrinks and small lesions usually appear around the mouth. The lesions gradually expand with increased mucus synthesis (Figure 8) over large areas of the body wall. The infected skin becomes eroded with deep ulceration (Figure 9) and assumes a bluish white colouration. Many of the infected sea cucumbers will eviscerate in severe infections, while the lightly infected ones will stop feeding.

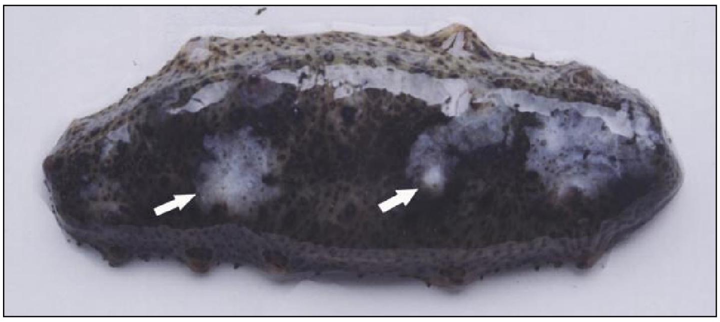

Figure 8. *White patches around the papillae of an infected sea cucumber adult (arrows).*

Figure 9. *Deep ulceration visible on an infected sea cucumber adult (arrows).*

Aetiology and morphology: Based on the isolation, there are two dominant bacteria (KL-1 & KL-2) (Figures 10 & 11). According to observation of the smear preparations, the infected tissues contain a large amount of bacterial cells, and parasitic nematoda are also found in some cases (Figure 12). The dominant bacteria are considered as the primary infectious agent while the nematode is a secondary invader. The smooth-edged colony of KL-1 is large, flat, moist and yellowish. The cells are Gram-negative with curved and short rods (approx. 2 µm) with a single polar flagellum. The colony of KL-2 is thick, moist, white and convex. The cells are Gram-negative with thick and short rods (approx. 1.5 µm). Preliminary studies on the morphological, physiological and biochemical characteristics of the two isolates have been carried out (Table 3).

Table 3. *Morphological, physiological and biochemical characteristics of the bacteria nominated KL-1 & KL-2 isolated from sea cucumber juveniles.*

Characteristic	KL-1	KL-2	Characteristic	KL-1	KL-2
Gram Stain	-	-	Indole production	+	-
Flagella	m	-	Esculine	-	+
Movement	+	+	Glucose	-	-
O/129 Sensitivity (10µg)	+	+	Nitrate reduction	+	+
O/129 Sensitivity (150µg)	+	+	Arginine dihydrolase	-	-
Growth on TCBS	-	-	Raffinose	+	-
0%NaCl , growth	-	-	Gas from glucose	-	-
3%NaCl , growth	+	+	Arabinose	-	-
6%NaCl , growth	+	-	D-Mannose	-	-
8%NaCl , growth	-	-	Mannitol	-	-
10%NaCl, growth	-	-	N-Acetylglucosamine	-	-
4°C, growth	+	+	Capric acid	+	-
25°C, growth	+	+	Sucrose	+	+
28°C, growth	+	+	Maltose	-	-
35°C, growth	+	+	Lactose	-	-
40°C, growth	-	-	Salicin	-	-
45°C, growth	-	-	Glucoheptonate	-	-
Oxidase	+	-	Cellobiose	-	-
Xylose	-	-	Gelatinase	-	-
Oxidation-Fermentation	O	-	Urease	-	-
Methyl red test	-	-	Adipate	-	-
Pigmentation	-	-	Malate	-	-
Citric acid	-	-	Phenylacetic acid	-	-

Symbols: +: positive reaction; -: negative reaction; ***m****: monotrichous;* ***O****: Oxidation;* ***x% NaCl****: (10x) g NaCl was added to the liquid media consisting of 15 g tryptone, 5 g phytone and 1litre distilled water.*

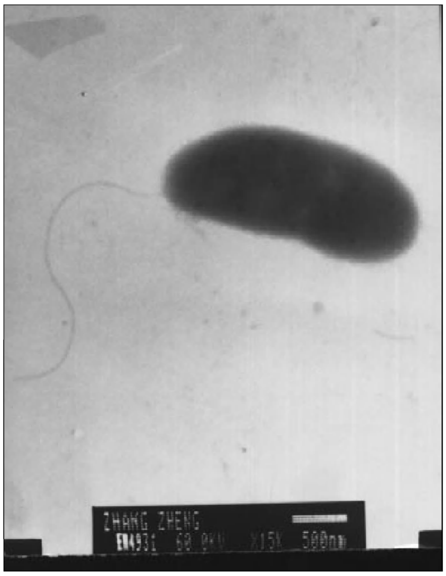

Figure 10. *Negative staining of the KL-1 bacteria showing curved cells and short rods with a single polar flagellum.*

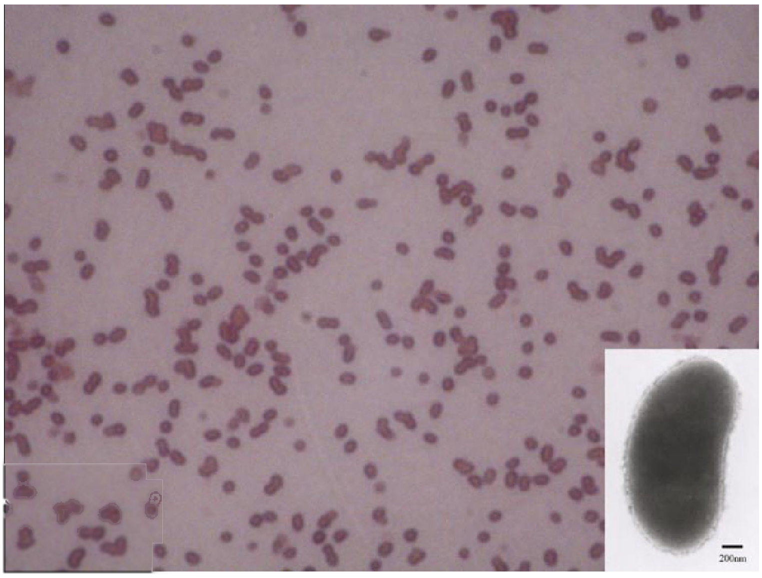

Figure 11. *Staining of the Gram-negative KL-2 bacteria. Insert: Negative staining of a cell under EM, showing thick and short rods without flagella.*

Figure 12*. Parasitic nematoda found in the lesion associated with the Bacterial Ulceration Syndrome (BUS) (400×).*

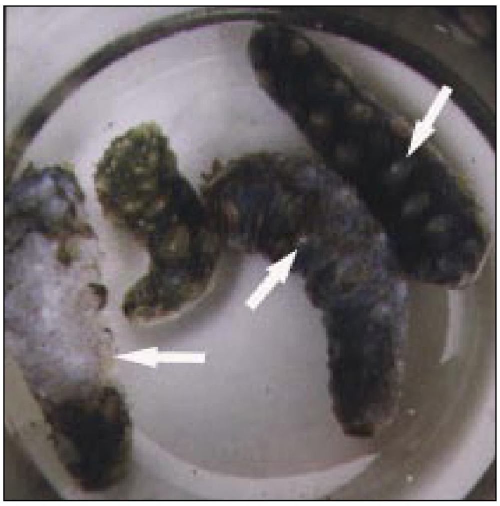

Figure 13. *Eroded papillae (white arrows) and a large area of body surface appearing bluish white (black arrows) of an infected sea cucumber.*

Fungal disease

Epidemiology: Fungal diseases frequently occur in pond cultured sea cucumbers from April to August. Both juveniles and adults can be infected by the fungi, but no case has been found in the larval stages. Although this disease does not cause widespread death, it will result in an unhealthy appearance and poor quality of the final product.

Clinical signs: The papillae of the sea cucumbers become white during the early stage of the infection (Figure 13). With the development of the infection, large areas of body wall appear bluish white as the skin is eroded by the fungi. Unlike bacterial infections, there is no obvious mucus around the lesions. In some cases, the whole body surface becomes discoloured and transparent; the body wall becomes thinner and the affected individuals develop oedema (Figure 14).

Figure 14. *Oedema condition associated with fungal infection in sea cucumber.*

Aetiology and morphology: Two fungal species have been found to be associated with the disease. Microscopic observations of smear preparations show that one of the fungi is quite large with branched hyphae and macroconidia that contain more than 8 spores (Figure 15), while the second species is thin, with straight hyphae and small sporangium.

Histopathology: Histopathological observations show that the fungal hyphae and spores can be detected in the muscular tissues (Figure 16). This is an indication that the fungus can invade the body wall and grow deep into the body tissues. Connective fibre tissue turns necrotic and disintegrates in heavy infections.

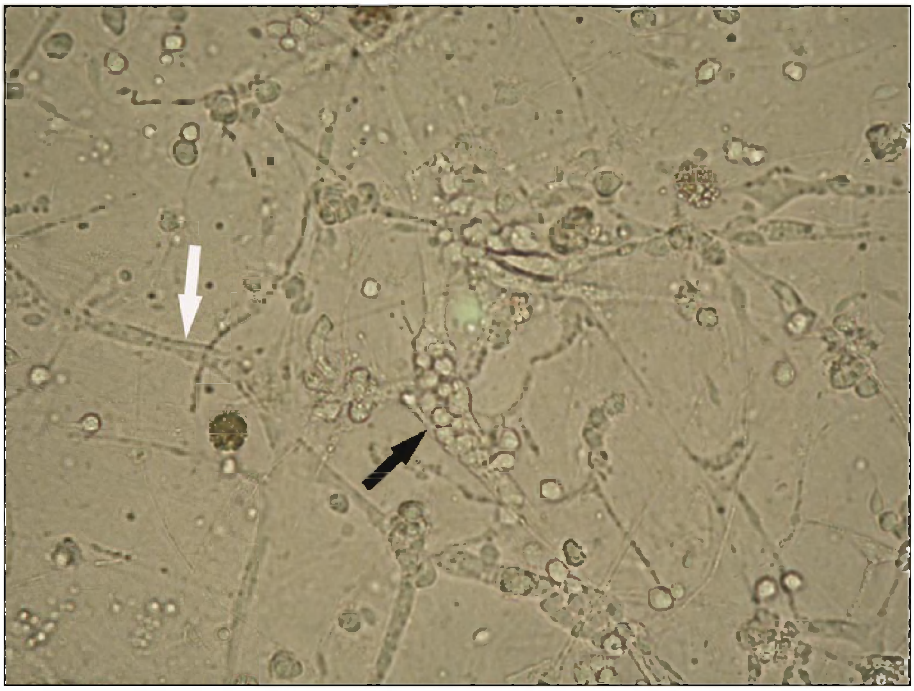

Figure 15. *Fungi with branched hyphae (black arrow) and distinct macroconidia (white arrow) growing on sea cucumber.*

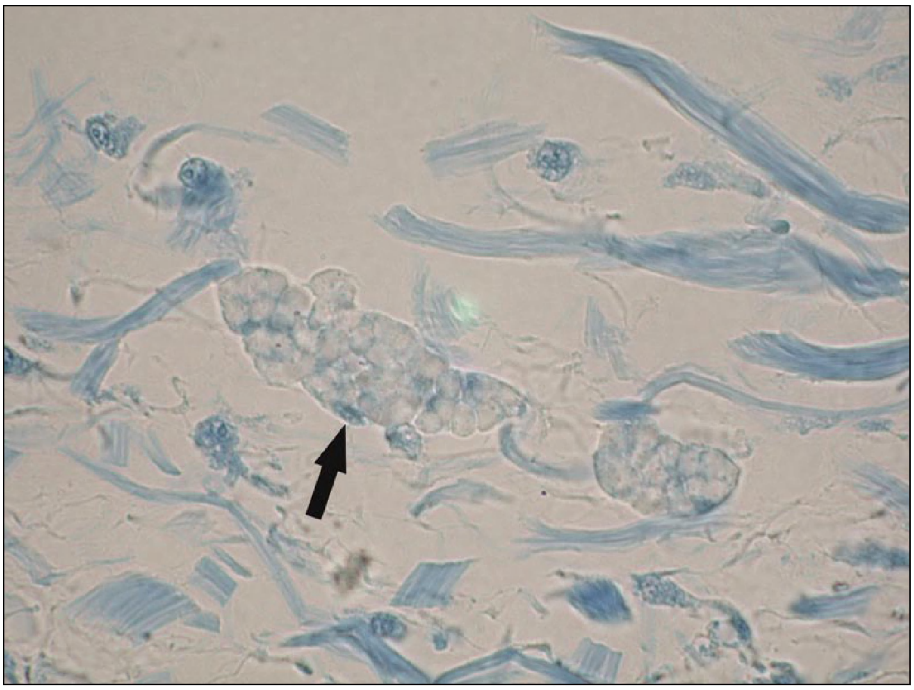

Figure 16. *Fungal spores detected in the muscular tissue (arrow) of a sea cucumber.*

Parasitic diseases - protozoan infection

Epidemiology: The infection generally occurs in young animals and adults, but generally does not cause a serious mortality problem.

Clinical signs: Compared with normal behaviour, the infected animals tend to be weak and sluggish. The body usually shows no conspicuous lesions, however the intestine, respiratory tree, etc. would be eviscerated in severe infections.

Aetiology: The disease is caused by a relatively large protozoan (about 70 µm), with a distinct nucleus and numerous ciliae covering the whole body surface. A large number of the parasites have often been observed in the inner wall of the respiratory tree (Figure 17).

Histopathology: Histological sections reveal large numbers of infusorians attached only to the inner wall of the respiratory branches. The head of the infusorian penetrates through the epithelial tissues of the inner wall from which they ingest nutrients (Figure 18). The epithelial tissue is usually damaged.

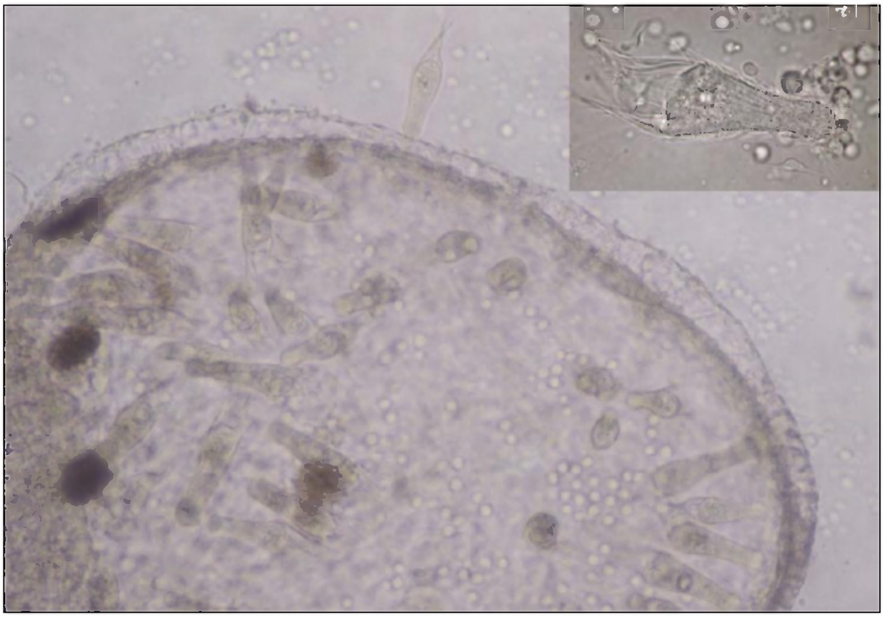

Figure 17. *Protozoans distributed along the inner wall of the respiratory tree of the sea cucumber. Insert shows the morphology of the protozoan.*

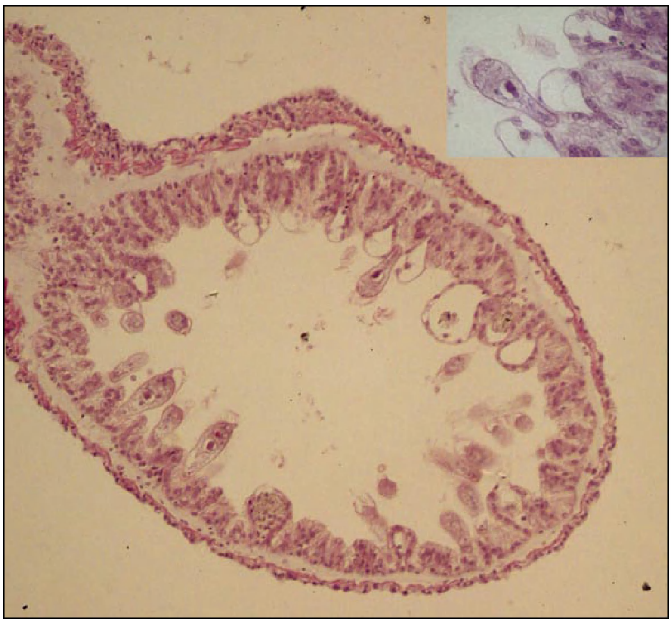

Figure 18. *Histological sections of the respiratory tree of a sea cucumber showing large numbers of infusorians. Insert shows a protozoan that has penetrated into the wall of respiratory tree.*

Parasitic diseases - Platyhelminthiasis

Epidemiology: The worms can infect both aestivated juveniles (larger than 1 cm) and adults. In all cases, the disease causes severe infection resulting in high mortality (over 90 %) within one month.

Clinical signs: Infected juvenile sea cucumbers are weak, anorexic and easily fall from the substrate to the bottom of the tanks (Figure 19). The body of the infected individuals is stiff and is covered in excessive mucus. The entire viscera or part of it (intestine, respiratory tree, etc.) is usually expelled as the infection progresses. Early ulceration usually occurs around the mouth or anus, and then spreads over the dorsal and ventral surfaces of the body and eventually the infected specimen dies (Figure 20).

Aetiology: One unidentified platyhelminth has been observed that caused heavy damage to the skin. Based on a series of biopsies numerous worms have been seen under the microscope. The presence of round projections budding from the segmented body of the parasites is an indication that asexual reproduction may take place (Figure 21). The size of the worm is variable, normally ranging from 50 to 130 µm.

Histopathology: Histological observations demonstrate that there is an abundance of worms in the tissues of the lesion area. The worms occupy a large space within the tissues and cause topical necrosis and scattering of the musculature (Figure 22).

Figure 19. *Infected sea cucumber juveniles are weak, anorexia and easily drop from the settlement substrate to tank bottom (arrow).*

Figure 20. *Infected sea cucumbers with severe ulceration resulting in the exposure of the inner body tissues.*

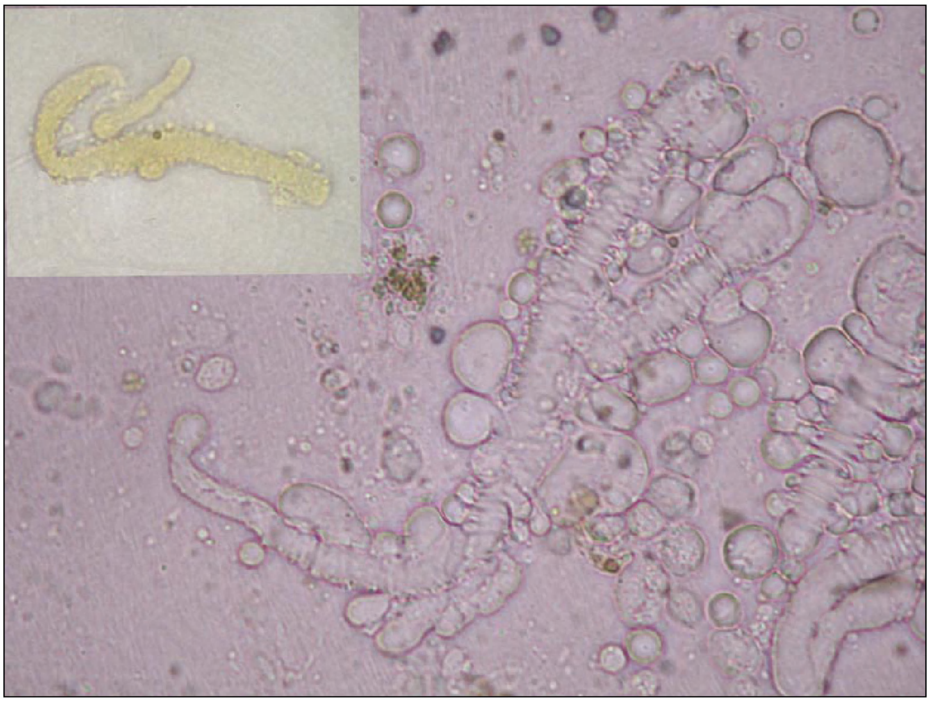

Figure 21. Platyhelminth isolated from sea cucumber skin lesions, showing round projections budding from the segmented body. Insert shows two pieces of worms stained with iodine.

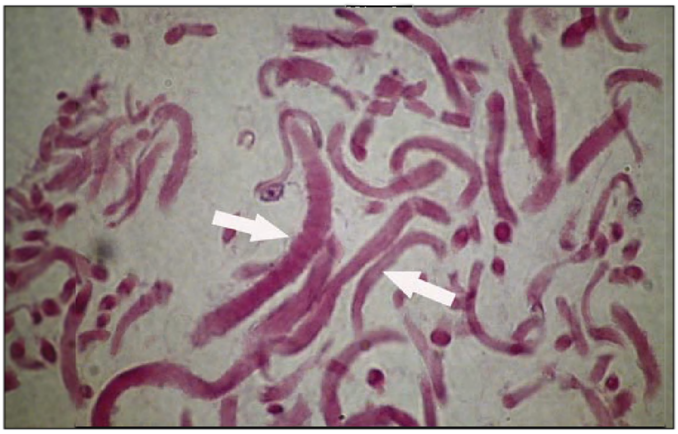

Figure 22. Skin histological sections showing infestation with Platyhelminth worms (arrows) within the muscular tissue (H&E staining, 1000×).

Summary

Study into the diseases of sea cucumbers is a relatively new area of research. So far, parasites e.g. sporozoans, turbellarians and gastropods have been reported in wild sea cucumbers (Smith, 1984; Jangoux, 1987a, b, 1990). Nevertheless, the rapid expansion of sea cucumber farming in China 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. The causative agents become increasingly complex to pinpoint as several kinds of pathogens such as bacteria, fungi, parasites and copepods have been detected. The diseases can occur during breeding, aestivation and outdoor cultivation stages. Several non reported diseases have been discovered.

Preliminary studies have revealed that several types of sea cucumber diseases could cause high mortalities. Amongst the pathogens, bacteria are the most significant aetiological agent, often through vibriosis, while parasites and fungi are regarded as secondary agents. As to the classification of these pathogens further studies on characterization and identification of the pathogens, reinfection processes, pathogenesis, rapid diagnosis as well as treatment methodology need to be undertaken.

Regarding prevention and treatment of these diseases, very little information is available since the fundamental studies have not been conducted yet. Thus, the basic solutions to the current problems rest in proper management. The following issues should be considered: (1) broodstock for reproduction should be healthy without any signs of pathogens to avoid vertical infections; (2) the stocking density should be adapted to the environmental conditions, culture method and experience - overcrowded conditions would lower resistance to diseases; (3) sea cucumbers should be fed with high quality diets that are supplemented with necessary elements including vitamins and minerals; (4) water quality should be maintained by keeping an optimum stocking density, avoiding over feeding and increasing water exchange rates while monitoring the water quality on a daily basis ; (5) total bacterial counts should be conducted routinely to monitor and prevent occurrence of diseases; (6) all equipment and tools should be disinfected before use or before transfer from one tank to another and excess food, faeces and other organic wastes should be siphoned and removed as quickly as possible; (7) as soon as a disease is detected, actions and effective measures should be taken and moribund individuals should be removed from the tanks and be properly disposed; and (8) antibiotics should only be used when the causative pathogen(s) has been confirmed and sensitive tests for antibiotics have been carried out.

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Parasites and biotic diseases in field and cultivated sea cucumbers

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Abstract

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 sections suffering from infestations 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 closer 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, a host haemal lacuna is occluded by trophozoites, or cysts are formed in the coelomic epithelium.

The most pathogenic agents reported from cultured sea cucumbers are bacteria. Cultivated holothuroids may suffer from a bacterial disease, called skin ulceration disease that affects their body wall. In particular, juvenile *Holothuria scabra* reared in the Aqua-Lab hatchery of Toliara, Madagascar, suffered from such a disease 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 the specimen. The lesions consist of areas where the epidermis is totally destroyed and where collagen fibres and ossicles are exposed to the external medium. The area is surrounded by a border line where degrading epidermis is mixed with connective tissue. Three bacterial morphotypes have been identified: rod-shaped bacteria, rough ovoid bacteria and smooth ovoid bacteria. Furthermore, three species of bacteria have also been identified in the white spot lesions from biomolecular analyses (DGGE and sequencing): *Vibrio* sp., *Bacteroides* sp. and an α-proteobacterium.

Keywords: Parasitoses, bacteria, holothuroidea

野生和养殖海参的寄生虫和其它生物性疾病

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摘要

在棘皮动物中，Holothuroidea　代表海参纲的动物。它们大多数都寄生有寄生虫。海参的寄生虫包括细菌、原生动物和后生动物。大约有150种后生动物寄生在海参体内，其中有涡虫、腹足类、桡足类、蟹类和鱼类。易受感染和侵害的部位是海参的消化系统和体腔，由后生动物引起的疾病有：体表的表皮损伤、呼吸树被穿透，或者刺穿体壁进入体腔。大多数寄生在消化系统内的后生动物不引起明显的疾病，而是与宿主之间建立起共栖关系。寄生在海参体内的原生动物主要是孢子虫。它们寄生于体腔或者寄生在血液循环系统中，其中有一种寄生于性腺内。被孢子虫大量寄生的宿主，有时宿主的血管腔为寄生虫的营养体所阻塞，但很少有严重的病症迹象；有时也在宿主的体腔壁的上皮细胞内形成包囊。

所报道过的发生在养殖的海参中的致病菌是细菌类，所引起的疾病有皮肤溃疡，即海参体壁被细菌感染。

在马达加斯加的托里阿水产实验室内培育的糙海参（*Holothuria scabra*）幼体被感染后的三天内而死亡。感染后的最初症状是靠近泄殖孔的体表出现白点，并迅速蔓延至全身，直至死亡。损伤部位的上皮组织完全被破坏，露出了胶原纤维和骨片。在损伤部位的边缘，被分解的上皮细胞与结缔组织混合在一起。感染上皮组织，造成损伤的细菌有三类：杆状细菌、粗糙卵形细菌和光滑卵形细菌。这三种细菌借助分子生物学的分析（DGGE和序列测定）被鉴定为：弧菌（*Vibrio* sp.）、类菌体（*Bacteroides* sp.）和α-蛋白细菌（α-proteobacterium）。

关键词：寄生虫病、细菌、海参纲

Introduction

Many organisms are reported to infest echinoderms, especially holothuroids. Holothuroid associates are either commensals or parasites. The former are harmless to the hosts: they often live on the surface of holothuroids acting as protective coverings against predators. Parasites on the other hand are always harmful to their hosts and, although mainly non-lethal can cause the host's death in some instances. For them, holothuroids provide biotic substrates where they can live, serving sometimes as a source of food and/or as a source of developmental stimuli without which they cannot complete their life cycle. According to a review on echinoderm diseases (Jangoux, 1990), more than one third of echinoderm parasites live in or on holothuroids. No bacteria had been recorded at that time and only protozoan and ten metazoan taxa of high rank in the Linnean hierarchy were known to infest holothuroids. According to Jangoux (1990), most parasitic animals were Platyhelminthes (39 turbellarian species and 3 flukes), followed by Mollusca (33 gastropods and 4 bivalves), Arthropoda (one tardigrade, 22 copepods, 8 crabs and 2 pycnogonids), Pisces (9 carapids), Bryozoa (4 species), Annelida (2 polychaetes) and finally Porifera, Cnidaria, Entoprocta (1 species each) and Nematoda (undetermined number of species).

The report covers the main parasites and biotic diseases of sea cucumbers and includes recent studies on the subject since the work of Jangoux (1990). It particularly emphasises new bacterial parasites and the diseases that they induce.

Bacteria

Almost nothing is known about bacterial parasites and diseases in holothuroids. Morgan (2000) reported that a broodstock of *Holothuria scabra* from Bribie Island (Australia) suffered from a bacterial disease. The infection provoked the loss of epidermal pigmentation associated with the presence of huge amounts of viscous mucus. The lesions first arose around the mouth and/or cloacal opening of the diseased animals and then spread on both sides of the individuals before possibly encompassing the whole body. If infected animals were not eliminated from the broodstock, up to 95 % of the reared individuals died (Morgan, 2000). According to this author, *Vibrio harveyi* was the predominant bacterium in the lesions of affected holothuroids.

Becker (2002) reported on a disease, called skin ulceration disease, affecting juvenile *H. scabra* reared in a hatchery at Toliara, Madagascar. Microscopic and biomolecular techniques (denaturing gradient gel electrophoresis and sequencing) together with bacterial cultures and infection assays were used to characterise the disease and to investigate the microbial communities of the lesions.

The skin ulceration disease, which affects the body wall of juvenile *H. scabra* at Toliara, appeared for the first time in September 2000 and broke out in February 2001, May 2001, February 2002 and July 2002. The infection extended very quickly in the aquaria, being highly contagious. In February 2001, the skin ulceration disease reached a peak and affected two thirds of the juveniles two days after its appearance. The disease was also highly virulent causing death three days after detection of the first symptoms.

The first obvious sign of the disease was the appearance of small, white, rounded spots of about 1 mm in diameter corresponding to areas where the epidermis was destroyed. The white colour of the lesions is due to exposure of the connective tissue that follows destruction of the cuticle, the epidermis and the upper part of the connective tissue.

Yet, the mesothelium, the muscles and the internal organs remained unaffected. The first white spots always appeared close to the cloacal opening and this was quickly followed by an outbreak of other spots similar in size, shape and colour in the posterior half of the individuals. The rest of the body remained healthy and the behaviour of diseased and healthy holothuroids was unchanged except that the former did not seem to burrow anymore. Twenty-four hours later, the white spots spread and joined together to form a large, posterior lesion which covered about a fifth of the body surface (Figure 1). Podia inside this lesion were totally destroyed. Other spots then appeared on the anterior part of the body and ossicles became visible externally, some of them separating from the integument. Forty-eight hours later, more than a half of the body surface was affected. Juveniles were much less active, became almost translucent, and their internal organs visible through the body wall. Three days after the beginning of the disease, the whole body surface was affected. Dead individuals were reduced to pellets of heavily infested tissue.

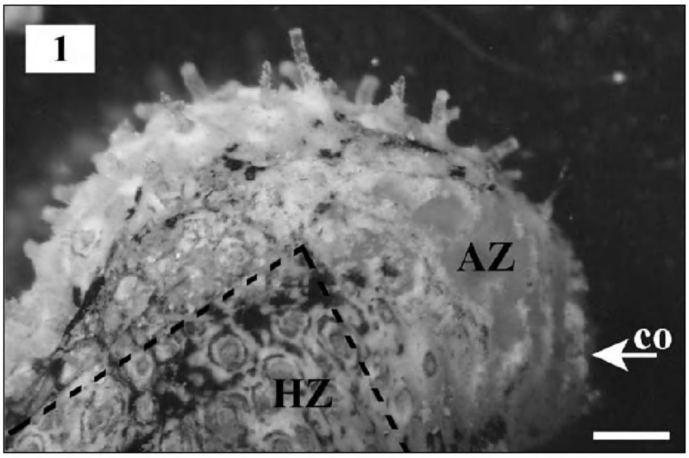


Figure 1. *Juvenile of* Holothuria scabra *affected by the skin ulceration disease (O.M.).* ***AZ****: affected zone;* ***CO****: cloacal orifice;* ***HZ****: healthy zone. Scale bar = 100 µm.*

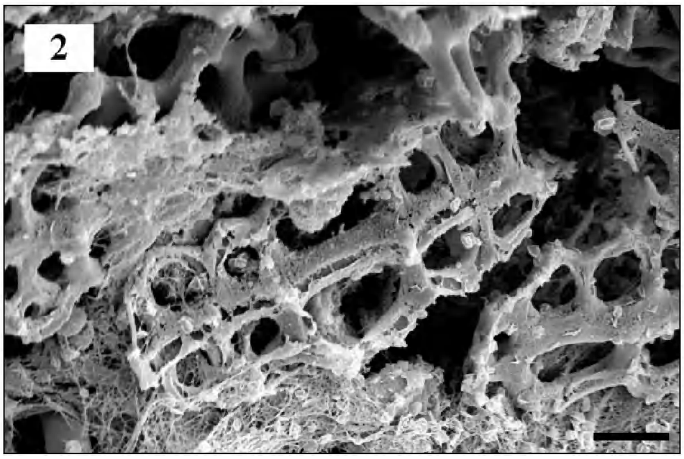


Figure 2. *SEM views of a lesion of a* Holothuria scabra *juvenile affected by the skin ulceration disease showing degraded ossicles in the affected zone and smooth ovoid bacteria on an ossicle, respectively. Scale bars = 10 µm.*

With the use of scanning electron microscopy (SEM), two different zones of the body surface may be observed in the white spot lesions of diseased holothuroids: (1) the affected zone, colonised by microorganisms, where the epidermis and cuticle are totally destroyed and where a disorganised connective tissue is exposed to the medium and (2) a borderline of a few tens of micrometers wide where the surface is colonised by microorganisms and where patches of degrading epidermis are mixed with degrading, exposed connective tissue. In the affected zone, collagen fibres run in all directions, breaking off from each other while the ossicles, some of them highly degraded, are exposed to the external medium (Figure 2). Three bacterial morphotypes are observed in these two zones: rod-shaped bacteria, rough ovoid bacteria and smooth ovoid bacteria. The smooth ovoid bacteria were observed degrading holothuroid ossicles (Figure 3).

The biomolecular techniques identified three species of bacteria in the lesions. The first, *Vibrio* sp., has been isolated in bacterial cultures of sea cucumber lesions and identified by DNA sequencing. The two other bacteria, *Bacteroides* sp. and an α–proteobacterium, have been detected by the denaturing gradient gel electrophoresis method.

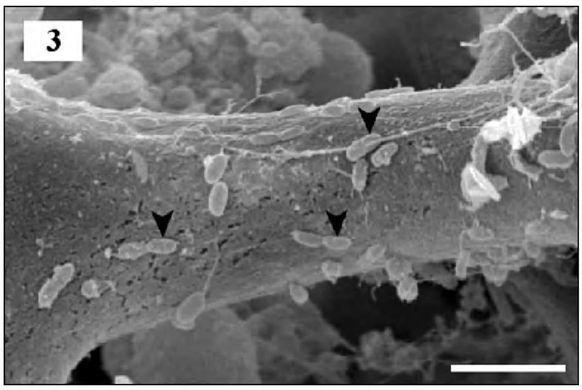


Figure 3. *SEM views of a lesion of a* Holothuria scabra *juvenile affected by the skin ulceration disease showing smooth ovoid bacteria on a degrading ossicle. Scale bars = 5 µm.*

From the three bacteria, *Vibrio* sp. is the best candidate as the etiological agent of the skin ulceration disease. It is indeed close to *Vibrio harveyi* and *V. alginolyticus*, two well-known pathogenic bacteria. *Vibrio harveyi* is responsible for numerous infections to both vertebrates and invertebrates.

Protozoa

Ciliates living in the digestive tract and in the respiratory trees of holothuroids have been reported by Barel and Kramer (1977). Holothuroids are otherwise mainly infested by members of five gregarine genera (13 described species) - *Cystobia, Diplodina, Goniospora, Lithocystis* and *Urospora* - and one species of coccidia (*Ixoreis psychropotae*). Deposit-feeding holothuroids are very sensitive to gregarine infestations. Kroll and Jangoux (1989), for example, observed that 90 % of the 50 *Holothuria tubulosa* collected in the *Posidonia* beds at Castello (Ischia Island, Italy) were infested by gregarines. The high infestations of holothuroids by gregarines can be explained by the fact that echinoderms may infest themselves simply by swallowing sediment that contains mature sporocysts. The life cycle of gregarines is complex and includes six developmental stages - sporocysts, sporozoites, trophozoites, gamontes, gametocysts and sporogonia - that are all observed within the holothuroids. Once in the digestive system, sporocysts are broken down and sporozoites are liberated owing to the physico-chemical properties of the digestive fluid (Jangoux, 1990). Generally, they penetrate cells of the digestive system and migrate into the haemal system or the coelom. A prolonged stay in the host's haemal system is necessary for a few species, probably for most of them, but the described species are often known only from one stage that infested a specific host's body part. Trophozoites and subsequent stages are extracellular and found in the haemal lacuna, attached to the coelomic epithelium or embedded in coelomic brown bodies. The escape of gregarines from the hosts is unknown though it is generally accepted that they leave holothuroids through evisceration or at the host's death. Recently, Doignon *et al.* (2003) observed that the coelomic content (brown bodies and parasites) of *Holothuria tubulosa* is purged seasonally, a phenomenon that could exist in other species. To explain this coelomic purge, the main hypothesis was that it would be an indirect result of the host's spawning as it occurs at that time: to discharge their gametes, holothuroids raise their body, adhere on the substratum by their posterior end and then contract muscles. This behaviour would cause an overpressure in the peri-cloacal end of the animal and consequently the expulsion of the coelomic fluids through the coelo-cloacal ducts, carrying the coelomic contents, brown bodies and parasites into the environment.

Diseases induced by protozoans to holothuroids are reduced to small internal wounds and no lethality due to gregarines has been described in the literature. Growth of the *Cystobia* trophozoites progressively occludes the host's haemal lacuna and a particular haemal outgrowth is formed like a bell-clapper protruding into the coelomic cavity; the clapper represents the so-called "stalked gregarine" that is formed by an evagination of the underlying haemal lacuna whose distal end encloses an enlarged trophozoite or a cyst (Jangoux, 1990). One species, *Diplodina gonadipertha*, infests the gonads of *Cucumaria frondosa* and could partially destroy the gonads (Djakonov, 1923). The single species of Coccidia, *Iroxeis psychropotae*, lives in the gut-associated haemal system of deep sea holothuroids (Massin *et al*., 1978).

Metazoa

Platyhelminthes

Jangoux (1990) has found 5 Acoela, 34 Umagillidae (Rhabdocoela) and 3 Trematoda infesting holothuroids. Five umagillids have been described since his review (Table 1). The acoels are found mostly in the digestive tract of holothuroids, one species has been observed in the coelom and another one in the respiratory trees. Umagillids infest either the coelom or the digestive tract. Snyder (1980) could determine neither beneficial nor detrimental effects due to the occurrence of gut-associated umagillids. He concluded that these symbionts should be considered as commensals. In contrast, Shinn (1981) reported that the gut-associated umagillids always compete with their host for nutrients and thus may exert adverse effects. He noted that all the umagillids studied by him ingest intestinal host tissue and he considered that they parasite their hosts to varying degrees. Whether they are living in the gut or in the coelom, they breed in the hosts and release egg capsules. Egg capsules are defecated in gut-associated umagillids or are accumulated in the holothuroid body cavity in coelom-associated umagillids. Coelomic umagillids swim in the host's body cavity and they are thought to ingest the host's coelomic fluid together with coelomocytes (Shinn, 1983) or to feed on coelom-associated organisms such as ciliates (Jennings, 1980).

Table 1. *New species of Platyhelminthes infesting holothuroids that have been described since the review by Jangoux (1990).*

Turbellaria Umagillidae	Host	Geographical area	Source
Anoplodium heronensis	*Stichopus* sp.	Great Barrier Reef, Australia	Canon (1990)
Anoplodium leighi	*Stichopus* sp.	New Zealand	Canon (1990)
Paranotothrix sp.	Various holothuroids	Seychelles	Martens and De Clerck (1994)
Anoplodium sp.	*Stichopus variegatus* *Actinopyga miliaris*	Seychelles	Martens and De Clerck (1994)
Wahlia westbladi	*Stichopus mollis*	Australia	Jondelius (1996)

Infestations by umagillids can be very high. The 27 individuals of *Thelenota anax*, *Holothuria fuscogilva*, *H. coluber* and *Actinopyga mauritiana* collected in Hansa Bay (Papua New Guinea) were all infested by gut-associated umagillids and some of them by more than 200 flatworms (Eeckhaut, pers. obs.). Doignon *et al.* (2003) studied the infestation of *H. tubulosa* by the coelom-associated umagillid *Anoplodium parasita*. They observed that 26 holothuroids out of the 202 collected at Banyuls-sur-mer (France) were infested by one to six adult *A. parasita*. The infestation of the holothuroids by the turbellarian egg capsules was very important: 128 out of the 202 holothuroids inspected contained at least 6 and up to 10 000 egg capsules (mean of 1 433). Quite uniform throughout the year, the number of egg capsules found in the coelom as well as the number of holothuroids infested by egg capsules fall drastically in July. Interestingly, this period is the one where the gonads of holothuroids were fully developed. Doignon *et al.* (2003) suggested that the release of the egg capsules could occur through coelo-rectal ducts and would be an indirect result of the host spawning.

The flukes *Himasthla leptosoma* and *Zoogonoides viviparus* infest the body wall at the base of the buccal tentacles of *Leptosynapta* spp. The first species has also been observed in the brown bodies (Cuénot, 1892, 1912; Jangoux, 1990). A third species, *Tetrarynchus holothuriae* occurs in the body wall of *Molpadia* sp. (Shipley, 1903). Holothuroids are probably intermediate hosts for flukes. Sea birds are the definite hosts of *Himasthla leptosoma.*

Annelida

The most recent review on symbiotic polychaetes is the one of Martin and Britayev (1998). They have found 18 polychaete species commensal of holothuroids, and one parasite. The parasite, *Ophryotrocha puerilis*, occurs in the coelomic cavity of *Ocnus planci* from Napoli (Monticelli, 1892; Barel and Kramer, 1977; Jangoux, 1990). Ganapati and Rhadakrishna (1962) noted that 50 % of the holothuroids *Molpadia* sp. were infested by the small hesionid *Ancistrocyllis* sp. either in the digestive tract or respiratory trees. Commensal polychaetes are simply attached by their parapodia to the surface of holothuroids and are considered totally harmless to their hosts. Britayev and Lyskin (2002), however, recently demonstrated that *Gastrolepia clavigera*, the commonest Indo-Pacific polychaete associated to holothuroids, partially eats the host's integument. Holothuroid spicules represented up to 75 % of the polychaete's gut content. These results suggest that symbiotic polychaetes currently considered as commensals could be true parasites.

Mollusca

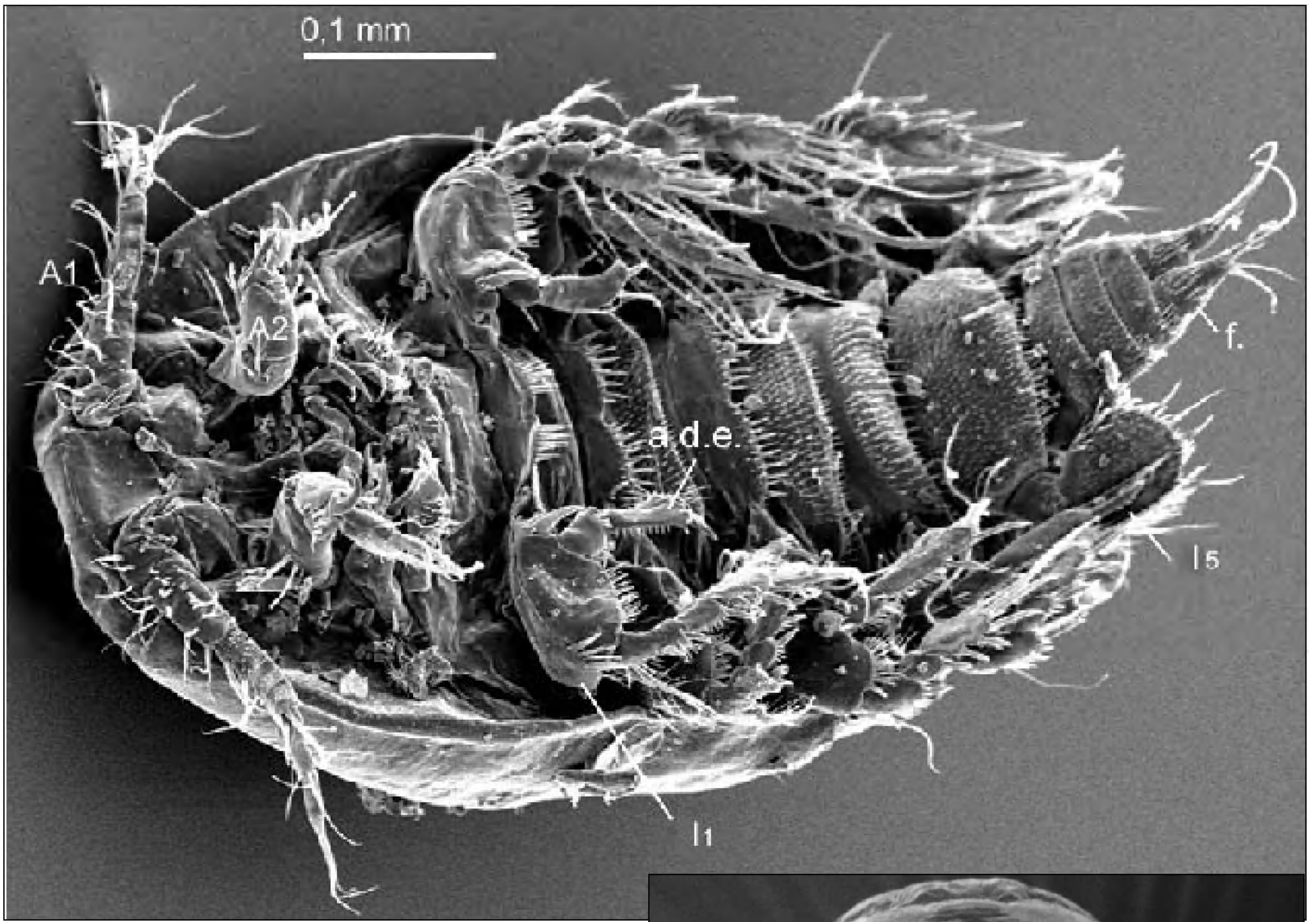
Four Bivalvia and 33 Gastropoda are known to infest holothuroids (Jangoux, 1990). Bivalves live in the cloaca or inhabit small pouches dug into the digestive wall of synaptid holothuroids (Jangoux, 1990). Gastropods are free on the body surface where they may induce galls, they are also found in the respiratory tree, the digestive tract or the coelom. Ectoparasitic gastropods feed on the host's tissues or fluids using their proboscis, which penetrates deeply into the holothuroid body wall or crosses it to reach the coelomic cavity or the haemal system (Jangoux, 1990). Intradigestive symbionts enter the digestive tract in order to feed by puncturing the digestive wall (Jangoux, 1990). A special case of intradigestive symbiosis is the one developed by *Megadenus cantharelloides* which attaches to the digestive wall of *Stichopus chloronotus* with its proboscis reaching the host's body wall in order to feed on dermal tissue (Humphreys and Lützen, 1972). With the exception of *Gasterosiphon deimatis*, which feed on haemal fluid (Koehler and Vaney, 1903), intracoelomic gastropods are believed to derive their energy from the host's coelomic fluid by direct absorption of nutrients through their body wall (Jangoux, 1990).

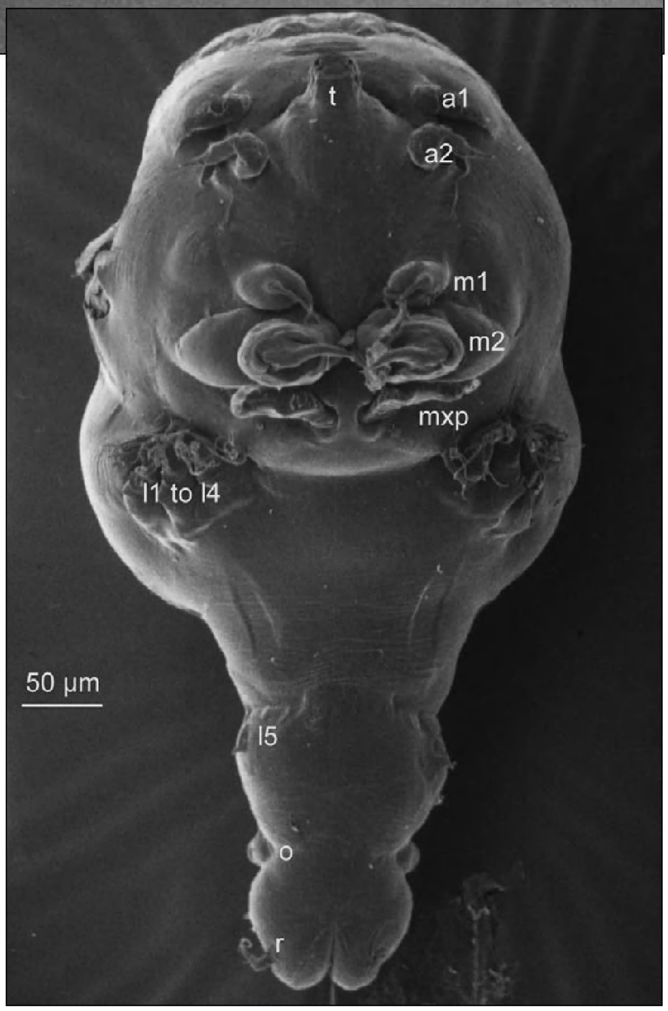
Harmful effects of parasitic gastropods are not restricted to their feeding activities, but they may produce attachment lesions involving host reactions and induction of galls. It is also reported that the intracoelomic *Entocolax* spp. may castrate their hosts (Heding and Mandahl-Barth, 1938). So far, there is no data indicating that parasitic eulimids can seriously affect the holothuroid cycle and the ecological consequences of this parasitism may be quite limited for the holothuroid populations involved (Jangoux, 1990).

Arthropoda

Twelve pinnotherid crabs are associated with holothuroids. Most live in the respiratory trees or the posterior part of the digestive tract. One, *Pinnotheres decanus*, is rarely found in the coelomic cavity. *Lissocarcinus orbicularis*, the commonest Indo-Pacific crab associated with holothuroids, is often found walking on the host's body surface. Presumably, holothuroid-associated crabs do not feed on host tissues and most of them do not cause any detrimental effects, except to slightly wound the wall of respiratory trees or cloaca (Jangoux, 1990). A notable exception to this rule is the pea crab, *Pinnotheres halingi*, which causes a significant atrophy of the right respiratory tree (Hamel *et al.*, 1999).

At least eighty-five cases of association between holothuroids and copepods have been described to date. The symbiotic copepods belong to four classes (Harpacticoida, Cyclopoida, Poecilostomatoida and Siphonostomatoida) and the holothuroid hosts to more than twenty genera. But still, there is little information regarding the relations between hosts and symbionts (see, for example, Humes, 1980). Most associations reported essentially describe the localisation of the symbionts in regards to the host and the presence/absence of conspicuous characteristics that would be induced by the symbiont's presence (Jangoux, 1990). In the majority of these associations (about 60 %), copepods are defined as external symbionts, with a rather unclear definition of their relations with the holothuroid host. Since the review by Jangoux (1990), only the work of Gomes da Silva (2001) focused on the biology of symbiotic copepods, *i.e.* the poecilostome *Synaptiphilus luteus* (Figure 4) and the siphonostome *Allantogynus delamarei* (Figure 5). The first has never been reported as free living and shows a wide range of host tolerance (weak specificity). Its hosts are the northern Atlantic synaptid holothuroids, *Labidoplax digitata*, *Leptosynapta inhaerens*, *L. gallienei* and *L. bergensis* (Bocquet, 1952; Bocquet and Stock, 1957; Humes, 1980). Gomes da Silva (2001) performed population studies on *S. luteus* and showed that, if females are encountered throughout the year on their hosts, infestation by males occurs seasonally, the males and females only being present simultaneously on the hosts for a restricted mating period. Gomes da Silva (2001) also studied the coelomocyte reaction induced by *Allantogynus delamarei* in the body cavity of the Mediterranean aspidochirotes holothuroids, *H. tubulosa* and *H. poli*. The parasite shows many peculiarities; no male is known, only the females and three larval stages are described (Changeux, 1958). The female shows a highly modified morphology. She secretes an incubating envelope in which she continuously secretes ovigerous sacs each containing two embryos. The female and her ovigerous sacs are embedded in this incubating envelope, from which only the buccal tube protrudes to puncture the mesothelium of the host's coelomic cavity.





Figures 4 and 5. *Ventral views of a female* Synaptiphilus luteus *and of a female* Allantogynus delamarei, *respectively.* ***a1****: antennula,* ***a2****: antenna,* ***ade****: distal endopodite article,* ***m1****: maxillula,* ***m2****: maxilla,* ***mxp****: maxillipede,* ***o****: laying orifice,* ***l1 to l4****: leg 1 to leg 4,* ***l5****: leg 5,* ***r****: caudal ramus,* ***t****: buccal tube.*

Pisces

Although some pearlfish (Carapidae, Ophidiiformes) are free-living, this family includes fishes that are able to live in association with different invertebrates. The origin of "pearlfish" is the discovery of dead carapid fish, paralysed and completely covered by a nacreous substance in an oyster shell (Ballard, 1991). However, the majority of the species belonging to the Carapini tribe (*Carapus* spp. and *Encheliophis* spp.) are usually found in the respiratory trees or in the coelomic cavity of holothuroids or in the coelomic cavity of asteroids.

Pearlfishes associated with sea cucumbers are listed in Table 2. Although the fishes are able to enter different host species, they often show a preference to a specific one (Trott and Trott, 1972; Gustato *et al*., 1979). *C. boraborensis*, *C. homei*, *C. mourlani* and *E. gracilis* can live in the same host species and are found in the same waters, but they usually do not inhabit the same host individual (Smith, 1964; Trott, 1981; Shen and Yeh, 1987; Vandenspiegel and Jangoux, 1989; Markle and Olney, 1990). If it exists, a system of sea cucumber recognition is not yet correctly highlighted. These fish are able to produce sounds (Parmentier *et al*., 2003). It is believed that these sounds are not used by the fish to identify the presence of another fish in the holothuroid before penetration, but are produced in the presence of congeneric individuals, inside holothuroids (Parmentier *et al*., 2003). Pearlfish sound emissions could be a form of communication used where the visibility is strongly reduced and where chemical communications may be masked by the host.

Table 2. *Fishes associated with echinoderms (Parmentier, 2003). (*) most common host (indicated when known); A: asteroid; B: bivalve; H: holothuroid.*

Carapidae		Host	Author
Carapus acus	H	*Stichopus regalis* (*)	Arnold (1953, 1957), Gustato et al. (1979), Vitturi & Catalano (1988), Kloss & Pfeiffer (2000)
	H	*Holothuria tubulosa* (*)	Arnold (1953, 1956, 1957), Gustato et al. (1979), Vitturi & Catalano (1988), Kloss & Pfeiffer (2000)
	H	*Holothuria poli*	Arnold (1956, 1957)
	H	*Holothuria helleri*	Arnold (1956, 1957)
	H	*Holothuria sanctori*	Arnold (1956)
Carapus bermudensis	H	*Actinopyga agassizi* (*)	Arnold (1956), Smith & Tyler (1969), Van Meter & Ache (1974), Trott (1970), Smith et al. (1981), Tyler et al. (1992)
	H	*Isiostichopus badionatus*	Smith and Tyler (1969)
	H	*Astichopus multifudus*	Trott (1970)
	H	*Holothuria glaberrima*	Trott (1970)
	H	*Holothuria princeps*	Dawson (1971)
	H	*Holothuria lentiginosa*	Miller & Pawson (1979), Valentine & Goeke (1983),
	H	*Holothuria mexicana*	Smith & Tyler (1969), Trott (1970), Tyler et al. (1992)
Carapus mourlani	H	*Culcita novaeguineae*	Mortensen (1923), Petit (1934), Schultz (1960), Smith (1964), Trott (1970), Trott & Trott (1972), Meyer-Rochow (1977, 1979), Meyer-Rochow & Tiang (1978), Machida (1989)
	A	*Pentaceros hawaiiensis*	Markle & Olney (1990)
	A	*Choriaster granulatus*	Markle & Olney (1990)
	A	*Acanthaster planci*	Cheney (1973), Machida (1989)
	H	*Stichopus variegatus*	Markle & Olney (1990)
	H	*Stichopus chloronotus*	Markle & Olney (1990)
	H	*Bohadschia argus*	Trott (1970), Meyer-Rochow (1977), Machida (1989), Markle & Olney (1990)
	H	*Actinopyga mauritania*	Markle & Olney (1990)
	H	*Holothuria scabra*	Markle & Olney (1990)

Carapidae		Host	Author
Carapus homei	H	*Bohadschia argus* (*)	Smith (1964), Branch (1969), Trott (1970), VandenSpiegel & Jangoux (1989), Markle & Olney (1990)
	H	*Stichopus chloronotus* (*)	Smith (1964), Branch (1969), Trott (1970), Trott & Garth (1970), Trott & Trott (1972), Seymour & McCosker (1974), Markle & Olney (1990)
	H	*Stichopus variegatus*	Trott (1970), Meyer-Rochow (1977)
	H	*Thelenota ananas*	Markle & Olney (1990)
	H	*Actinopyga echinites*	Markle & Olney (1990)
	H	*Holothuria ocellata*	VandenSpiegel & Jangoux (1989)
	A	*Culcita schmideliana*	Hipeau-Jacquotte (1967), Jangoux (1974)
	A	*Mithrodia fisheri*	Jangoux (1974)
	B	*Pteria lotorium*	Mahadevan (1959)
Carapus boraborensis	H	*Thelenota ananas*	Smith (1964), Trott (1970), Meyer-Rochow (1977), VandenSpiegel & Jangoux (1989), Markle & Olney (1990)
	H	*Bohadschia argus*	Smith (1964), Markle & Olney (1990), VandenSpiegel & Jangoux (1989)
	H	*Stichopus chloronotus*	Markle & Olney (1990)
	H	*Pearsonothuria graeffei*	VandenSpiegel & Jangoux (1989)
	H	*Thelenota anax*	Ballard (1991) – Parmentier et al. (2002)
Encheliophis sagamianus	H	*Holothuria mertensiothuria*	Tanaka (1908), Arnold (1956)
	A	*Certonardoa semiregularis*	Yosii (1928)
	A	*Nardoa semiregularis*	Arnold (1956)
Encheliophis vermicularis	H	*Holothuria kefersteinii*	Trott (1970)
	H	*Holothuria leucospilota*	Murdy & Cowan (1980), Masuda et al. (1984)
	H	*Holothuria lubrica*	Steinbeck & Ricketts (1941)
	H	*Thelenota ananas*	Markle & Olney (1990)
	H	*Holothuria atra*	Schultz (1960)
	H	*Holothuria scabra*	Murdy & Cowan (1980)
Encheliophis gracilis	H	*Holothuria scabra*	Arnold (1956)
	H	*Thelenota ananas*	Shen & Yeh (1987), Markle & Olney (1990)
	H	*Holothuria atra*	Strasburg (1961), Schultz (1960)
	H	*Actynopyga crassa*	Markle & Olney (1990)
	H	*Bohadschia vitiensis*	Markle & Olney (1990)
	H	*Bohadschia argus*	Smith (1964), Trott (1970), Machida (1989), Markle & Olney (1990)
	H	*Stichopus chlronotus*	Smith (1964)
	H	*Holothuria chilensis*	Trott (1970)
	H	*Stichopus sp.*	Markle & Olney (1990)
	A	*Culcita discoidea*	Arnold (1956)
	A	*Cuclcita novaeguineae)*	Branch (1969), Trott (1970)
Encheliophis chardewalli	H	*Actinopyga mauritania*	Parmentier (2003)

In most cases, there is only one fish per host. However, specimens of *Encheliophis* (*E. gracilis*, *E. vermicularis* and *E. sagamianus*) were reported to be sexually paired in various holothuroids (Murdy and Cowan, 1980; Trott, 1981). More than two specimens of *C. homei*, *C. mourlani* and *C. bermudensis* can be observed in the same host (Aronson and Mosher, 1951; Meyer-Rochow, 1977; Trott and Trott, 1972; Smith *et al.*, 1981). Meyer-Rochow (1977) holds the record with fifteen *C. mourlani* in a specimen of *Bohadschia argus*. Although no data were reported in the literature, the presence of sexual pairs suggests that sea cucumbers serve also as breeding sites. Sea cucumbers also act as developmental stimulators for some carapid larvae. In *Carapus* and *Encheliophis* species, the penetration inside a sea cucumber is followed by heavy transformations during which the fish length is reduced by 60 %.

The stomach contents (Trott, 1970; Murdy and Cowan, 1980; VandenSpiegel and Jangoux, 1989) and the musculo-skeletal descriptions of the buccal and pharyngeal jaws (Parmentier *et al.*, 1999, 2000a,b) have suggested different kinds of symbiosis depending on the species. Various authors have suggested that *Carapus* adults could be parasites (Arnold, 1953; Gustato, 1976; Trott, 1981), while others consider them as commensals, using their hosts as shelters and leaving them to hunt small preys such as annelids, crustaceans (shrimp, decapod, amphipod) and small fish (Trott, 1970; Meyer-Rochow, 1979; VandenSpiegel and Jangoux, 1989; Parmentier *et al.*, 2000a,b). They can also be cannibals, feeding on other carapids within their host (Parmentier, pers. obs.). In contrast, *Encheliophis* species are true parasites, feeding on the internal tissues of their host, mainly the gonads (Smith, 1964; Trott, 1970; Trott and Trott, 1972; Murdy and Cowan, 1980; Trott, 1981).

Some individuals are frequently found in the general cavity of holothuroids, implying a perforation of the respiratory tree or the stomach. This kind of injury, also occurring when the fish leaves its host, should be negligible as pearlfish do not always infest the same host. However, in a heavily infested population, chances that a given host is regularly infested increase; hence, repeated loss of coelomic fluid and successive wound repairs have to be considered (Jangoux, 1990). On the other hand, Cuverian tubules are never exuded and holothuroid eviscerations do not seem to occur at the time of pearlfish entry.

General considerations

Platyhelminthes, Mollusca and Arthropoda are the taxa that include the highest numbers of holothuroid parasites but low attention has been devoted to holothuroid-associated gregarines and it is very probable that the number of infesting species recorded in the future will be higher than that of metazoan taxa (Figure 6). The digestive tract (including the cloaca) is the body part that is the most infested (Figure 7) and gut-associated parasites are flatworms, molluscs and crustaceans. Most of them are living free in the digestive tract, gliding on the digestive wall. The symbiotic relations that they develop with the holothuroids are still not well understood and their parasitic status relies more on suggestions than on true experiments. The coelom of holothuroids is also commonly infested and other flatworms, molluscs and crustaceans live there as well as protozoan gregarines and carapid fishes. Other body organs and systems, such as the haemal system, ambulacral system, respiratory trees, gonads and body wall are less affected by parasites. The body wall, in particular, is mainly affected by gastropods.

Infestation of holothuroids by internal parasites takes place mainly through body openings (mouth and cloacal aperture). Intracoelomic organisms reach the coelom by passing through the digestive wall. Intracoelomic copepods enter the

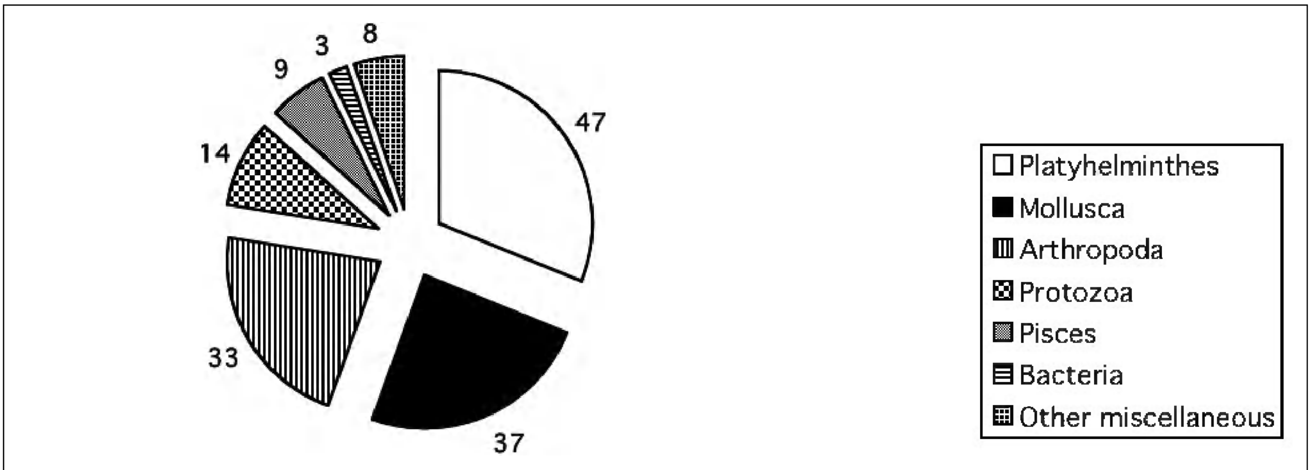


Figure 6. *Number of species per taxon infesting holothuroids.*

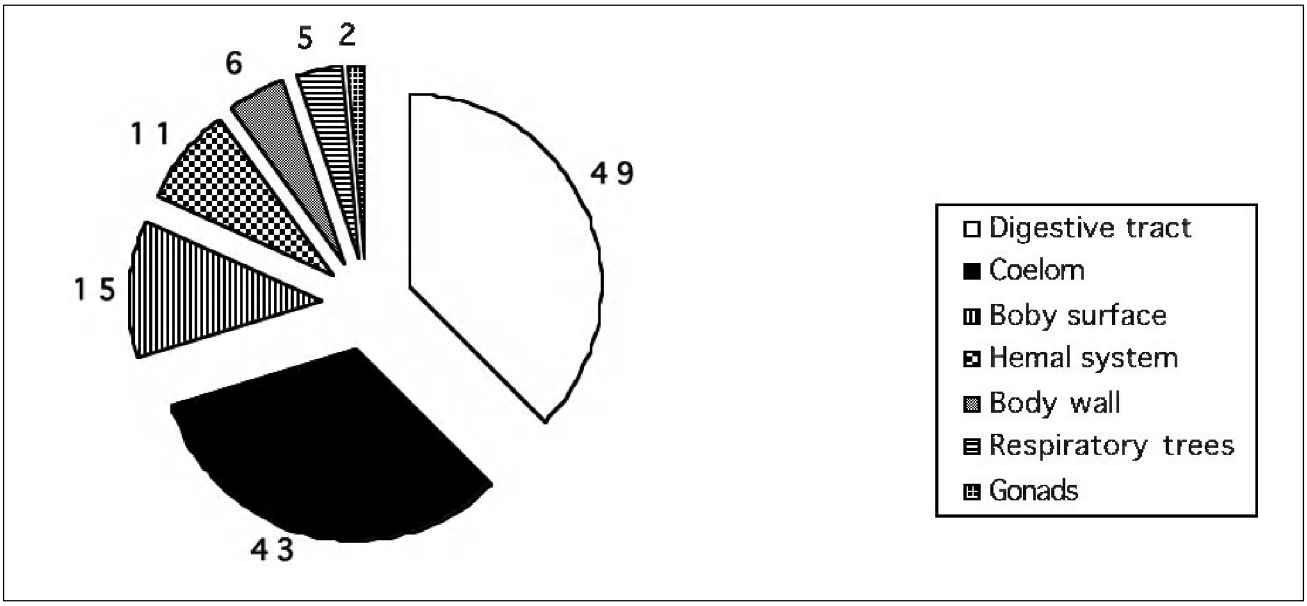


Figure 7. *Location of the parasites in the holothuroid body. When a parasite infested two body compartments, both have been included in the graph.*

coelom by penetrating the anterior part of the gut, larvae of most intracoelomic gastropods enter the coelom through the digestive wall and carapid fishes pierce the cloacal wall (Jangoux, 1990). Holothuroid reactions to parasites are of three types: (1) inflammatory-like reactions; (2) connective tissue reactions and (3) coelomocyte reaction (Jangoux, 1990). Inflammatory-like reactions consist of the migration of defensive cells (red spherules and coelomocytes) to the site of infection, and occur mainly with diseases caused by microorganisms. Connective tissue reactions counteract organisms such as gastropods that tend to stay within the connective tissue layer. Coelomocyte reactions are directed towards intracoelomic parasites and result in the phagocytosis or the walling off of foreign organisms.

All the protozoans and metazoans parasites currently described in scientific literature are not lethal for wild or cultured adult holothuroids. They are thus of no economic importance and their presence in or on adult holothuroids should not alarm the sea cucumber industrial stockbreeders. However, it should be emphasised that high densities of holothuroid populations could favour overinfestation by parasites, and thus influence some important parameters in farming such as the growth rate of individuals or the reproductive abilities of breeders. Most alarming are the infections of sea cucumber juveniles by bacteria that can eradicate nearly all individuals of cultured populations in a few days. Parameters that cause the appearance of bacterial diseases are poorly known, but it is possible that an increase in temperature and/or too high density of individuals in aquaria can favour the infection of individuals. The best way to avoid such bacterial disease is to constantly check the health of juveniles and to remove sick individuals. Juveniles that are not too infected can recover by treating them with a faint formalin solution in salt water for a few minutes.

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

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Abstract

Research into sea cucumber is a relatively recent field of interest for the aquaculture sector. There are only a limited number of reports on the feeding and growth of sea cucumber juveniles. The present paper summarizes the latest results on the nutritional requirements of *Apostichopus japonicus*. A first set of feeding experiments with juvenile sea cucumbers were conducted over 70 days using an artificial feed, mainly composed of fish meal, *Sargassum thunbergii* and lees (by-products from wine and beer production). Using chromium oxide as a marker, the authors determined that the weight gain rate and feed digestibility increased with the protein content of the diet. The optimal protein content was estimated at 21.5%. Based on a second growth experiment over a 40-day period, during which five different feed formulas were tested, the results indicated that the weight gain rate was maximal when the diet was rich in the following amino acids: threonine, valine, leucine, phenylalanine, lysine, histidine and arginine. Furthermore, the highest growth rates were obtained when the ratio between calcium and phosphorus (Ca/P) content ranged from about 6.8-8.8:1. On the other hand, the weight gain rate decreased when the sea cucumber juveniles were given a fibre rich diet.

Keywords: Nutrition, protein, amino acid, feed formula

刺参（*Apostichopus japonicus*）的营养需求与生长

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摘要

海参的研究是近年来水产界较为关注的事，但是，对海参摄食与生长的研究方面的报告较少。本文报道了近期对刺参营养需求的研究，实验是以鱼粉、鼠尾藻和酒糟等为主要成份的人工配合饲料喂养幼参，试验持续70天，以三氧化二铬作标志物质。实验表明：实验刺参的增重率和消化率随着饲料中蛋白含量增加而增加。最适的蛋白含量为21.49%。另一组试验对5种配合饲料进行了对比试验，实验进行了40天。结果表明，饲喂富含苏氨酸、缬氨酸、亮氨酸、苯基丙氨酸、赖氨酸、组氨酸和精氨酸饲料的刺参增重率最高。同时，饲料中Ca/P比达到6.78~8.80：1时，实验刺参得到较高的增重率。实验还证实，饲料中过多的纤维素含量不利于刺参的生长。

关键词：营养、蛋白质、氨基酸、饲料配方

Introduction

There are about 1 100 species of sea cucumbers in the world. Over 100 species are present in China of which more than 20 species are edible and of commercial value. These include *Apostichopus japonicus*, *Actinopyga mauritiana*, *A. lecanora*, *Holothuria nobilis*, *H. scabra*, *Bohadschia marmorata*, *Stichopus chloronotus* and *Thelenota ananas*.

The most valuable local species, *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 the sea cucumber 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 rapidly. 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 cover some 15 000 hectares and that a harvest of 2 250 tonnes can be expected.

In recent years, studies on *A. japonicus* have been focused on culture techniques in order to improve and expand the culture scale. Numerous diets were tested to optimise sea cucumber culture. However, there are very few reports available on the basic nutritional requirements for the optimal growth of this species. Most commercial feeds lack the essential ingredients to meet the nutritional requirement of this holothurian. The present paper summarizes the latest results on the nutrition and growth of *A. japonicus*. It is expected that these data can provide a scientific basis for the development of an improved commercial feed.

Materials and methods

Experiment No. 1 - Effect of protein content on the digestibility of food and weight gain of sea cucumbers

The influence of different proteins on the digestibility of the feed and growth rate of *A. japonicus* was tested. The experiment, over a period of 70 days, was conducted in an indoor concrete tank (4x6 m) in which 12 rectangular net-cages (90×80×100 cm) were placed for different experimental treatments. . Artificially bred juveniles of *A. japonicus*, obtained from the Penglai hatchery in Shandong Province, were used. The sea cucumber juveniles were randomly distributed in the twelve cages. The initial weight of selected individuals ranged between 4.5-4.8 g. They were distributed in groups of 30 individuals per cage. Four treatments were scheduled for the experiment. Each treatment had three replicates. During the experimental period the sea cucumbers were fed with four different diets once a day. The amount of feed administered equalled 3 % of the body weight. The tanks were aerated and the water temperature maintained between approximately 15 to 20 °C. The experimental feed formulas tested are listed in Table 1.

Table 1. *Diet composition and protein content.*

Components	Composition of diet (%)			
	Diet 1	Diet 2	Diet 3	Diet 4
Sargassum thumbergii	45	39	30	23
Fish meal	0	6	15	22
Lees	20	20	20	20
Mud	15.5	15.5	15.5	15.5
Kelp powder	7	7	7	7
Yeast	3	3	3	3
Vitamin	0.5	0.5	0.5	0.5
Mineral	0.5	0.5	0.5	0.5
Soybean meal	5	5	5	5
Bran	3	3	3	3
Chromium oxide (Cr_2O_3)	0.5	0.5	0.5	0.5
Protein content	*14.7*	*17.7*	*19.1*	*21.5*

The sea cucumber juveniles were acclimated to the four experimental diets for a month. After a month, faeces samples were collected by siphoning the particles from the tank bottom. The faeces collected were then centrifuged, dried in an oven at 65 °C for analysis. Both freeze-dried food and faeces were finely ground prior any analysis took place.

Crude protein content was determined by the Kjeldahl method. Crude fibre was determined by an automatic analyser (Fibertec, Tecator-Sweden). Amino acids were analysed using an automatic apparatus (Hitachi Model 835-50, Japan) with an ion exchange column. Chromic oxide was determined by a wet-acid digestion method (Furukawa and Tsukahara, 1966). The digestibility and weight gain rates were calculated as follows:

$$Weight\ gain\ rate = (W_{initial\ weight} - W_{final\ weight})/W_{initial\ weight}$$
$$Apparent\ digestibility\ rate = (1\text{-}dietary\ Cr_2O_3/fecal\ Cr_2O_3\ x\ faecal\ nutrient/dietary)\ x\ 100$$

Experiment No. 2 - Relationship between amino acid composition, Ca/P ratio and fibre content on the growth rate of sea cucumbers

The juvenile sea cucumbers used were artificially raised and were cultured in indoor concrete tanks. Seawater was maintained between 8-12 °C and was constantly aerated. Seawater in each culture tank was completely replaced daily during the 40-day experimental period. Each treatment had two replicates, in which 50 sea cucumber with an initial weight of 2.1 g were used. Table 2 shows the composition of amino acid in each experimental diet.

Table 2. *Composition of amino acid in five experimental diets.*

Amino acid	Composition (% - 100 g of the formulated feed)				
	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Asp	1.40	1.34	1.22	1.68	1.45
Thr	0.63	0.62	0.55	0.55	0.62
Ser	0.59	0.61	0.54	0.54	0.61
Glu	2.88	3.06	2.32	2.24	3.23
Gly	0.78	0.75	0.7	0.69	0.77
Ala	0.89	1.02	0.8	0.74	1.02
Val	0.91	0.94	0.85	0.76	1.00
Met	0.14	0.10	0.13	0.31	0.13
Ile	0.63	0.65	0.59	0.56	0.67
Leu	1.11	1.38	1.04	0.92	1.35
Tyr	0.19	0.21	0.00	0.00	0.15
Phe	0.63	0.72	0.54	0.60	0.66
Lys	0.92	0.77	0.79	0.73	0.83
His	0.18	0.20	0.18	0.15	0.19
Arg	0.75	0.69	0.63	0.71	0.71
Protein content (%)	*16.64*	*17.74*	*14.77*	*15.38*	*17.14*

Results and discussion

Experiment No. 1 - Effect of protein content

The weight gain rates of cultured sea cucumbers fed on different formulated feeds are shown in Table 3. Statistical analysis indicates that there is significant difference between the different treatments tested. The experiments suggest that the growth rate and digestion efficiency of cultured animals increase with the protein content. The highest growth rate occurred when food had a protein content of 21.5 %, which is consistent with the protein content in the meat of fresh sea cucumber. However, it remains to be tested whether further increases in protein content in the food will further increase the growth rate of cultured sea cucumbers.

Table 3. *Effect of protein content on food digestibility and growth of sea cucumber juveniles.*

Parameters	Diet			
	1	2	3	4
Protein content (%)	*14.7*	*17.7*	*19.1*	*21.5*
Digestibility rate (%)	40.6[a]	48.2[b]	55.8[c]	63.9[d]
Weight gain rate (%)	105.8[a]	113.8[b]	122.7[c]	145.6[d]
Survival rate (%)	93.3	98.3	90.0	93.3

Statistical significance was determined using analysis of variance and Duncan's new multiple range test. Values (mean of three replicate groups) in each column with a different letter are significantly different (P<0.01).

Experiment No. 2 - Relationship between amino acid composition and growth of sea cucumber juveniles

As shown in Table 4, the highest weight gain rates was observed with diet 1 and diet 5, in which there were high contents of both lysine and arginine which are also essential amino acids for fish and shrimp. Other diets yielded a slightly lower weight gain rates. The results obtained seem to reveal that lower content of lysine or absence of lysine can influence the growth rate of sea cucumbers.

Table 4. *The growth of sea cucumber during experimental period.*

	Experimental diet				
	1	2	3	4	5
Weight gain rate (%)	174.1	119.2	149.3	157.6	159.2
Survival rate (%)	100.0	99.6	98.5	100.0	98.0

Experiment No. 2 - Relationship between Ca/P ratio in the diet and growth rate of sea cucumber juveniles

The Ca/P ratio is a crucial factor influencing the growth rate of juvenile sea cucumbers. The results of Table 5 show that the highest weight gain rate was observed with Ca/P ratio ranging from 6.78 to 8.80. Sea cucumber fed with diet 1 and diet 5 grew faster than those supplied with diet 2, diet 3. Although the ratio of Ca/P in diet 4 is as high as 9.41, its growth gain rate is almost the same as that for diet 5. The Ca/P ratio in all diets is higher than that measured in the sea cucumber body (5.36). This value is also far higher than what is found in fish (Ca/P ratio values of common carp and red sea bream, *Pagrosomus major*, are 0.5 and 0.13, respectively, and that of juvenile shrimp is 0.59). From the results it appears that the optimal Ca/P ratio in a sea cucumber diet may be between 7 and <9. It is apparent that the growth gain rate of sea cucumbers is influenced by numerous factors and therefore a careful diet formulation is required to ensure optimal growth.

Table 5. *The effect of Ca/P ratio on weight gain rate of sea cucumber juveniles.*

	Experimental diet				
	1	2	3	4	5
Ca/P ratio	8.80	5.81	6.84	9.41	6.78
Weight gain rate (%)	174.1	119.2	149.3	157.6	159.2

Experiment No. 2 - Relationship between crude fibre content and growth of sea cucumber juveniles

The experimental results seem to indicate that the weight gain rates decreased with increasing dietary fibre contents (Table 6). So far no enzymes for digesting fibre have been identified and isolated from the digestive system of sea cucumber. The authors therefore conclude that crude fibre is not a necessary source of energy.

Table 6. The effects of fibre on the growth rate of sea cucumber juveniles during the experimental period.

	Experimental diet				
	1	2	3	4	5
Crude fibre content (%)	4.3	11.2	16.5	8.6	8.1
Weight gain rate (%)	174.1	119.2	149.3	157.6	159.2

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Breeding and rearing of the sea cucumber *Holothuria scabra* in Viet Nam

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Abstract

The aims of this project were to develop large scale breeding and rearing methods for sandfish *(Holothuria scabra)* for commercial culture and/or restocking. Wild collected sea cucumbers were initially difficult to spawn, but after a period in earthen ponds or seabed pens could be induced year-round, using temperature changes, emersion, treatment of water with UV light, and addition of dry phytoplankton. Numerous batches of larvae were reared to settlement and to larger sizes using simple hatchery methods.

Juveniles produced in indoor hatchery tanks (mostly below 3 mm in length) were nursed outdoors to a few grams, or tens of grams, in two or three stages. Nursery methods were tested in different kinds of tanks, earth ponds (sometimes using fine-net bags or hapas), larger bag nets and pens inside ponds, and in the sea using various seabed cages, covers and pens. Both monoculture and polyculture nursery trials (with the shrimp, *Penaeus monodon,* or the babylon snail, *Babylonia areolata*) were carried out.

Nursed juveniles were grown out in ponds, pens and cages. Growth was often rapid, in the range of 1-3 g/day. At best, growth in a pond from 30 to 300 g took only 3 months. Hatchery-produced sandfish from ponds were spawned at less than one year of age, and several batches of their progeny were produced. Big pens (up to 2 000 m²) were built in marine protected areas and stocked with hatchery-produced sandfish, to test their potential as alternative income sources for local fishermen. Pens proved cheap and effective for broodstock ripening and for ongrowing.

Constraints to commercial 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 150-300 g/m²), high variability in survival rate at many stages, predation pressures (including by shrimp), the need to guard pens against theft and problems of pond management. Positive factors include the wide temperature and salinity tolerance of sandfish, ease of containment, good growth in ponds and pens without added feed and the belief that sandfish may help clean the pond floor or seabed of organic wastes from other aquaculture activities.

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

Keywords: Hatchery, nursery, culture, pond, pen, sandfish

越南糙海参（*Holothuria scabra*）的育苗和养殖

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摘要

该项研究的目的是为了开展大规模养殖糙海参（Holothuria scabra）和资源增殖。刚从海里捕捞来的亲参难以诱导产卵，但是在池塘中或是在设于海里的网围中暂养一段时间后，采用水温变化、干露、紫外线照射的海水处理，以及用浮游藻类的干粉诱导等措施都可以使之全年产卵。利用简单的育苗设备就可以得到大批量的幼虫，并培养到大规格幼体。

在室内育苗池内育成的稚参（大部分在3毫米以下）移到室外，经历2-3个阶段，养到几克，甚至几十克。做了不同的室外暂养方法实验，有不同规格的水池、土池（有时用小网目的网袋，或用网围）、大网袋和网围等，设在海里的网箱有的加盖，有的不加盖。还进行了单养，以及与斑节对虾（*Penaeus monodo*），海螺（*Babylonia areolata*）混养的实验。

经过暂养的大规格幼参移到池塘、网围和网箱中养殖。生长速度很快，日生长率约1-3克/日。在池塘中养殖的个体，只用3个月的时间就由30克长到了300克。在池塘中养成的海参，大约一龄可以达到性成熟，并已生产出几批幼参。网围（约2 000 m^2）被设置在海中避风浪的地方，投放人工苗种，目的是为当地渔民寻找其他生财之道。网围是一种可取的方式，既可用来暂养亲参达到性成熟，又可用于海参养殖。

影响海参养殖的负面因素主要有：中间商的出价太低，暂养和养成需要较大面积（当放养密度超过150-300克/ m^2 时，海参生长速度下降），在不同生长时期造成高死亡率的因素难以确定，捕食动物的危害（包括虾类），以及防范偷盗和其他管理上的问题。有利因素包括该种海参对水温、盐度有较强的抗性，不易逃逸，在不投饲料的情况下可以在池塘和网围中良好生长，并且在养殖过程中，有助于清除池塘或海底的有机废物。

糙海参的资源状况尚未开始调查，仅仅放流过少量人工苗。已被过度开发的海参资源，由于生活史的不同阶段受到干扰，而影响到它的自然恢复。这就需要对可能存在的种种因素有较深入地理解和进行实验，包括放流人工苗种。希望于此介绍的情况，如生长率、密度、性成熟年龄和全年生产幼苗等具有参考价值。

关键词：育苗、暂养、养殖、池塘、网围、糙海参

Introduction

The pioneering breeding work of Dr James in India (James *et al*., 1994), and subsequent research by Battaglene *et al*. (1999) and Mercier *et al*. (2000) in the Solomon Islands, showed that sandfish, *Holothuria scabra*, is one of the most promising sea cucumber species for aquaculture. It has a short larval phase, relatively high tolerance of changing environmental conditions, and can be processed to produce high-value beche-de-mer (FAO, 1990; Hamel *et al*., 2001). However, despite anecdotal accounts of commercial-scale sandfish culture (Battaglene, pers. comm.) little is known about the extent to which this species has been farmed, or whether past attempts at growout have been based on wild-caught or hatchery-bred juveniles.

Several authors deal with the spawning and larval rearing of sandfish in the hatchery (James, 1996; Hamel *et al*., 2001) and early nursery phase until they reach a size of a few grams (Battaglene *et al*., 1999; Hamel *et al*., 2001). However, information on subsequent growth rates is scarce, although Shelley (1985) estimated natural growth in Papua New Guinea at about 14 g/month by following cohorts identified from size-frequency measurements and Mercier *et al*. (2000) reported an average size increase of 300 %, from 65 to 197 mm, in 2 months after releasing laboratory reared juveniles in the Solomon Islands. There is also little information on practical systems for producing large quantities of bigger animals. The aims of this project, therefore, were to address these gaps and to develop systems of mass rearing for sandfish to help assess the potential for commercial culture and/or effective restocking of depleted marine areas.

The research described here is a collaborative project between the Viet Nam Ministry of Fisheries and the WorldFish Center (formerly ICLARM). It was done in Khanh Hoa Province, Viet Nam, where there is an important seafood and aquaculture sector. This area was selected because large numbers of shrimp ponds and hatcheries have been built there and many other forms of aquaculture, e.g., cage-culture for spiny lobsters also occur in the area. The existing infrastructure and aquaculture activities assisted the authors to develop and test methods for farming sandfish in shrimp ponds, either as an alternative crop or in polyculture. Shrimp disease problems here, as in many other countries, mean that ponds are often left empty and farmers are interested in new aquaculture species and management systems. The cage and pen-based culture industry also offered opportunities to test grow-out methods directly on the seabed.

One potential problem facing the project initially was the reported scarcity of sandfish in the Province. Of the four major bays along the Khanh Hoa coastline (Van Phong, Nha Phu, Nha Trang and Cam Ranh) sandfish were thought to occur only in Cam Ranh. Elsewhere, it was believed that they had been fished to local extinction and that none had been caught in the past decade or so. This turned out to be incorrect. Small-scale commercial landings were still being made in Van Phong, and a few sandfish were found in the Nha Trang area. In Cam Ranh, commercial fishing was still continuing, and some farmers also try to rear small collected sandfish to larger sizes in ponds. A strip of land 300 m wide along the eastern side of this bay, which is closed to fishing by the military, may have helped to keep stocks in better condition there than elsewhere.

Methods and results

Experiments with collected sandfish

Sandfish were bought for broodstock from dealers in Cam Ranh, about 60 km south of Nha Trang. They were small, typically averaging between 150 and 200 g. These individuals could only be spawned once (in February) during the first year. After some months of ongrowing in sandy ponds they had increased their weight to an average of 260 g. Lacking hatchery produced juveniles (or wild sandfish below about 70 g) there were limits to the tank trials that could be done in the first year. However, trials were possible in constructed pens and rented ponds and data were collected from wild sandfish (Pitt *et al.*, 2001).

Very short-term growth trials are rather inaccurate because weight is difficult to ascertain accurately. There was a weight loss of about 4 % on drying adult sandfish for 15 minutes and similar changes due to voiding sand contents over 2-3 days. However, individual short term weight fluctuations, due presumably to changes in the amount of water held inside the body cavity, were often several times larger. These were sometimes caused by conditions during short term storage or transport. Overcrowding in bags or baskets led to swelling by 10-20 % or even more. Sometimes the causes were unknown, perhaps linked with salinity changes.

Sandfish in bare tanks, fed on shrimp pellets or unfed, all lost weight, with animals in the fed tanks losing weight more rapidly than those that were unfed. In tanks with sand, weights were maintained, with little difference among sandfish fed with different diets, i.e., chick feed or wheat flour mixed with shrimp pellets, with algae *Gracilaria* sp., or sea grass. Another interesting observation is that a wide range of finely ground vegetable materials were eaten and defecated, without apparent change of form or colour.

In ponds, sandfish grew at about 1-3 g per day, showing an inverse relation with stocking density. Two attempts to look at different densities and different substrates were cut short by major mortalities caused by heavy rain and stratification. However, there was some indication of a negative density effect and slight advantage of sandy over hard or muddy substrates.

Seabed pens proved useful for holding small numbers of sandfish. Survival was generally very good. Growth rates appeared lower than in ponds, and depended on both location and density.

Spawning and larval rearing

A pen of 800 m² was stocked with 392 wild sandfish (average weight of 138 g) in July 2001. These were used regularly as broodstock. After 16 months, the remaining 203 sea cucumbers had to be maintained at higher densities due to relocation of the pens on the farm where the work was done. Hatchery produced second generation broodstock were stored nearby in a 450 m² pond.

After further rearing in ponds or pens, broodstock became much easier to spawn. As well as being bigger, they may secrete some chemical to coordinate gonad maturation between themselves, as found for the sea cucumber *Cucumaria frondosa* (Hamel and Mercier, 1999). In New Caledonia, it was also observed that even very large, newly collected sandfish were difficult to spawn. Individuals that had been held in a pond for some months were easier to induce to spawn. Although newly collected wild sandfish were generally used with relative success for spawning in Solomon Islands these had often come from dense lagoon populations.

Groups of 30-45 individuals (average weights 250-415 g) have been spawned on a regular basis since the end of August 2001, and once or twice every month from March 2002 to August 2003. Over a 24-month period, 40 broodstock groups were used and underwent spawning stimulation attempts on 71 occasions. Spawning occurred on 38 of these, producing 275 million eggs. The percentage of successful attempts did not show a clear cycle by time of year (Figure 1), but the average production of eggs (per gram of total spawning group weight) was higher from December to April than at other times (Figure 2). Similarly, although there was no marked difference between the success rate of spawning attempts at different times in the lunar month, there was a higher production of eggs around the new moon than at other times (Figure 3).

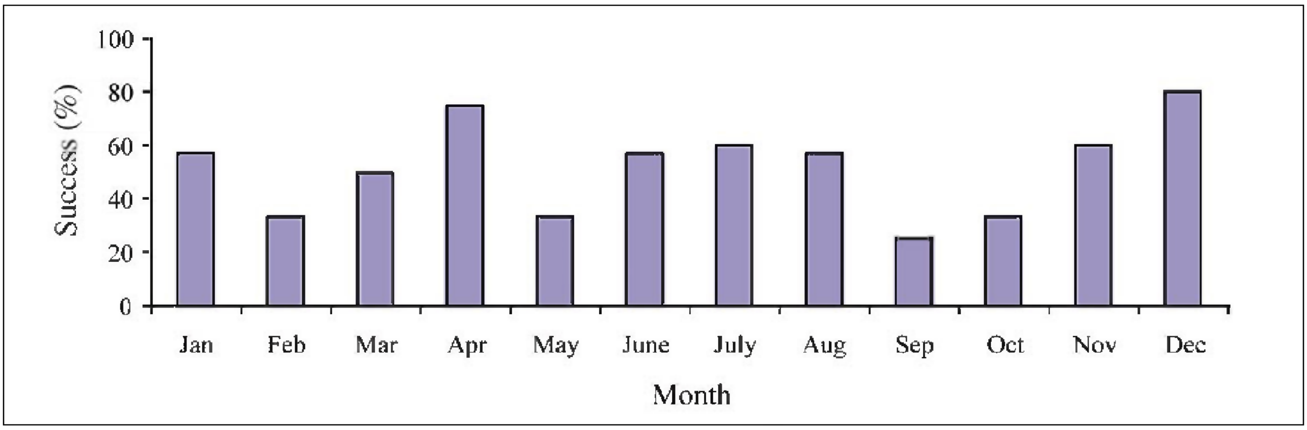

Figure 1. *Percentage of group spawning stimulation attempts which were successful, by month. Groups contained 30-45 adult sandfish.*

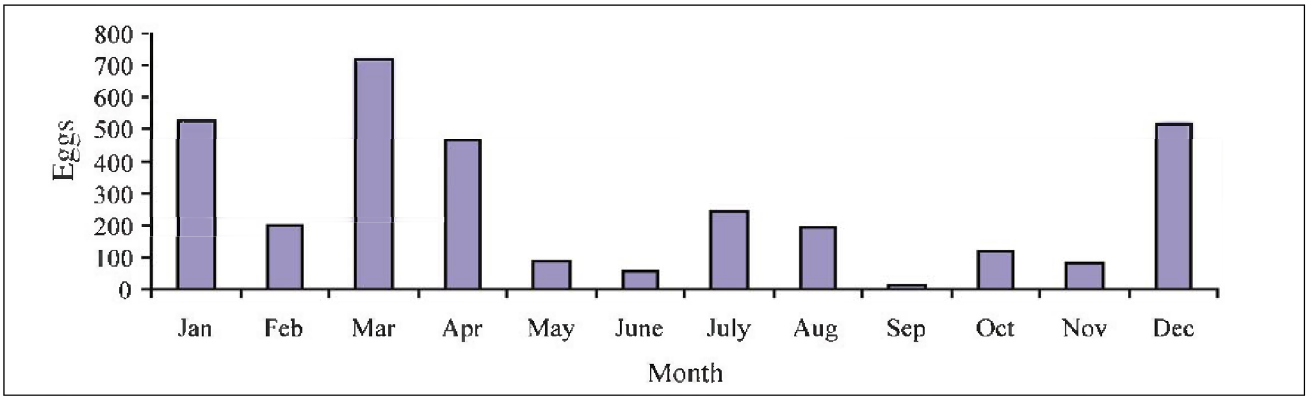

Figure 2. *Monthly average number of eggs per gram of adult sandfish per group of 30-45 adult sea cucumbers.*

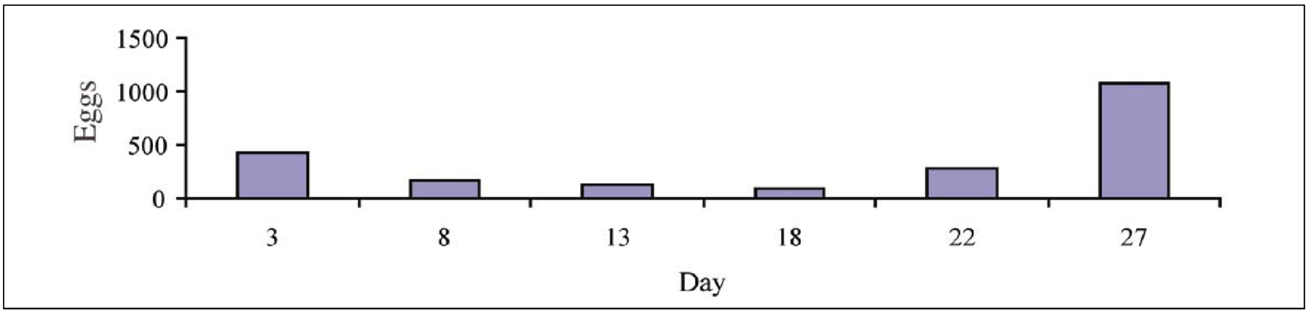

Figure 3. *Average number of eggs per gram of adult sea cucumber per group of 30-45 individuals, by day considering the lunar cycle. (Lunar day 3 refers to the central day of the 5-day period 1-5, day 8 to the period 6-10, and so on, except for 18 which refers to the 4-day period 16-19).*

After transportation (using battery aerators or oxygen-filled bags), broodstock were usually left for a few days in a shallow bare 1 m^3 fibreglass spawning tank. During this time, they voided sand from their digestive tracts. They were sometimes fed with dried grounded *Sargassum* powder. Broodstock were returned to their pen or pond a few weeks later, generally after 2 or 3 spawning stimulation attempts. A new group of broodstock was collected.

On the morning of a spawning attempt, broodstock were subjected to a range of stresses. These usually included complete or partial drying in shade for 30-45 minutes. This was followed by a slow flow of sun-warmed water at about 5 °C above ambient, often passed through a UV unit. Sometimes ice was used before or instead of drying, to give a cold shock of about 5 °C below ambient before the hot shock. Occasionally, instead of being left dry, the sandfish were subjected to water jetting, or left standing in a couple of centimetres of water. If they were not already spawning at midday, powdered algae (*Spirulina*) were often then added to the water in the tank (30 g in 300-500 litres). If successful, spawning would usually occur between 1300 and 1600 hours and only rarely at night. Sometimes excess spawning males were removed from the spawning tank, but females were not disturbed. Contrary to what was usual in the Solomon Islands, female sandfish often stopped spawning if moved, and failed to start again.

Fertilization occurred inside the spawning tank. Eggs were siphoned out of the tank into a 50 µm mesh bag and washed in filtered seawater to remove excess sperm and powdered algae. Aliquots from stirred buckets were counted and the eggs were stocked in hatchery tanks. Hatching, larval rearing, settlement and early juvenile rearing were usually all carried out in the same indoor fibreglass or concrete tanks of 1.7-6 m^3. Hatchery seawater was sand filtered, stored briefly in a reservoir tank and then passed through (nominal) 1 µm filter bags or cartridges. Partial water changes of about 15-30 % per day were made using a 100 µm mesh outlet screen. EDTA was routinely added after water changes at a rate of about 5 ppm of the added water.

Larvae were fed with algae from open outdoor batch cultures. *Chaetoceros muelleri* and *C. calcitrans*, *Nanochloropsis occulata*, *Platymonas* sp., *Isochrisis galbena* and *Rhodomonas salina* were used as available. The algae were given twice daily, at gradually increasing concentrations. Feeding rate was judged by the colour of the water in the rearing tank, since it was difficult to count residual algal cell densities. Tank floors were sometimes cleaned by siphoning after hatching and during early larval rearing.

At the start of metamorphosis, preconditioned stacks of plastic plates (PVC, polythene or polypropylene) were added to the tanks. Several conditioning systems were tried. These included painting plates with dry algae and allowing the plates to air-dry, immersing them in benthic diatom cultures (*Navicula*, etc.) or in *Platymonas* cultures for a few days, or immersing them in running unfiltered seawater for a few days, with or without the addition of chemical fertilizers. All the materials and conditioning systems worked quite well and gave good settlement results on at least some occasions. Conditioning in running seawater was simple, requiring only that plates be put into a conditioning tank 5-7 days after spawning, while painting with *Spirulina* (1-2 g dry algae/m^2) had the advantage that unwanted organisms would not be introduced.

After settlement, live algae were supplemented with algal powder, mainly *Spirulina*, sometimes with added *Schizochytrium* (Algamac, 2000). Depending on temperature, most larvae metamorphosed and settled (or died) within 10-20 days of spawning. Pentactulae and juveniles were usually left indoors (in the same tanks) for a further 2 to 10 weeks, depending on the availability of outdoor tanks for first nursery. Many had by then become juveniles of 1-2 mm in length, although both much larger and many smaller individuals could usually be found, as growth rates were very variable.

Despite filtration, copepods were able to multiply in the hatchery tanks. Heavy infestations destroyed good batches of settled juveniles within a few days, whether due to direct attack or to repeated collisions causing skin damage. On plates with a thick coat of benthic algae, the juvenile sandfish seemed to be somewhat protected. Treatment with the organophosphate insecticide Dipterex (trichlorofon) at 1-3 ppm for 1-3 hours, followed by rapid dilution to about half or one-third the concentration was usually effective in killing swimming stages of the copepods, but not the eggs. Over the years, treatment rates to kill most copepods had to be increased. It is not clear whether this was due to development of resistance, chance infestation with less sensitive species, or a drop in strength of the insecticide as sold.

Juveniles were transferred outdoors by moving the plate stacks on which they had settled, by siphoning the floor (into a bowl or onto a sieve), or by draining and hosing down the tank walls and floor. Juveniles could be separated from dirt by their rapid attachment to clean plastic surfaces, or by catching and washing on a 250 µm mesh screen. Potassium chloride detachment was not used.

Numbers at transfer were estimated either by direct total counts on plates or in bowls, or by counting random samples of known area. Very small juveniles were sometimes re-suspended in a known volume and aliquots counted under a microscope. Overall, survival in the indoor hatchery tank was very variable, but rarely more than 1-2 % from egg to transfer outdoors. Much higher rates of survival through the larval period, and during settlement, were sometimes found in small-scale trials (in tanks, buckets or jars), but over shorter periods.

Complete or partial collapses in the first few days of larval rearing were not uncommon, sometimes with the appearance of mucus strings to which the larvae became attached. Trial use of antibiotics (erythromycin) gave mixed results; positive in jar trials, but negative in tanks. There may be improvements to be made by controlling spermatozoa levels at fertilization, better egg handling, more frequent chlorination of hatchery water supply pipes, different levels of water exchange, use of separate incubation, larval rearing and settlement tanks or earlier transfer outdoors. Tanks were not usually cleaned at all after settlement to avoid loss of juveniles.

Outdoor batch algae cultures were not always reliable. *Chaetoceros muelleri* (or other *Chaetoceros* spp.) and *Rhodomonas salina,* perhaps the best algae for larval culture (Battaglene, 1999), were often in short supply or unavailable when needed. Sometimes the 'weed' species, *Nanochloropsis occulata* and/or *Platymonas* sp., formed the main food source.

Complementary research on larval rearing of sandfish being undertaken by students at the Research Institute for Aquaculture No. 3 is also contributing to knowledge about hatchery methods. A summary of this research is included here with the permission of the people involved. Do Thanh Tam examined the effects of transferring larvae to clean tanks prior to introduction of settlement plates. Eight indoor tanks were stocked with 0.7 larvae/ml in 200 litres of water (140 000 larvae/tank), after 2 days incubation in a separate hatching tank. Half the tanks underwent high water changes (40 % every day) and half low water changes (20 % every second day). On day-9 after spawning and before settlement had started, larvae from half of the tanks were transferred to clean tanks containing settlement plates which had been painted with a *Spirulina* slurry (1.5-2 g/m² dry matter) and air-dried. Larvae from half of the tanks were not transferred but *Spirulina*-painted plates were put into the rearing tanks (which is the more usual procedure). Twenty days after spawning, estimates of juvenile numbers were made by counting randomly selected sample areas of the plates and tank surfaces. These varied from 3 600-19 500 per tank. Two weeks later all remaining juveniles were counted for stocking in first nursery tanks. Numbers had dropped by about 43 % in this period. There appeared to be no advantage in transfer before settlement, but high water exchange was better than low. The best tanks had over 10 % survival from newly-hatched larvae to juveniles, and produced more than 70 000 juveniles/m³.

Le Thi Thu Huong investigated the effects of salinity on survival and growth. Larvae were stocked two days after spawning had occurred in normal seawater at the rate of 0.54 larvae/ml in 5 litre buckets indoors, at salinities from 15-40 (3 replicates of 6 salinities). Adjustment of salinities took several hours, at 2 units per hour. Buckets had light aeration and near-opaque covers. Larvae were fed live algae, usually 50 ml *Chaetoceros* sp. daily, and 20 % of the water was changed every second day. At metamorphosis, *Spirulina*-painted plates were inserted in the buckets, and feeding was supplemented with dry *Spirulina* and Algamac. Twenty days after spawning, juveniles on the plates and bucket surfaces were counted. All larvae died within 3 days at a salinity of 15, but metamorphosis and settlement were achieved in salinities from 20-40, with survival rates of recently-hatched larvae to juveniles at up to 44 % (at a salinity of 35).

Le Thi Thuy tested the effects of different feeding regimes, including dried algae. Larvae were raised in 5 litre buckets, stocked and managed as above, using 5 feeds with 3 replicates. Some buckets received live algae, usually 50 ml/day of *Chaetoceros* sp. or 10 ml/day of the stronger *Nanochloropsis occulata* culture. The other buckets received 5mg/day of the dry feeds; Frippak micro-encapsulated shrimp larval diet (unfortunately old and in poor condition), *Spirulina* powder, and a mixture of 1 part *Spirulina* and 1 part Algamac 2000. Average survival rates to the juvenile stage for the different feeding regimes were *Chaetoceros* 24.8 %, mixture 12.7 %, *Spirulina* 4.9 %, Frippak 3.8 % and *Nanochloropis* 0.36 %.

As eggs were abundant, nursery and grow-out facilities were more of a production bottleneck than low hatchery survival. Often, because all the nursery tanks were full, juveniles were kept in hatchery tanks long past the time when they were ready for transfer. Their growth slowed and numbers gradually dwindled. The 30 m^3 hatchery could supply far more 1-2 mm juveniles than the 250 m^2 of nursery tanks could support. It is estimated (Pitt and Duy, 2003) that a hatchery of this size in the tropics should be able to supply over 1 000 m^2 of nursery tanks (or hapas and bag nets in ponds), 1.5 ha of nursery ponds and 12 ha of grow-out ponds or pens, to produce 100 tonnes live weight of sandfish per year.

First nursery in tanks

Outdoor first nursery tanks were of 0.5-1 m depth and 0.6-16 m^2 floor area. Inner surfaces were fibreglass, flexible PVC-cloth liner or concrete. They were usually bare, without any added sand. Stocking rates were generally 500-1 500/m^2. Different tank pre-conditioning methods, additional substrate, shade levels, flow rates, water treatments and feeding systems were investigated, some in controlled trials.

Tanks were generally pre-conditioned for a few days using flowing unfiltered water. Dry algae or fine grade shrimp starter feed were usually fed to tanks at a rate of not more than 0.5 g/m^3, twice a day. This was occasionally supplemented by live phytoplankton when available. All tank materials were satisfactory but very small tanks (about 300 litres) did not give good results. It appeared that water should be at least 60 cm deep. Square fibreglass tanks of about 1.6 m^2 surface area and 60 cm depth were useful for experiments. Bigger PVC-lined pools of 10 m^2 and 70 cm depth, or concrete tanks of 6 m^2 or more and 1 m deep, were better for production.

Quite heavy shading seemed to be helpful in the first weeks of first nursery; later it could be reduced. Unfiltered seawater gave better results than filtered sea water, and high flow rates were better than low rates. There was no clear advantage in putting in additional surfaces such as seagrass (*Enhalus* sp.), additional plate stacks or roofing tiles. Small juveniles appeared to avoid the brighter and more open parts of tanks until they attained adult skin colouration. After 1-2 months, yields from first nursery tanks were typically about 100-300 juveniles/m^2 of a wide size range, from very small (less than 0.1 g) up to 2 g and more. On occasion, as many as 500 juveniles/m^2 were obtained with survival up to 50 %. Quite often, however, the survival was much lower and for unknown reasons.

First nursery in ponds

Small juveniles were only transferred directly into a pond once as they disappeared without trace. Total mortality also occurred when small juveniles were placed in a hapa (a 2x2x1 m bag made of 450 µm netting) installed on a raft in a sheltered bay and stocked with post-hatchery individuals of 1-3 mm.

However, the use of hapas inside ponds has given some very good results. Juveniles were transferred either out of water on their 40x50 cm settlement plates separated by damp *Gracilaria* in a styrofoam box, or without plates in oxygen-inflated bags of seawater, with transfer times of 1-2 hours. Newly-installed hapas were stocked (without conditioning), small quantities of *Gracilaria* were added and a few lengths of coconut leaf put inside for shade. Juveniles were not fed and the netting was rarely cleaned.

The initial five trials of these first nursery batches in hapas (carried out without any tank comparison) gave extremely good results. The best survival was 97 % and the average was 56 %. This was better than had been achieved in tanks. Growth too was good. Nursed juveniles of 1 g mean weight were produced after an average of 41 days.

Two trials were run to compare first nursery in hapas with small fibreglass tanks of 1.7 m^2 floor area and 60 cm depth. Small larvae (mostly of length 1-2 mm) were taken from the same hatchery tank on the same or following days. However, in the first trial mean survivals were 31 % for 4 tanks compared with only 26 % for 3 hapas. In the second trial, survival was very low: 19 % for 4 tanks and 13 % for 3 hapas. Mean sizes after 6 weeks were 0.5 to 0.8 g, with no clear difference between rearing systems.

Part of the problem with the latter two trials was that ponds were being used for multiple batches of sandfish of different sizes at the same time, in bag-nets, pens and the main body of the pond. Therefore, they had not been dried for many months and appeared very eutrophic. Consequently, the hapa meshes clogged and the hapa floors became muddy with low dissolved oxygen levels. Another drawback was the short life of the mesh used when exposed to sunlight. Nevertheless, the use of hapas in shrimp ponds is considered to have many benefits as a method to get around the considerable cost of pumping water to onshore tanks to provide the conditions needed for first nursery.

Blocks of small independently manageable ponds could be very valuable for nursery work at all stages. Ideally, they should have sandy floors and be in a location where salinity can be kept above 20 in the wet season. An aeration system would also be useful to keep pond floors from becoming anaerobic and break up any stratification caused by rain.

Second nursery

Juveniles from the first nursery bare tank system were usually sorted by size and stocked in outdoor tanks for a second nursery period. These tanks were supplied with a thin layer (3-5 mm) of fine sand on the floor. They were generally unshaded. Numerous experiments were run to look at the effects of flow rate, substrate type, density, diet, shading, water filtration and co-culture with shrimp during the second nursery stage.

Complementary research on feeding during the first nursery phase has also been done by Mai Van Dinh (unpublished data). This experiment used 15 (lightly shaded) outdoor tanks of 0.57 m² with sand on the floors and a water flow of about one exchange per day, in which 30 juveniles of about 0.77 g average weight were stocked per tank and fed 0.5 g/day of different dry diets (5 diets, 3 replicates). They were weighed every 2 weeks. Fine shrimp starter food supported faster growth than (a) the same shrimp food mixed with *Spirulina* and powdered seaweed; (b) 'five-powder' (consisting of finely-ground corn, rice, soybeans, black and green beans); (c) chicken manure; or (d) those left unfed (Figure 4).

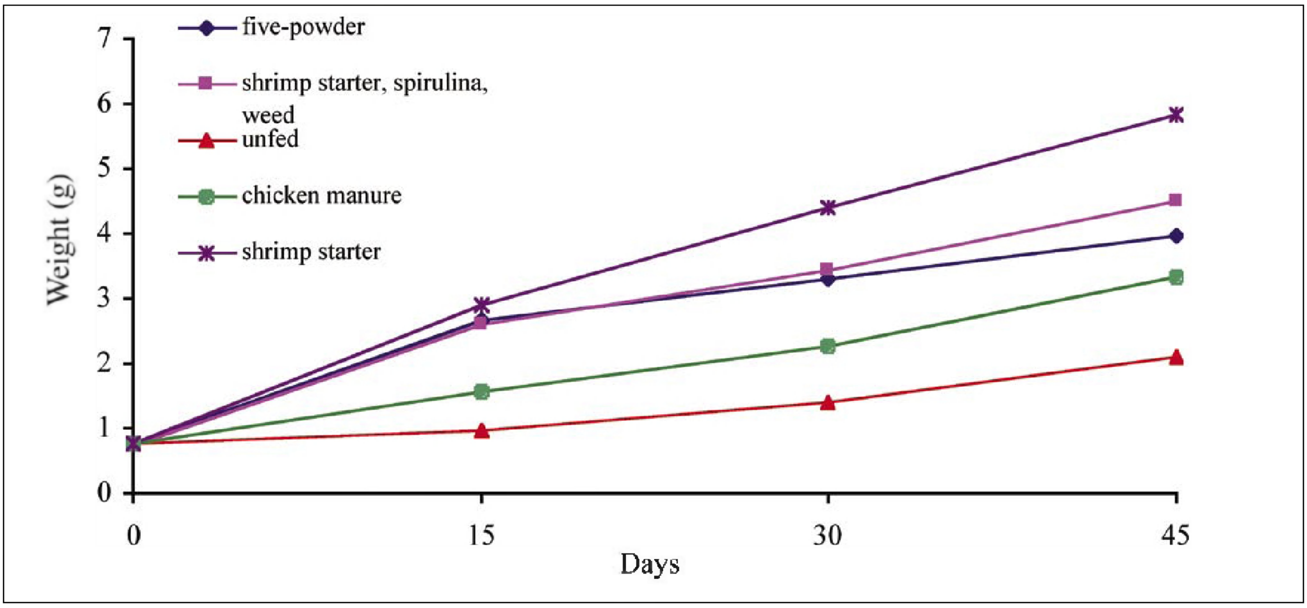

Figure 4. *Growth (average weight) of juvenile sandfish fed with different dry diets during the second nursery stage.*

A factorial trial in 16 outdoor tanks (1.7 m²) was designed to assess the contributions of supplied food, development of food organisms inside the tank based on photosynthesis and incoming suspended particles as food sources. It compared growth with added food (0.6 g/m² twice daily of fine shrimp starter feed) or without feeding with flows of filtered or unfiltered water (exchanging about half the tank volume per day) and with opaque or clear covers on the tanks. Tanks were stocked with 35 juveniles each (average weight 2.1 g), which were weighed every 2 weeks. It turned out that both feeding and light were necessary for good growth (Figure 5). After 6 weeks of these treatments, all tanks were given food, unfiltered water and light for another 4 weeks and growth recovered in most of the tanks that had been held back.

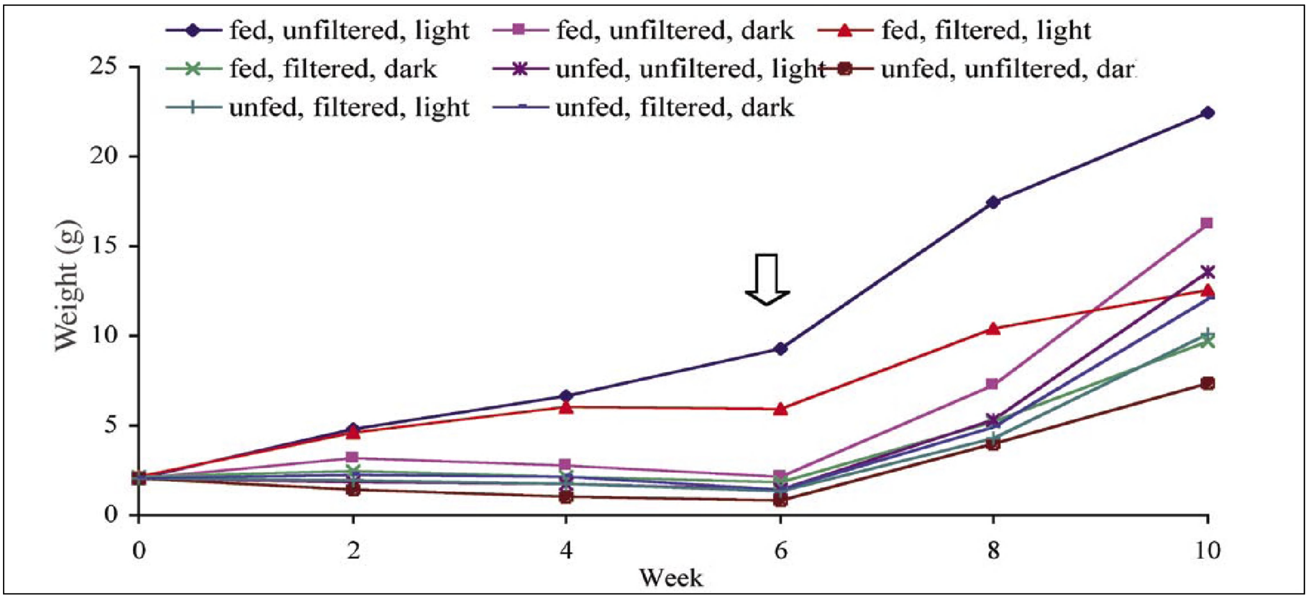

Figure 5. *Growth of juvenile sandfish under different rearing combinations of fed (shrimp starter) or unfed, unfiltered or filtered water, light or dark. After six weeks, all tanks were given optimal conditions (arrow); i.e., fed, unfiltered water and light.*

Culture with *Penaeus monodon* shrimp post-larvae (80/m^3) often produced improved growth for the sandfish without appearing to harm the shrimp. However, there were also cases of mass losses of the sandfish, particularly with high densities of larger, underfed shrimp. First, some flat or bitten sandfish were seen then, within a few days, all the sandfish would die or vanish. There was no doubt, both from tanks and from aquarium observations, that under some circumstances *P. monodon* shrimp will prey on juvenile sandfish. A release of hatchery-bred megalops larvae of swimming crabs (*Portunus pelagicus)* into a second nursery sandfish tank resulted in similar patterns of damage. The crabs developed well, but survival of sandfish was low. In aquaria, small rabbitfish (*Siganus* sp.*).* under consideration as tank cleaners also appeared to cause the death of sandfish juveniles.

Juveniles from harvested hapas in ponds were transferred to larger bag-nets inside ponds. These were 4 x 4 m or 6 x 6 m square cages of 1.2 m height, made from a cheap 1 mm mesh. They gave good protection against potential predators (shrimp, fish and crabs) and dissolved oxygen levels on the bag-net floor were often higher than on the pond bottom. Survival and growth could be good; in one case 96.5 % of 1.2 g juveniles reached an average weight of 13.6 g in 2 months, at a high density of 460 g/m².

Later nursery and ongrowing in pens and cages at sea

A trial was conducted together with the Hon Mun Marine Protected Area Management Project on the largest island (Hon Tre) of Nha Trang Bay. Two sites were chosen, after discussion with local fishermen as being apparently suitable for sandfish. At each site a nearby resident agreed to observe and guard the pens. The first site (Bich Dam) was inside a very sheltered bay in water of 1.5 - 2.5 m depth, with sandy-silt substrate, a little coral or coral rubble and some seagrass. The second site (Vung Ngan) was more exposed to the south, in water of 4-5 m depth, on a substrate of sand with some rocks and coral sand. Although big seas were rare here (with fishing boat moorings and lobster cages in the immediate vicinity), there were often quite noticeable water movements, even close to the seabed.

Four open pens were constructed at each of the two sites by building fences standing 80 cm high off the seabed. The fence bottom was buried in the substrate and pegged down, with sandbags arranged around the edge on top of the pegs. Each pen enclosed an area of 46 m². Some pens were stocked more than once.

Even in the more sheltered location, survival of small juveniles (2.3 or 6.3 g average) was poor. Two batches disappeared within a month, while only 18 % of a third batch reached 200 g average after 9 months. Most small juveniles disappeared within the first few weeks. Wounded, bitten or flat (eviscerated) juveniles were found, similar in appearance to those from tanks containing shrimp or swimming crabs. Survival of bigger juveniles (18 or 32 g) was fair, with 70-82 % averaging 140-220 g after 6-8 months. In the more exposed location, survival after 3 months again appeared to depend on release size. Recovery was zero for the juveniles stocked at 4.9 g average weight, 3 % for those stocked at 11.4 g, 11 % at 30.4 g and 50 % for those stocked at 50.6 g. However, after about 4 months none of the sandfish were found, due perhaps to wave action or to theft.

Seabed cages used for culturing babylon snails were tried for rearing small (nursed) sandfish juveniles. Rigid cages consisted of 2 m x 2 m x 30 cm steel frames covered on all six faces with 1 mm or 3 mm plastic mesh. Hinged doors in the top surfaces allowed access. The floors lay directly on the seabed and sand was added to cover the netting. Each cage was stocked with 50-200 juveniles. Survival after 2 months was above 50 % for juveniles of average initial weight 1.5-6.3 g, even in a cage with babylon snails. There was good growth to 8.7-31.6 g, depending on initial size and density. However, for the smallest (0.5 g) juveniles only 24 % were recovered. Babylon snail farmers commonly use cages or pens with netting walls rising above high water. Cage floors are usually covered with sand, while pen walls are buried and pegged down in the seabed. The smallest mesh is usually about 4 mm knot to knot. Sandfish were supplied to several farmers, with apparently good results (although clear data were never easy to retrieve). In two cages at one site, juveniles of 5 g appeared to reach 44 and 70 g in five weeks. At another site, 2 g juveniles reached 16-20 g, and 4 g juveniles reached 33 g after one month.

Seven different attempts at grow-out during the nursery phase directly on the seabed were carried out at two sites. On three occasions, sheets of 2 mm netting were laid directly on the seabed, with the edges buried and pegged down (like clam-culture parks). In two other attempts, similar 2 mm netting was formed into shallow boxes (open below but covered on top), with walls about 35 cm high. The walls of these boxes were also partly buried and pegged down, and the roof was held off the sand with numerous small foam floats. Two long netting bags were also made and laid on the seabed. The floor of these bags was partly covered with sand and in one case the roof had small foam floats attached.

Reasonable numbers of sandfish were retrieved in only two out of seven of these trials. From one 11.7 m² box-shaped net, 47 % of 250 juveniles released at 3.3 g were collected after 3 months, averaging only 12.2 g. From a 14.1 m² bag, 39 % of 210 juveniles released at 3.1 g were collected after a similar period, averaging 11.2 g. From other attempts, only a few or no sandfish were found. These systems might be made to work reliably if there was easy access to suitable sheltered sites with firm substrate (sand or silt) and nets were cleaned at least weekly. However, use of these bags would then probably be costly in diver time. The use of bag-nets and pens in ponds, or co-culture in existing babylon snail cages seem be more promising methods.

Two pilot-scale pens were built in marine protected areas along the Khanh Hoa coast to test sandfish farming as an alternative income source for local fishermen. The first was in collaboration with the International Marinelife Alliance. They had recently established a locally managed Marine Protected Area (MPA) at Ran Trao, a patch of silty sand, seagrass, coral rubble and coral reef in Van Phong Bay some 60 km north of Nha Trang. The protected area (0.5 km²) was a couple of kilometres offshore from the same village (Xuan Tu) where the sea cucumber project's broodstock pens and experimental ponds were located.

The pen consisted of a fence of 5 mm mesh 145 m long and 1 m high built in an approximate circle in water of 5-6 m depth. Steel posts supported the net at 2 m intervals. The foot of the net was buried 10-20 cm and fixed down with bamboo pegs every 50 cm. Long narrow sandbags were laid around the foot of the net on top of the pegs. It enclosed an area (1 600 m²) of silty sand with some short seagrass. Although partly protected by a submerged fringing reef, it was exposed to the southeast.

The Ran Trao pen was stocked in July 2002 with 1 458 hatchery-produced sandfish from various pond nursery experiments (ca. 0.93/m²), averaging 97 g. Growth was somewhat disappointing with an average weight reaching 180 g by April 2003. There was then a partial harvest, which only fetched about US$ 0.84/kg. By late September

2003, the net fence was in poor condition, having fallen down, torn or lifted in many places. The remaining sandfish were not harvested but left in the sea for local restocking. Sandfish remained quite plentiful within the pen (which still seemed to be a substantial barrier to migration) and a samples averaged 335 g.

The second pilot-scale pen was in the same sheltered bay (Bich Dam) as the earlier pen nursery experiments, in the area of the Hon Mun MPA and maintained in collaboration with their staff. It was made from a strip of 8 mm netting 60 cm high and nearly 200 m long. It was laid in a rectangle in water 1.5-2.5 m deep, supported on bamboo posts every 2.5 m. The substrate was mainly silty sand with some broken coral. The foot of the net was buried about 5-15 cm, held down with bamboo pegs but without sandbags. It enclosed an area of about 2 000 m² and was stocked in March 2003 with 1 460 (ca. 0.73/m²) hatchery-bred sandfish nursed in ponds, averaging 84 g. By August these sandfish averaged 221 g, a growth rate of 1.05 g/day.

Later nursery and ongrowing in ponds

Sandfish juveniles of various sizes were transferred for further nursery and ongrowing into earth ponds, or pens inside ponds. Efforts were made to rid the ponds of crabs and shrimp (by drying or spreading insecticide-laced bait) and fish (using saponin) before stocking. Conditions inside the ponds were often tested by releasing 50-100 juveniles in a small pen (9-25 m²) built inside the pond before the main stocking. Survival in a pen inside a pond was often better than in the main body of the pond, although growth slowed down sooner. This led to the use of fences built inside the pond along the base of the banks.

In one early success, juveniles of 30 g stocked at a density of 1/m² exceeded 300 g in just 3 months without any losses. These hatchery-bred sandfish were later spawned at less than one year of age and several batches of second generation juveniles have been reared.

In the example shown below, juveniles of 2.3, 5.8 and 11.6 g average weight were stocked in six experimental (coral and coral sand substrate) ponds at about 1/m² (Figure 6). After 113 days, the small juveniles averaged 119 and 148 g, the middle-sized ones 166 and 156 g and the large ones 200 and 182 g.

On a few occasions, sandfish in ponds became sick, with white lesions on the dorsal surface. *Vibrio* bacteria (tentatively identified as *V. salmonicida*) were isolated from these lesions, but it is not known what the primary cause was; possibly attack by crabs, which were never possible to exclude completely from the ponds and pens. Sometimes the diseased individuals recovered spontaneously in ponds or recovered after being moved to a tank with clean seawater.

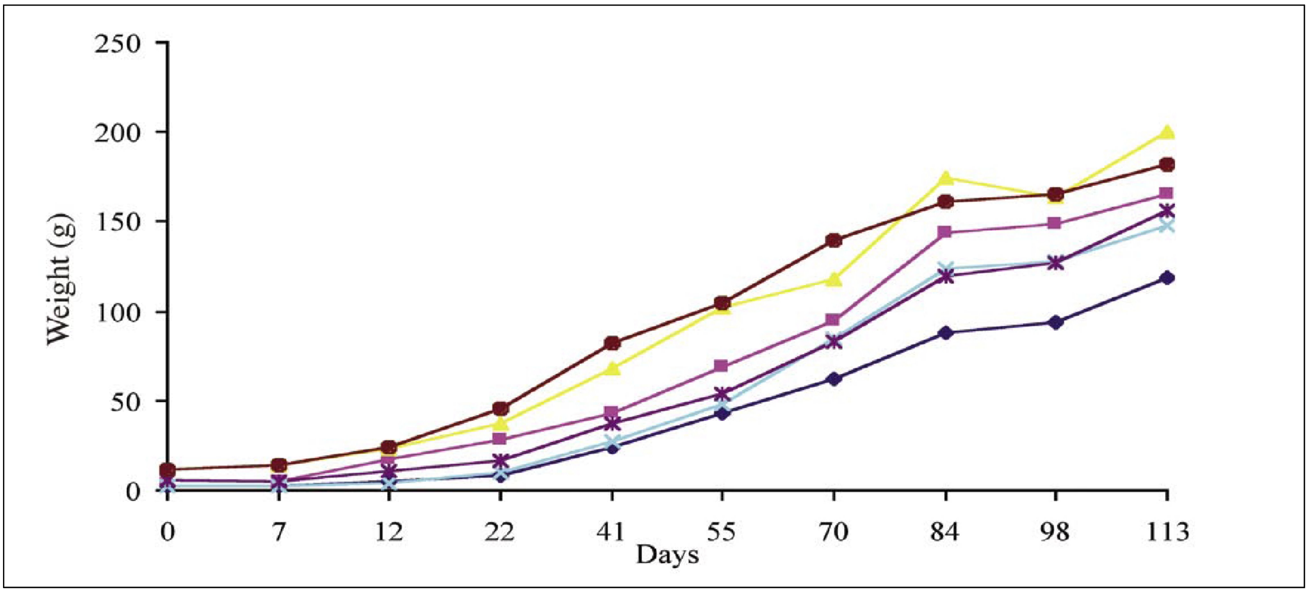

Figure 6. *Average weights (g) of sandfish stocked in ponds as juveniles for a period of 113 days.*

Battaglene (1999) observed that growth of juveniles in tanks slowed down or stopped when sandfish density reached about 200-225 g/m^2. This was generally confirmed, although in ponds the limit could be a little higher and on the seabed it was often lower. Growth also often stopped at an average weight of about 250-350 g, whether the density was high or not. It is not yet known whether this is due to energy being put into gonad development and spawning, to depletion of a limiting nutrient in the substrate or to some other cause.

Co-culture with shrimp in ponds

With help from the Support to Brackish Water and Marine Aquaculture (SUMA) program of DANIDA, the scientists of the Research Institute for Aquaculture No. 3 (RIA3) carried out a series of experiments in earth ponds and small scale containers to look at the feasibility of co-culture of sandfish with *Penaeus monodon* shrimp (Thu, 2003). In the first year, wild collected sandfish were used, however, after artificial breeding became routine, these experiments used hatchery produced juveniles.

There was reasonable survival to harvest of both shrimp and sandfish in two out of four co-culture ponds on the first attempt, and one of two co-culture ponds on the second. Apparently, reduced levels of total organic matter and hydrogen sulphide were found in ponds with sandfish and shrimp, as opposed to with shrimp alone, and growth rates of shrimp were improved. In buckets, sandfish juveniles survived at salinities of 15 (95 % after one month), at 10 (92 % after 3 weeks) and at 40 (83 % after one month). At a salinity of 45, all were dead after one week. Sandfish juveniles in buckets tolerated the use of the chemicals dolomite, zeolite and lime (used to manage water quality in shrimp ponds) at below 30 ppm.

Conclusions

Prospects for commercial culture of sandfish

In trying to answer the question 'can the development of hatchery methods of sandfish lead to commercial-scale farming in Viet Nam' there are a number of positive and negative factors that need to be considered. The positive factors are:

- Sandfish are easy to contain inside simple, low submerged fences.
- Sandfish do not need feeding in pens or ponds at medium densities (1.5-3 tonnes/ha).
- A second crop may make low density shrimp culture more profitable.
- Sandfish might improve benthic conditions and water quality in shrimp ponds.
- Sandfish are likely to thrive on detritus around fish, lobster or babylon snail cages.

The negative factors are:

- The current local wet (whole-body) price is only US$ 0.70-2/kg.
- The processing weight loss is 90-95 %.
- Sandfish in central Viet Nam do not appear to reach the large sizes (over 1 kg) of those in the South Pacific.
- Culture is density-limited; nursery and growout need large areas.
- Sandfish are vulnerable to water stratification, low salinities and anoxic conditions in ponds.
- Sandfish can be easily stolen, particularly from large submerged pens.
- Predators of juveniles include crabs, shrimp, some snails and fish.

Farmers have shown some interest in growing hatchery produced sandfish. Juveniles have been supplied to both pond and pen farmers usually at around 2 g average weight, but few if any appear to have yet reared significant quantities to sell, however, clear feedback from farmers has always been difficult to obtain. The low price paid by some local processors (under US$ 1/kg wet weight) has discouraged major efforts to overcome the technical problems of pond management. Successful shrimp culture, albeit a high-risk enterprise, remains the primary goal of most pond operators. The situation might be improved with better processing and marketing, perhaps on a cooperative basis. At a guaranteed live-weight price of US$ 2/kg or more there would certainly be more interest.

A longer term goal would be development of profitable systems of pond polyculture. Potential advantages are the more efficient use of feeds, a reduced load on the environment and a lower risk to farmers than intensive shrimp culture. Components might include shrimp at low densities, filter feeding bivalves, seaweed, fish or gastropods. Sandfish could fit well into such systems.

Prospects for restocking depleted populations of sea cucumbers with hatchery reared juveniles

At present, hatchery breeding methods only exist for a very small number of the commercial tropical sea cucumber species and large juveniles remain expensive to produce. It is far from obvious that the release of hatchery juveniles will be either useful or cost effective in restoring overfished sea cucumber populations. A few points to consider are outlined below.

If populations do not recover after fishing has been controlled, or recover only slowly, effective interventions will depend on the stage(s) in the life cycle where the recruitment bottlenecks occur. For example, if the remaining adults are too sparsely distributed for fertilization to occur, concentrating spawners in a few suitable sites and/or bringing in adults from nearby areas might be cheaper and easier than a hatchery breeding program.

Restocking without effective protection is likely to be futile. Where some stocks still remain, testing the effects of the two measures (protection and release) may not be easy or cheap (although genetic profiling could prove useful), requiring good pre- and post-intervention surveys at multiple sites.

It is not known to what extent planktonic sea cucumber larvae control their own dispersal by tide and current. While released, juveniles might survive, grow and spawn in a particular location. The long term effect of a restocking program may be limited if their larvae cannot not reach and settle in suitable nursery areas. The geographical scale on which release tests need to be done is also not clear, since it is not known how far larvae travel.

Juveniles of most species are rarely found and their nursery requirements are little known.

Despite the patchiness of data, a comparative study of the histories of different sea cucumber fisheries worldwide might be useful, in particular looking at recovery times between fishing pulses and the effectiveness of traditional and modern management methods.

It is hoped that some of the findings of this project, as well as contributing to practical large scale breeding, may also add to the knowledge needed for management of sandfish populations. In particular it has been shown that:

- Sandfish are capable of rapid growth (1-3 g/day) under good conditions.
- They can reach maturity at less than one year of age.
- They are partial spawners and can be spawned year round under tropical conditions. It is likely that a female will be able to spawn several times in a year in nature, producing 1-2 million eggs or more each time. Female sandfish can therefore probably produce of the order of 10^7 eggs in an undisturbed lifetime.
- Some shrimp, crabs and perhaps rabbitfish can damage and kill sandfish juveniles.
- Adults, and even larvae, can survive salinities as low as 20.

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Aquaculture of the Galapagos sea cucumber, *Isostichopus fuscus*

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Abstract

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, fertilization, 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 %. Furthermore, preliminary experiments have shown that the growth of young sea cucumbers in abandoned 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.

Keywords: Holothurian, spawning, larvae, development, juvenile, growth, disease

厄瓜多尔等刺参的养殖

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摘要

本文介绍了在厄瓜多尔沿海首次利用陆基实施培育等刺参（*Isostichopus fuscus*）的实验结果。产于厄瓜多尔沿海和加拉帕戈斯岛的该种海参多年来被大量捕捞，为保护资源免遭破坏的种种努力受到当地社团的反对，因此，厄瓜多尔等刺参的种群在最近的10多年来遭受严重破坏。本文介绍了等刺参的产卵、受精、幼虫培养、病害控制和幼参的养殖。在三年多内，每月进行的试验数据表明，在适宜条件下，幼体在3个半月的时间内体长可以达到8厘米。具有代表性的成活率在30–50%之间。进一步的实验证明，在废弃的对虾池内养殖等刺参是有前途的。总之，试验表明，等刺参可以在池塘等实施条件下进行养殖，为单纯的捕捞渔业找到了另一条途径，或者说，找到了可持续收获的路子，最终为天然资源增殖做出贡献。

关键词：海参、产卵、幼虫、发育、稚参、生长、病害

Introduction

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

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

In spite of the worldwide concern, the Galapagos sea cucumber populations became the focus of an intensive and poorly managed exploitation in the early 1990s. Since then, governmental attempts at regulating sea cucumber harvests, and banning them in some areas, have met strong opposition from local fishermen in Ecuador. In fact, illegal fisheries have always been a preoccupation and still occur along the mainland, around the Galapagos Islands and elsewhere in the distribution area of *I. fuscus*. Official information on the fisheries and actual total catches are consequently difficult to obtain and remain sparse (Salgado-Castro, 1993; Castro, 1996; Fajardo-Barajas, 1996; Sonnenholzner, 1997; Gutierrez-Garcia, 1999; Jenkins and Mulliken, 1999). Nevertheless, recent data and reports on average capture sizes (Sonnenhelzner, 1997; Martinez, 2001) indicate that *I. fuscus* populations have declined drastically and that natural stocks may irreversibly crash in the near future (Toral and Martinez, 2004).

In spite of this alarming situation, a very limited amount of studies have been conducted on the reproductive biology, spatial distribution, population structure, growth and survival rate of this species (Herrero-Perezrul, 1994; Fajardo-Leon *et al*., 1995; Toral, 1996; Sonnenholzner, 1997; Herrero-Perezrul *et al*., 1999; Hamel et *al*., 2003).

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

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

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

Methods and results

Spawning and fertilization

Adult sea cucumbers were routinely collected from nearby coastal areas to serve as broodstock. The adults were conditioned for a few days prior to spawning. Various methods of spawning induction have been tried at different periods of the month. However, close monitoring of the broodstock and spawning experiments over several months have revealed that the species follows a predictable spawning periodicity, even in captivity (Figure 2).

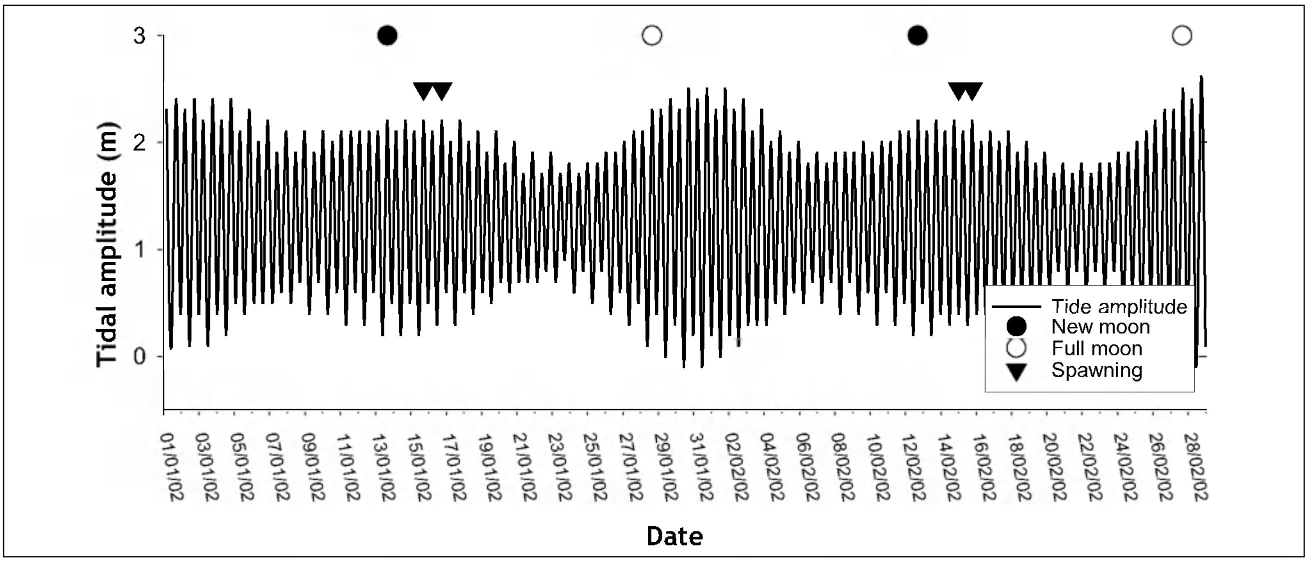

Figure 2. *Example of the typical spawning periodicity observed in captive* Isostichopus fuscus.

It has thus been possible to obtain male and female gametes on a monthly basis. Only a very limited number of spawning trials have been unsuccessful, mostly due to poor environmental conditions. Typically, between 300 and 400 adults were maintained in large 30-tonne tanks. Males and females were isolated in plastic buckets as soon as they showed signs of imminent spawning. Each female was then placed separately in a 300 litre spawning tank and maintained there until it had released its oocytes. Once the female had been removed from the tank, a dry sperm solution, prepared using the isolated spawning males, was added to the oocytes. The best fertilization rates and lowest occurrence of polyspermy were obtained with a concentration of 500 spermatozoa/ml.

After fertilization, the eggs were rinsed to remove excess sperm. A few hours later, the developing larvae were transferred to the hatchery tanks where their development was closely monitored. The routine protocol included daily cleaning of the tanks during the first days, followed by installation of a flow-through system. The larvae were fed every day using a mix of live microalgae (dominated by *Rhodomonas* and *Dunaliella*) at a frequency and concentration dictated by the daily observation of the digestive tract contents. Although several million oocytes could be obtained almost every month, space constraints have kept the size of the cultures between 1 000 000 and 1 500 000 eggs. With the improvement of the rearing techniques over the past year, a 50 % survival rate has often been achieved but the average success remains approximately 30 % of juveniles developed from every larval culture.

Larval development

Isostichopus fuscus possess oligotrophic transparent larvae that follow an indirect development, meaning that the larvae will need to feed during their pelagic phase and will undergo a series of transformations to reach the juvenile stage (Table 1, Figures 3 and 4).

In most trials, the development, settlement and early growth of the juveniles were somewhat asynchronous, and different stages and sizes could be found simultaneously in the culture. Extreme examples were observed in a few tanks where residual auriculariae neighboured 4 mm long juveniles. However, Table 1 provides a developmental kinetic that is based on the observation of the bulk of the culture, discarding the asynchronous animals.

***Table 1**. Development of* Isostichopus fuscus, *from fertilization to 35 mm long juvenile, at a salinity of 34-35, a temperature between 22 and 29 °C, a pH of 8.4-8.5 and a dissolved oxygen level between 5.4 and 6.1 mg/l.*

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

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

Ovulation in *I. fuscus* occurs in the gonadal tubule and gonoduct as the oocytes are released (Figure 3a). Thus, fully mature oocytes (ca. 120 µm in diameter) are expulsed directly in the water column at the metaphase-I of meiosis, after the germinal vesicle breakdown.

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

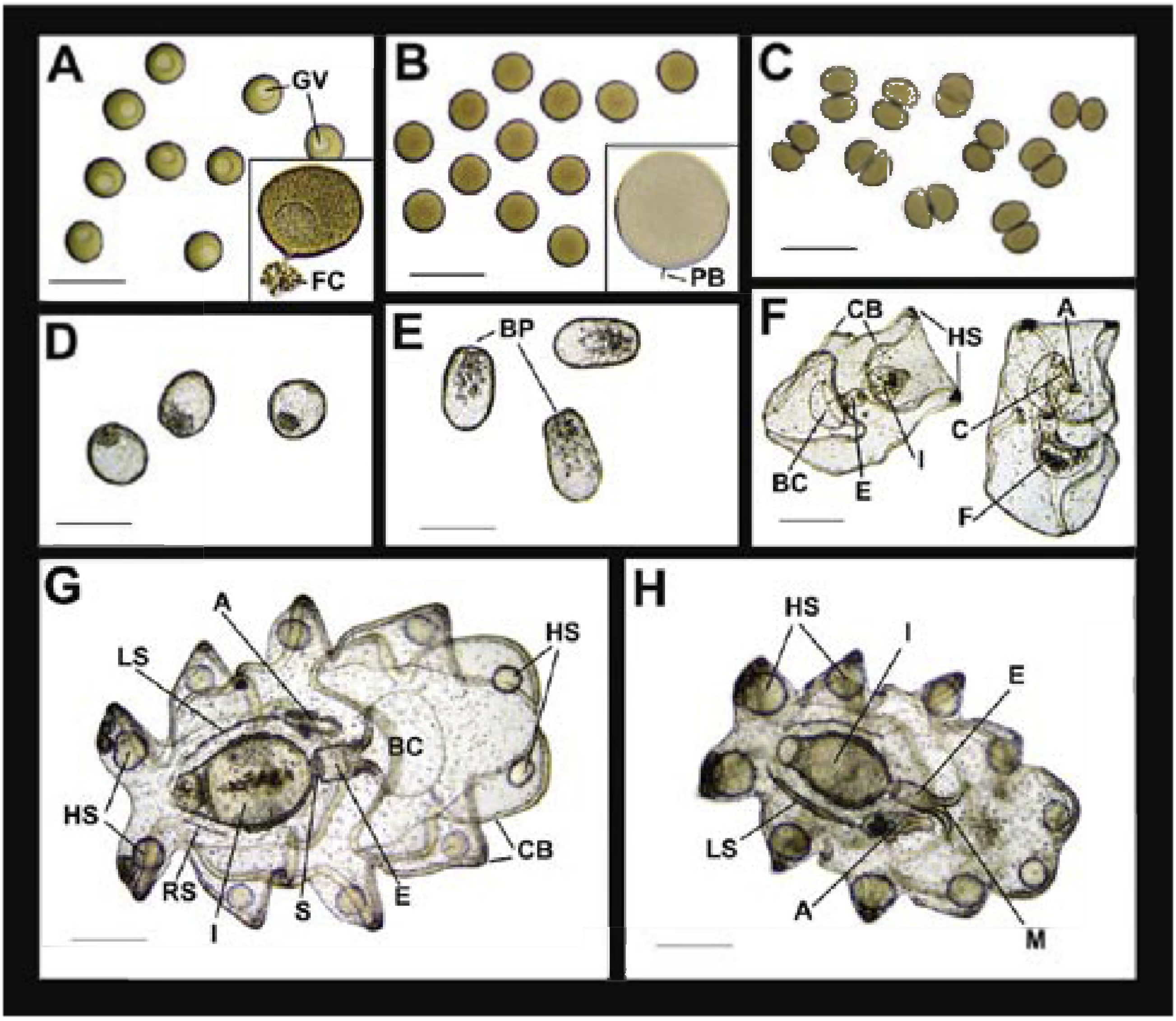

Figure 3. *Early development of the sea cucumber* Isostichopus fuscus. *The bars represent 200 µm.* ***A****. Oocytes collected surgically from a mature gonad. The germinal vesicle (GV) is clearly visible. The insert shows a close-up of an ovulating oocyte with the follicular cells (FC) still attached to it.* ***B****. Fully mature, newly fertilized eggs with clear germinal vesicle breakdown. The insert shows the expulsion of the two polar bodies (PB).* ***C****. 2-cell stage.* ***D****. Newly hatched gastrula.* ***E****. Elongated gastrula with visible blastopores (BP).* ***F****. Early auricularia on which the ciliary bands (CB), hyaline spheres (HS), buccal cavity (BC), oesophagus (E), intestine (I), cloaca (C) and anus (A) are identifiable. Food items (F) are present in the buccal cavity.* ***G****. Ventral view of a fully developed auricularia showing the left somatocoel (LS), axohydrocoel (A), hyaline spheres (HS), ciliary bands (CB), buccal cavity (BC), oesophagus (E), sphincter (S), intestine (I) and the right somatocoel (RS).* ***H****. Dorsal view of a metamorphosing auricularia. With a noticeable decrease in size, the buccal cavity disappears and the hyaline spheres (HS) are pulled closer together. The mouth (M), intestine (I), oesophagus (E), left somatocoel (LS) and axohydrocoel (A) are clearly visible.*

In the following hours, many auriculariae initiate the transformation that will lead to the doliolaria stage (Figure 3h). In the course of this process, the larvae shrink down to nearly 50 % of their initial size, the buccal ciliated cavity disappears and the hyaline spheres are pressed closer together (Figure 4a). The doliolaria stage is reached ca. 19-24 days after fertilization (Figure 4b, Table 1) as the larvae stop feeding and the cilia are aligned in five distinct crowns along their cylindrical body. At this time, the movement of the primary tentacles can be observed through the translucent body wall. The somatocoel is also visible. A few days later, the doliolaria transforms into an early pentactula possessing five buccal tentacles (Figure 4c). At this stage, the larvae remain close to the substrate, successively going through swimming and settling phases. Definitive settlement, with the complete loss of cilia, completion of metamorphosis and emergence of the two first ambulacral podia, occurs about 22 to 27 days after fertilization (Figure 4d, e).

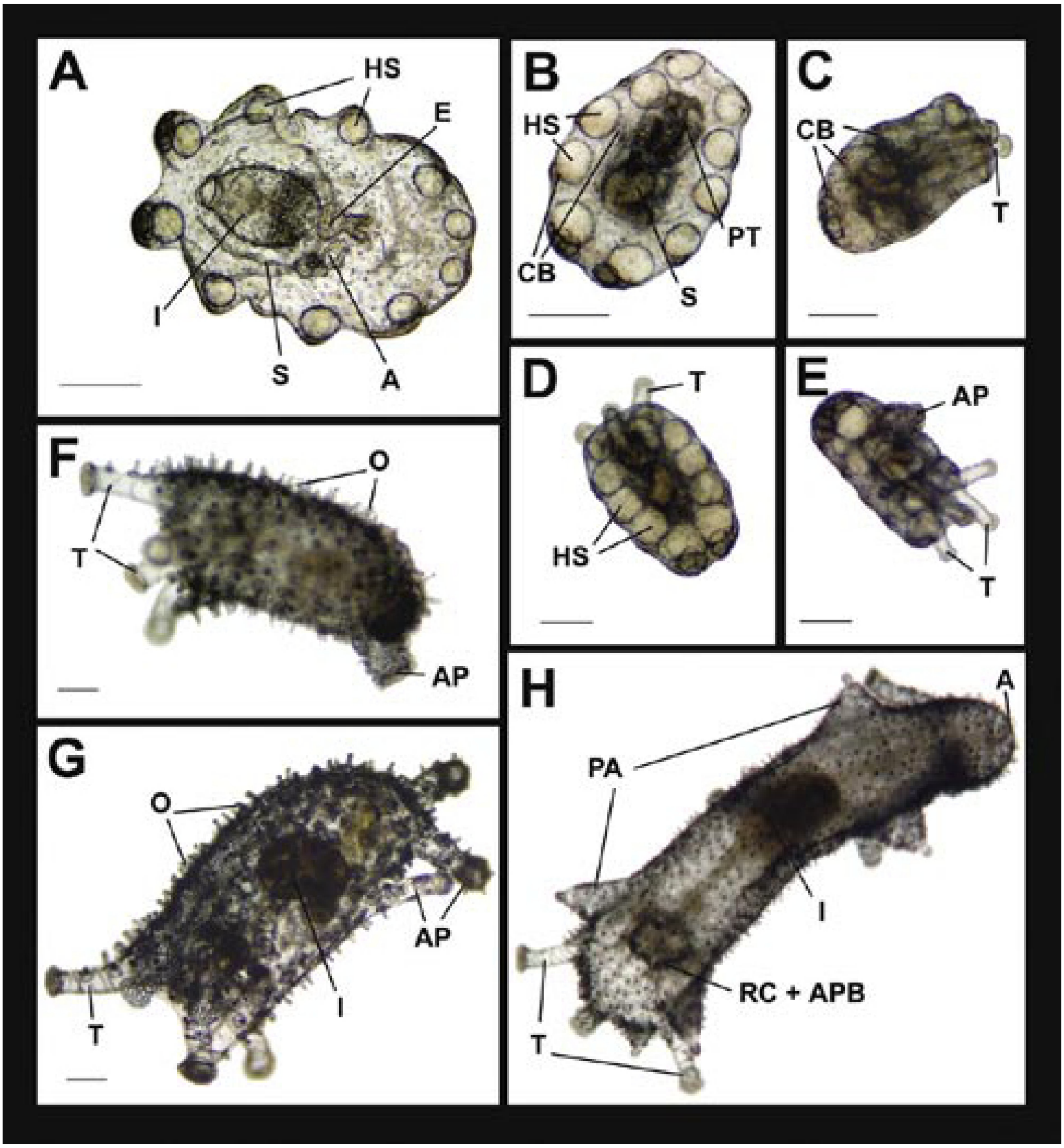

Figure 4. *Late development of the sea cucumber* Isostichopus fuscus. *The bars represent 200 µm.* ***A****. Late metamorphosing auricularia, showing the hyaline spheres (HS), oesophagus (E), intestine (I), somatocoel (S) and axohydrocoel (A).* ***B****. Fully developed doliolaria with hyaline spheres (HS), primary tentacles (PT), ciliary bands (CB) and somatocoel (S).* ***C****. Early pentactula with 5 tentacles (T) and the still visible ciliary bands (CB).* ***D****. Dorsal view of newly settled pentactula with tentacles (T) and hyaline spheres (HS).* ***E****. Ventral view of newly settled pentactula showing the first ambulacral podia (AP) and the 5 buccal tentacles (T).* ***F****. Early juvenile, measuring 1.5 mm in length, with tentacles (T), ambulacral podia (AP) and ossicles (O). The hyaline spheres have disappeared.* ***G****. A 2 mm long juvenile with 5 tentacles (T) and 3 pairs of ambulacral podia (AP). The intestine (I) and ossicles (O) are visible.* ***H****. A 3 mm long juvenile showing the tentacles (T), papillae (PA), intestine (I), anus (A) and the ring canal and aquapharyngeal bulb (RC + APB).*

Juvenile growth

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

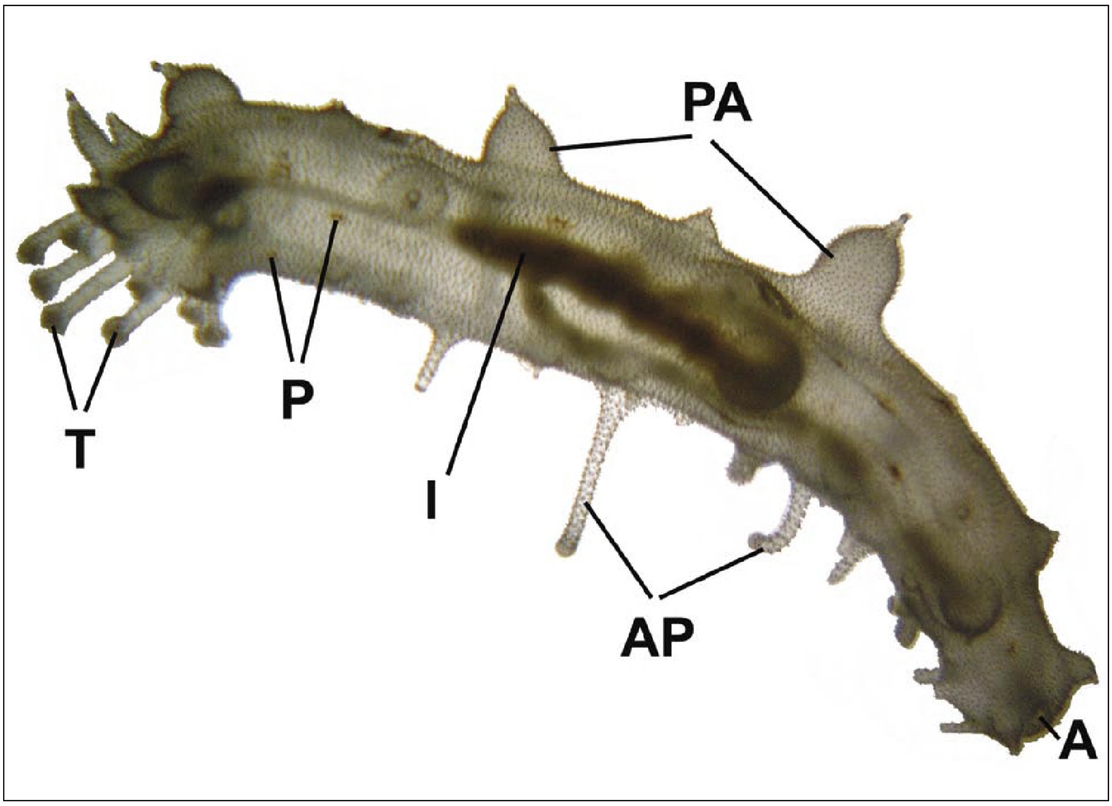

Figure 5. *Juvenile sea cucumber* Isostichopus fuscus *measuring 1.5 cm in length and showing the tentacles (T), early body wall pigments (P), intestine (I), ambulacral podia (AP), anus (A) and papillae (PA).*

The typical growth of *I. fuscus* larvae and juveniles is shown in Figure 6. Recent cultures have yielded significantly faster growth rates with juveniles measuring 1.1 cm after 28 days, 3.1 cm after 56 days and 5.6 cm after 77 days. However, the average growth of juveniles during the second month (Figure 6b) roughly follows the second-order polynomial equation below:

$$f(x) = 0.77 - 0.29(x) + 0.01(x^2)$$

where f(x) is the size in mm and x is the time in days (r^2=0.99).

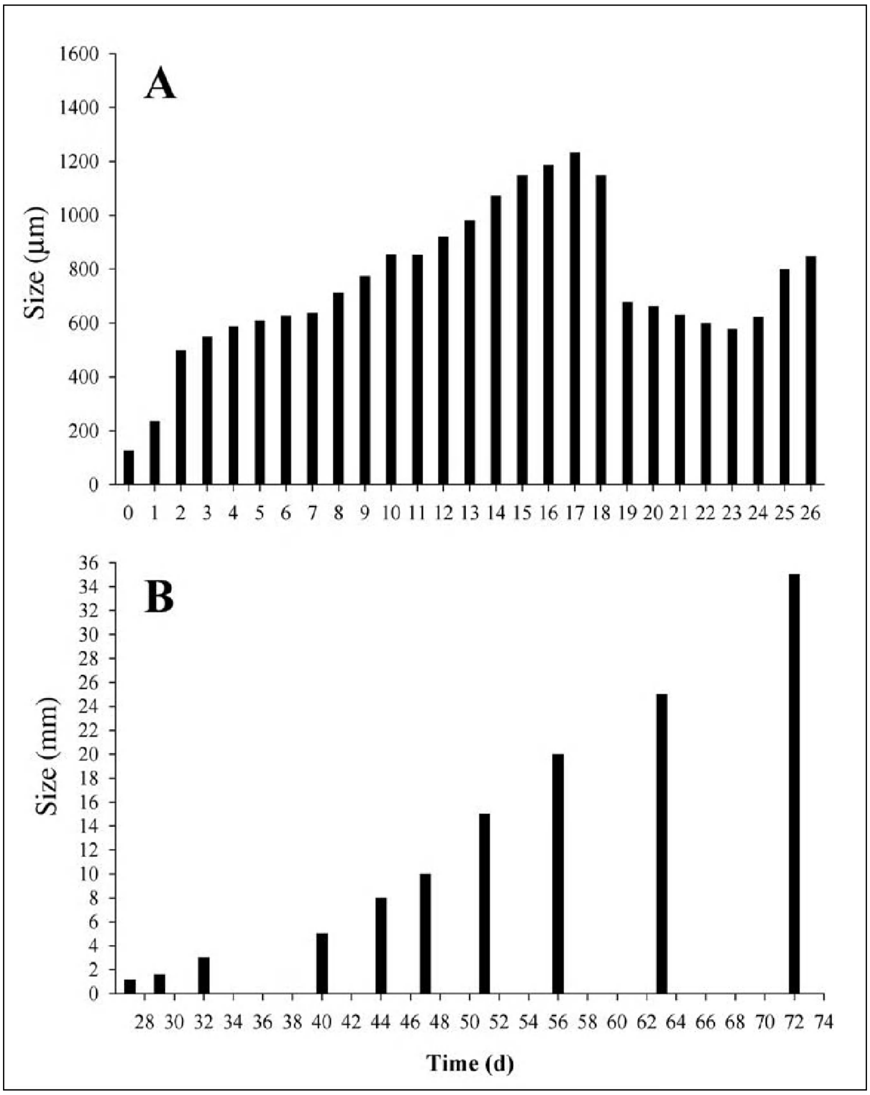

Figure 6. *Average growth of the larvae (A) and juveniles (**B**) of the sea cucumber* Isostichopus fuscus. *Note that the x axis in B is a prolongation of the one in A, with a slightly different scale, and that size is expressed in µm in A and in mm in B.*

Diseases and other problems

Intestinal parasites in larvae - The most common problem observed during the culture of *I. fuscus* is the development of a disease in the digestive system of early larvae. The first stage is the appearance of opaque cells around the digestive tract. The second visible symptom is the contraction of the intestine and stomach. In the worst cases, the digestive tract completely shrivels up and disappears. When it becomes visible, the condition is usually fatal to the larvae.

Upon close examination of the affected larvae under the microscope, the authors have determined that the disease is probably caused by parasites (Figures 7, 8). A protozoan displaying jerky movements has been observed outside the larvae, whereas a slower moving, smoother form appears inside the larvae. The authors have not yet been able to establish whether they are dealing with the same organism at two different stages of development, or two completely different causal agents.

During the first stage of the disease, the parasites can be seen entering through the body wall and the digestive tract, probably inducing the observed contraction. Later on in the development of the disease, the parasites become larger and are present everywhere around the intestine, both inside and outside. The parasites appear to feed on the intestinal contents or tissues, slowly making it shrink and disappear, typically causing the death of the larvae.

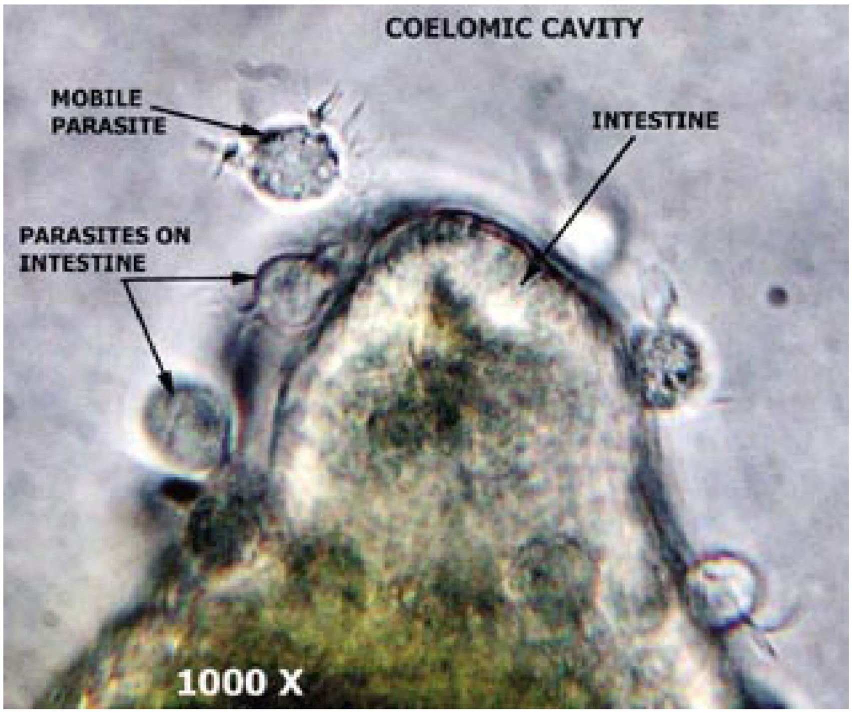

Figure 7. 1000 x enlargement of an infested intestine of I. fuscus.

Figure 8. Close-up view of the intestinal parasite of I. fuscus.

The parasites have never been observed in the larvae before hatching. However, the condition develops rapidly shortly thereafter, suggesting that the causal agents are present in the surrounding environment and that they enter the larvae at the first opportunity. They seem to remain inactive until the larvae start to feed. Afterwards, they can be seen to develop in different areas of the mouth and, most commonly, the digestive tract (stomach and intestine). A form with thin appendices can be found attached all over the larvae, but the amoeboid form is mostly observed around the digestive organs; it has the ability to move in and out of in what appears to be a trophosoit form. The parasites penetrate the intestine and feed on the intestinal contents or tissues, sometimes rupturing the intestinal wall.

The authors have tried different methods of collecting the gametes to establish whether the parasites were coming from the seawater itself or from the spawning adults. It has proven impossible to develop a culture without the presence of the parasites at one stage or another, even when using artificial seawater from the start of the trial. It would seem that the parasites are either present around the gametes and/or develop spontaneously in the culture.

Fortunately, the authors have found that a close monitoring of the early larval stages allows the detection of the first occurrence of the parasites. This enables to control the further development of the disease by using different environmental parameters. If the disease is not contained in its earliest phase, the whole culture usually crashes.

Another less virulent problem has been noted to affect mainly the body wall of cultured larvae. It appears as dense agglomerations and furrows at the surface of the affected individuals. This condition may degenerate and cause the larvae to shrink and eventually die. Whether the same parasite or another agent is involved is still not clear. Bacteria of the *Vibrio* genus are suspected to be involved, either as primary or secondary pathogens.

Water and food quality - Due to variable and often poor environmental conditions along the coast where the water was being pumped, a very complete filtration system, including UV treatment, had to be installed to provide the best possible water quality throughout the trials. The conventional treatment used for prawn culture was not dependable enough to grow sea cucumber larvae with optimum success. Strict sanitary measures were adopted in the handling of gametes and larvae to maximize survival rates and minimize incidence of infections and diseases. Bacterial counts are routinely made from water samples to monitor the efficiency of the sanitary and filtration procedures.

Bacterial contamination of algae cultures was another common problem that had to be overcome. Growing larvae need large quantities of healthy live algae to develop steadily, especially during the crucial step of metamorphosis into pentactulae. The inability to provide a healthy mix of algae can significantly delay growth and metamorphosis of larvae for extended periods. Thus, it has proven crucial to develop a system of algae production that is reliable and efficient.

As the size of the culture batches grew from a few tens of thousands to over a million larvae per month, rearing conditions had to be maintained and eventually improved to avoid mass mortalities.

Grow-out experiments

From settlement (0.5-1.0 mm) onward, the juveniles are usually transferred to larger 18 m^2 pre-conditioned flow-through tanks, with or without settlement plates. After about 110 days, some of the juveniles have reached sizes up to 8 cm (ca. 26 g; Figure 9). The authors are presently trying to assess at which size they would be fit to be transferred into growout ponds or eventually released in the wild.

Isostichopus fuscus juvenile can survive and grow in abandoned shrimp ponds. A preliminary experiment has been conducted early in the study to find out if small sea cucumbers collected from the wild would fare well in ponds from different locations. Enclosures of 1 m^2 were used to facilitate recapture. As it turned out, the sea cucumbers grew an average of 17 g/week and presented a 98 % survival rate, suggesting that shrimp ponds along the coast can provide a good environment to grow *I. fuscus* juveniles to adult size in a reasonable delay. Further research on pond grow-out techniques is currently being conducted.

Figure 9. *Two 110-day old* Isostichopus fuscus *juveniles.*

Conclusions and future prospects

So far, after three years of research and development:

- A good portion of the effort has been placed on adapting the shrimp farm equipment and larval rearing conditions to fit the needs of sea cucumbers.
- The species has been found to follow a predictable monthly spawning cycle which facilitates the collection of mature gametes (oocytes and spermatozoa). Several monthly trials have been conducted using 300-400 adults as broodstock.
- A larval rearing protocol has been developed with an optimal microalgal diet as well as water quality management and disease control.
- Survival rate of juveniles is now between 30 and 50 %. Based on the best growth rates, juveniles can reach 8 cm (ca. 25 g) in about 110 days.
- Further growth of young sea cucumbers in shrimp ponds appears to be a promising option.

Current and future research efforts are focused on:

- Investigating the feasibility of conditioning adults to spawn when maintained in tanks to avoid having to continuously disturb the wild populations.
- Fine tuning of the hatchery and larval rearing protocols to maximize commercial mass production.
- Experimenting with growout techniques to determine the best diet, substrates and location to grow the juveniles.
- Determining the commercial and ecological prospects for hatchery-produced *I. fuscus*.

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Synchronous gamete maturation and reliable spawning induction method in holothurians

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Abstract

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 groups. 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 synchronization 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 period.

The other aspect of the study arose 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 for about 20 min, without shedding gametes, triggered spawning in 71-100 % 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 triggering 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 can be used to spread and maximize spawning among the entire broodstock.

Keywords: Chemical ecology, coelomic fluid, gametogenesis, reproduction, sea cucumber

海参配子的同步成熟和可靠的诱导配子释放的方法

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摘要

多年来对不同种类海参的配子发育和释放所得到的研究结果在水产养殖和渔业管理上得到了应用。第一手的资料表明，海参释放出一种生物学活性物质，该物质可以使得同一物种的配子同步生成。实验室的研究表明，如将不同个体分别放在不同的自然条件下，其配子的发育的同步性显著地差于处在同一条件下的配子发育。还进一步显示，成熟的个体有诱导不太成熟个体的性腺发育。海参的活性物质存在于其体壁分泌的黏液中，能传播相当远的距离，起到引诱配对和群聚的作用。这一发现指出，月相的周期变化、光周

期、食物和温度等因素不能单独地用来解释生殖同步发生的过程，更精确地说，应该是多种环境因素，通过生物活性物质在种群内和种群间的协同作用的结果。这一过程在渔业和水产养殖技术中得到了印证。为了保护原始种群不受到高强度捕捞的影响，在繁殖季节到来前的相当长的时间里就应该将亲本群体保持在一个能够得到相互交流的范围之内。

在大多数具有商业利用价值的海参中，有些种类的人工繁殖还难以稳定地进行。最近的研究显示，海参的体腔液（PCF）可以用来成功地诱导成熟个体的产卵和排精，实验结果是将已经显示产卵行为长达大约20分钟，但尚未产卵的海参体腔液转移到同一种的海参体内，有71-100%的个体可以被成功地诱导产卵和排精。在注射2-3毫升体腔液后的海参，在30-62分钟内，就表现出欲产卵和排精的行为，57-83分钟后就开始大量排放精卵。结果上的差异与体腔液供者的产卵、排精的行为和注射的剂量有关。诱导物质与性别无关，因为来自于同一性别和不同性别的供者的体腔液都可以得到正向反应。因此，先产卵的海参的体腔液可以诱发整个群体达到最大程度的产卵。

关键词：化学生态学、体腔液、配子发生、繁殖、海参

Introduction

Proper gamete maturation and spawning synchrony are key factors in the sustainable development of sea cucumber aquaculture and fisheries programs. Studying and understanding the biological and chemical factors that play a role in the reproductive cycle of sea cucumbers can provide valuable insights for the management of captive-breeding facilities.

Maturation

Photoperiod has been shown experimentally to be the main factor responsible for synchronizing gamete development, or gametogenesis, in shallow-water echinoderms (McClintock and Watts, 1990; Hamel *et al.*, 1993; Hamel and Mercier, 1996a). Increasing temperature and food supply (Chia and Walker, 1991; Hamel *et al.*, 1993) and the lunar cycle (Mercier *et al.*, 2000; Hamel *et al.*, 2001) seem to constitute the other most determinant factors. It is proposed that the environmental fluctuations perceived by the organisms initiate a reaction leading to changes and modifications in the reproductive metabolism, possibly through gene activation or hormone synthesis (Shirai and Walker 1988; Hines *et al.*, 1992; Barker and Xu, 1993). It is not as easy to explain the onset and harmonious inter-individual development of gametogenesis in populations living in total darkness, whether exposed to similar or distinct local environmental conditions. It becomes especially important for freely spawning marine invertebrates, like most holothurians, that may waste a large portion of their gametes if this synchronization is not well orchestrated.

The investigation carried out revealed that environmental factors, coupled with various endogenous reactions, could not adequately explain the synchronous initiation and harmonious development of gamete synthesis in male and female sea cucumbers. This brought up an interesting question: are chemical mediators involved in the harmonious inter-individual development of gametes? This work explores the role of chemical mediators during gametogenesis in populations of sea cucumbers, while providing basic data and explaining a possible synergism with environmental factors. The mucus, one of its constituents or a chemical emitted with it, plays a determinant role in the fine tuning of gametogenesis among entire populations of holothurians.

Spawning

Spawning in holothurians has mostly been observed in the field and correlations with environmental factors have been outlined (Cameron and Fankboner, 1986; Smiley *et al.*, 1991, Hamel *et al.*, 1993, Hamel and Mercier, 1995a, 1996a). Some laboratory studies have tested the importance of environmental factors in spawning induction. Hamel and Mercier (1996a) induced gamete release in *Cucumaria frondosa* by manipulating the temperature and light factors with a maximum success of ca. 30 %. The use of a powerful jet of water on drying individuals also triggered spawning in *Holothuria scabra* (James, 1994) and *Parasitchopus japonicus* (Liu *et al.*, 2004; Wang and Yuan, 2004). Recently Battaglene *et al.* (2002) were able to trigger spawning in roughly 10 % of mature females *Holothuria* *fuscogilva* by adding a solution of dried algae *Schizochytrium* sp. (Algamac). However, apart from spontaneous spawning following the stress of capture recorded in different species (Reichenback, 1999; Hamel *et al*., 2001), thermal shock, alone or combined with other stresses, remains the most common method used to induce spawning in holothurians (Smiley *et al*., 1991; Yanagisawa, 1998; Hamel *et al*., 2001; Pitt and Duy, 2004; Sui, 2004; Wang and Yuan, 2004). All these methods give very inconsistent results that vary with the protocols, the species used and even the different batches of individuals collected. Most of the known physical, chemical or biological treatments used to induce spawning or to activate the final maturation of oocytes in other marine invertebrates act at the cellular level (Smiley *et al*., 1991) and give essentially species-specific results (Maruyama, 1980). They are not, or only partially, effective in holothurians.

The present work investigates the role of perivisceral coelomic fluid (PCF) in the spawning induction of holothurians, providing evidence of its importance as a transmitter of chemically active substances. The outcomes of this study include a reliable method to induce gamete release and propagate spawning among mature individuals under laboratory conditions.

Methods

The detailed methods used during the various experiments can be found in Hamel and Mercier (1996b, 1999), Mercier *et al*. (2000) and Mercier and Hamel (2002).

Results and discussion

Gametogenesis and maturation

Influence of environmental factors - Field and laboratory investigations demonstrated that gamete maturation was influenced by several physical and chemical factors, acting either together, successively or independently of one another. This can be observed in numerous species of sea cucumbers and is particularly evident in species that spawn once a year.

As expected from reports pertaining to other marine invertebrates (McClintock and Watts, 1990; Hamel and Mercier, 1995a, 1996a), photoperiod appeared necessary to initiate the gametic cycle of sea cucumbers as only individuals collected after the first increase of day length were able to complete their development when subsequently kept under constant conditions (Figure 1). However, the gonadal index of deep populations living in the absence of light was found to follow the same pattern as that of individuals exposed to light in the shallow photic zone (Figure 2).

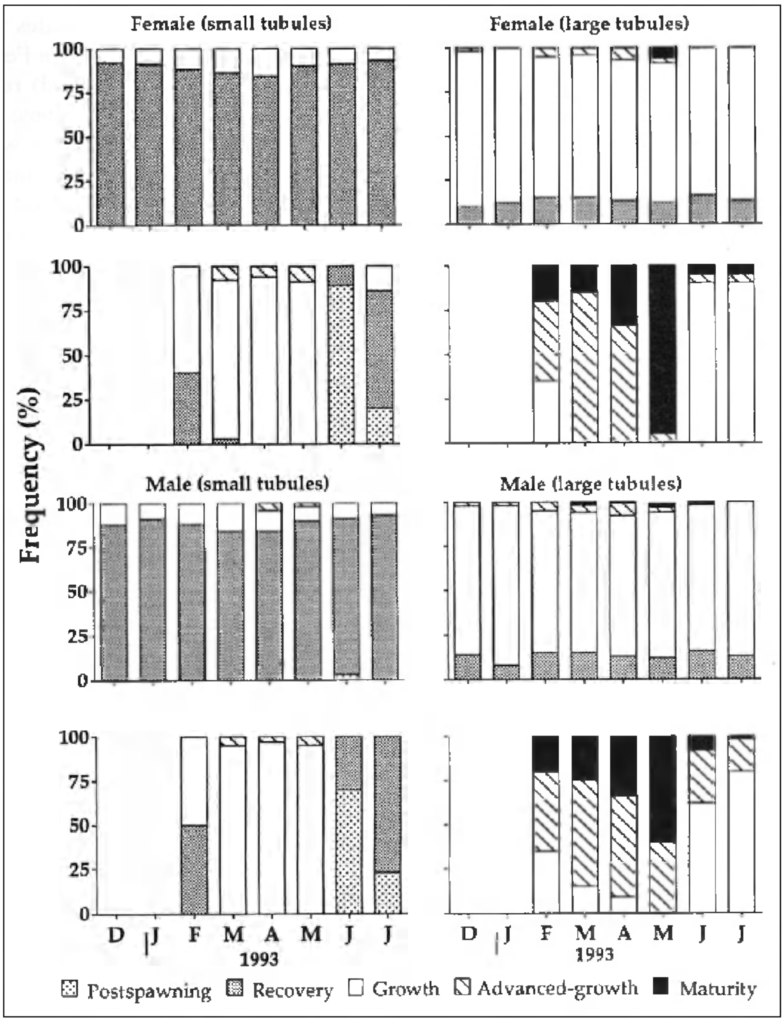

Figure 1. *Relative frequency of different gametic stages observed in small and large tubules of male and females* Cucumaria frondosa *collected either before the first increase of day length (December) or after it (February), and kept under naturally varying environmental conditions (from Hamel and Mercier, 1996b).*

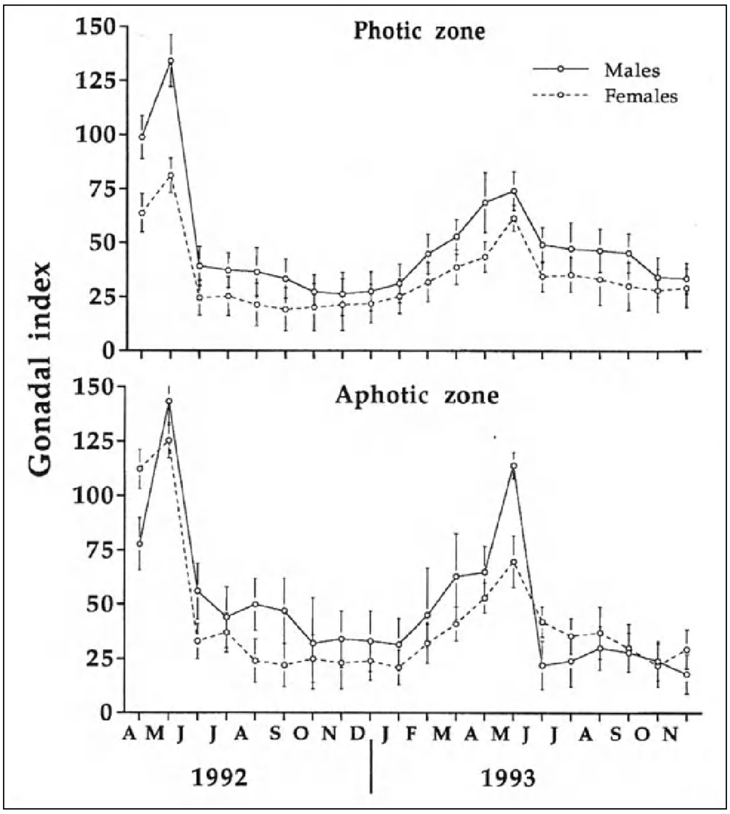

Figure 2. Seasonal changes of gonadal index in males and females Cucumaria frondosa *collected either in the photic (10 m) or aphotic (110 m) zone. Vertical lines indicate the 95 % confidence intervals (from Hamel and Mercier, 1996b).*

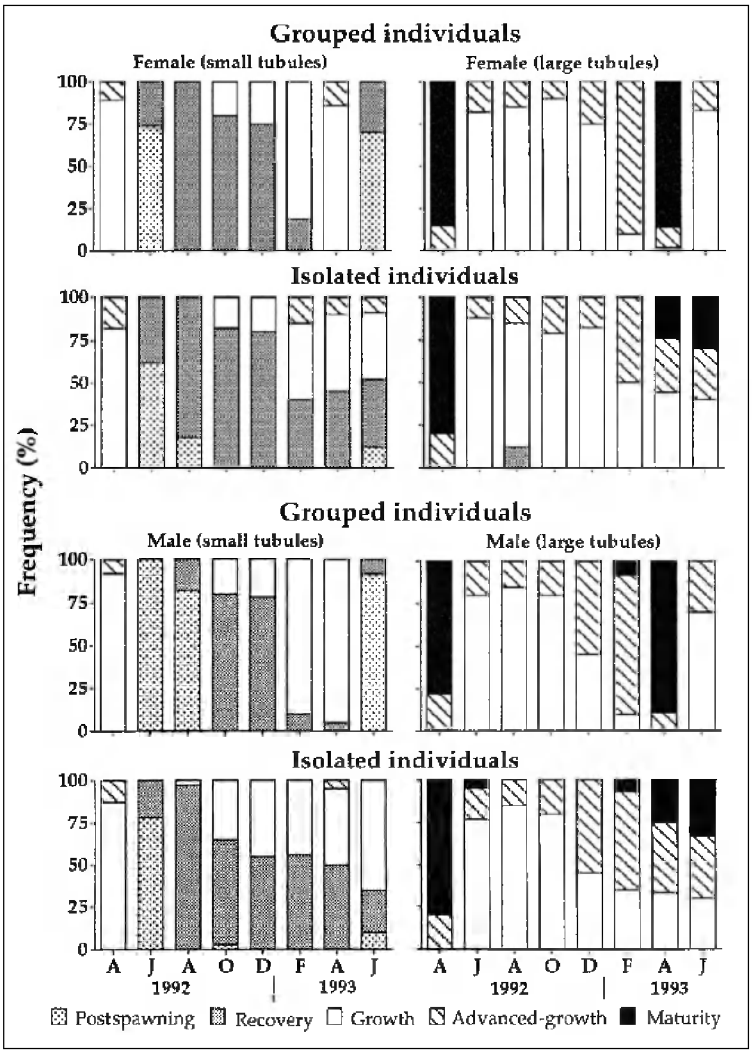

Figure 3. Relative frequency of different gametic stages in grouped and isolated Cucumaria frondosa *kept under natural environmental conditions (from Hamel and Mercier, 1996b).*

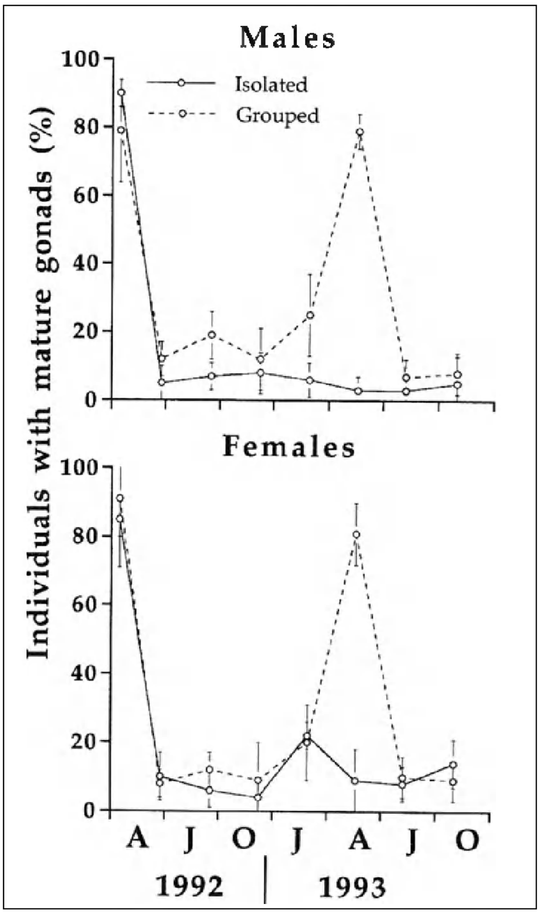

Figure 4. *Number of males and females (± 1 SD) showing mature gonads from April 1992 to October 1993 when maintained either grouped or isolated. Note that only one month out of three is identified on the x-axis (from Hamel and Mercier, 1996b).*

Inter-individual fine tuning of gamete development - Another set of experiments was thus carried out to explain the synchrony in the maturation of deep water and shallow water populations of sea cucumbers, despite the fact that individuals in deep water cannot directly perceive the initial environmental cue. Interindividual communication could play a key role, especially since most species of sea cucumbers live in close proximity to one another and often are continuously distributed over a depth range. Waterborne chemicals could be the mode of such communication.

Indeed, interindividual synchrony was obtained only among sea cucumbers allowed some contact with one another, either directly or through the water medium (Figures 3, 4). Furthermore, the presence of more mature individuals of the same sex induced gametic development in less developed sea cucumbers, even when they had not previously been exposed to an increase in day length (Hamel and Mercier, 1996b).

Aggregations - In the field and broodstock tanks, aggregations have been observed to shape the distribution of adult sea cucumbers, mostly in tropical regions, on a regular basis. Since no clusters were observed in the juveniles stage (before the fist sign of sexual maturity), and given the fact that maximum aggregation typically occurred just before spawning events, aggregative habits of some species of sea cucumbers appear to be related to reproduction. Breeding aggregations have been observed in a number of asteroids (Ormond *et al.*, 1973; Hamel and Mercier, 1995b) and echinoids (Levitan *et al.*, 1992; Young *et al.*, 1992), and many authors suggest that aggregations minimize

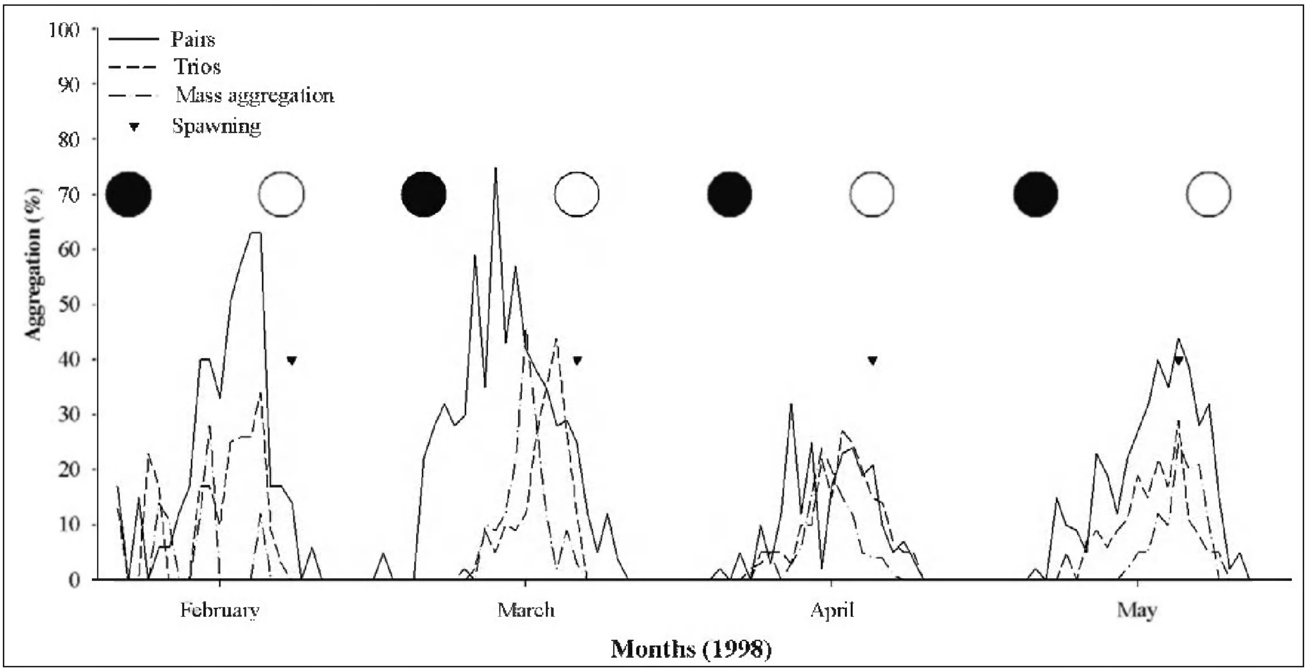

Figure 5. *Aggregative behaviour (lines) and spawning (triangles) of adult* Holothuria scabra *in outdoor tanks. Open circles indicate full moons and darkened circles represent new moons. (from Mercier et al., 2000).*

sperm dilution and increase fertilization success. Recently, Rodgers and Bingham (1996) observed aggregations of the sea cucumber *Cucumaria lubrica* and proposed that they were a result of their subtidal zonation in response to light. Figure 5 illustrates the aggregative behaviour recently observed in *Holothuria scabra*.

Mucus and chemical communication - This set of data further refines the previously described results by showing that the seasonal production of mucus, secreted by the body wall of sea cucumbers, can play the role of chemical mediator in this interindividual sexual exchange. Synchronous gamete development is apparently related to mucus synthesis which enables the transfer of sexual information between conspecifics (Figure 6). Either a component of the mucus itself or a chemical secreted simultaneously and carried with it acts as the messenger.

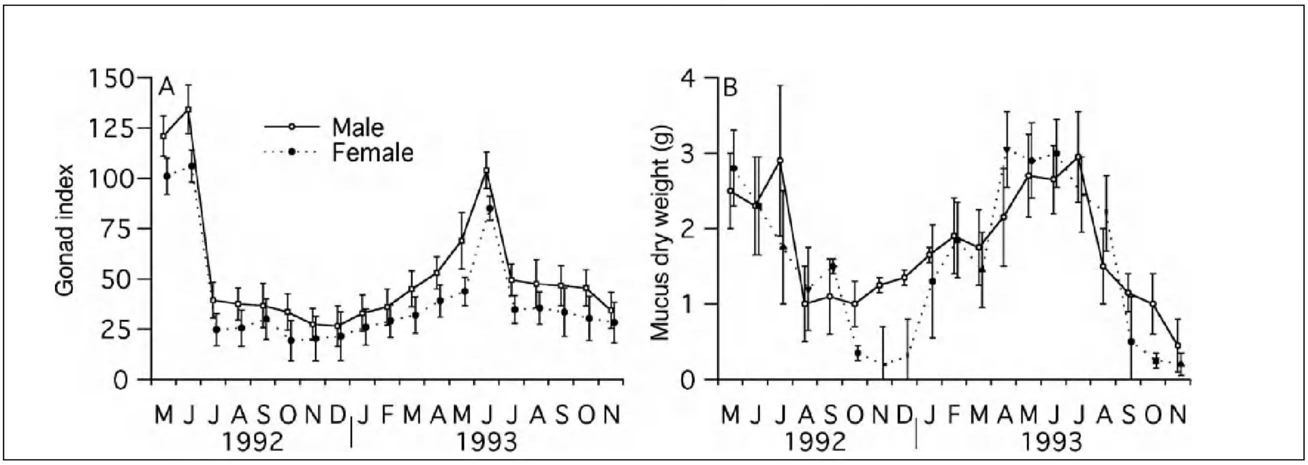

Figure 6. Cucumaria frondosa. *Seasonal cycle of (A) gonad index of 50 sea cucumbers collected monthly from May to November correlated with (**B**) the abundance of mucus synthesized by another group of individuals submitted to similar environmental conditions of day length and temperature. The vertical lines indicate the confidence interval (95 %) (from Hamel and Mercier, 1999).*

To the best knowledge of the authors, mucus has never before been described to play a role during gametogenesis in any species of marine invertebrate. The data indicate that mucus synthesis follows the gonad cycle, hence it is proportional to the level of maturity of the gonadal tubules, enabling mature individuals to stimulate conspecifics with more efficiency (Figure 7). This suggests that the chemical nature or the quantity of mucus synthesised by an individual changes over time and modulates the intensity of stimulation applied on conspecifics over the seasonal cycle. In fact, the seasonal synthesis of mucus seems to be correlated with the initiation of gametogenesis and with the progressive increase of the gonad index.

Spawning induction

Having shown that sea cucumbers can influence one another during the maturation process by aggregating and transmitting chemical cues, it is only natural to wonder if spawning induction can be achieved by artificially enhancing the transmission of chemical signals. Indeed, the present work demonstrates that a substance or a combination of substances implicated in the initiation and progression of spawning behaviour and gamete broadcasting in holothurians can be transmitted via the perivisceral coelomic fluid (PCF). The injection of PCF collected from a mature individual showing spawning activity, prior to and until gamete release, into a mature non-spawning individual triggered spawning behaviour and subsequent gamete release in up to 100 % of individuals (Figure 8). The same PCF spread in the immediate environment also induced a proportion of spawning behaviour (47-65 %) and gamete release (20-31 %). A broad interpretation of the latter results suggests that messages sent via the PCF could help holothurians synchronize and propagate spawning both in captivity and in the field.

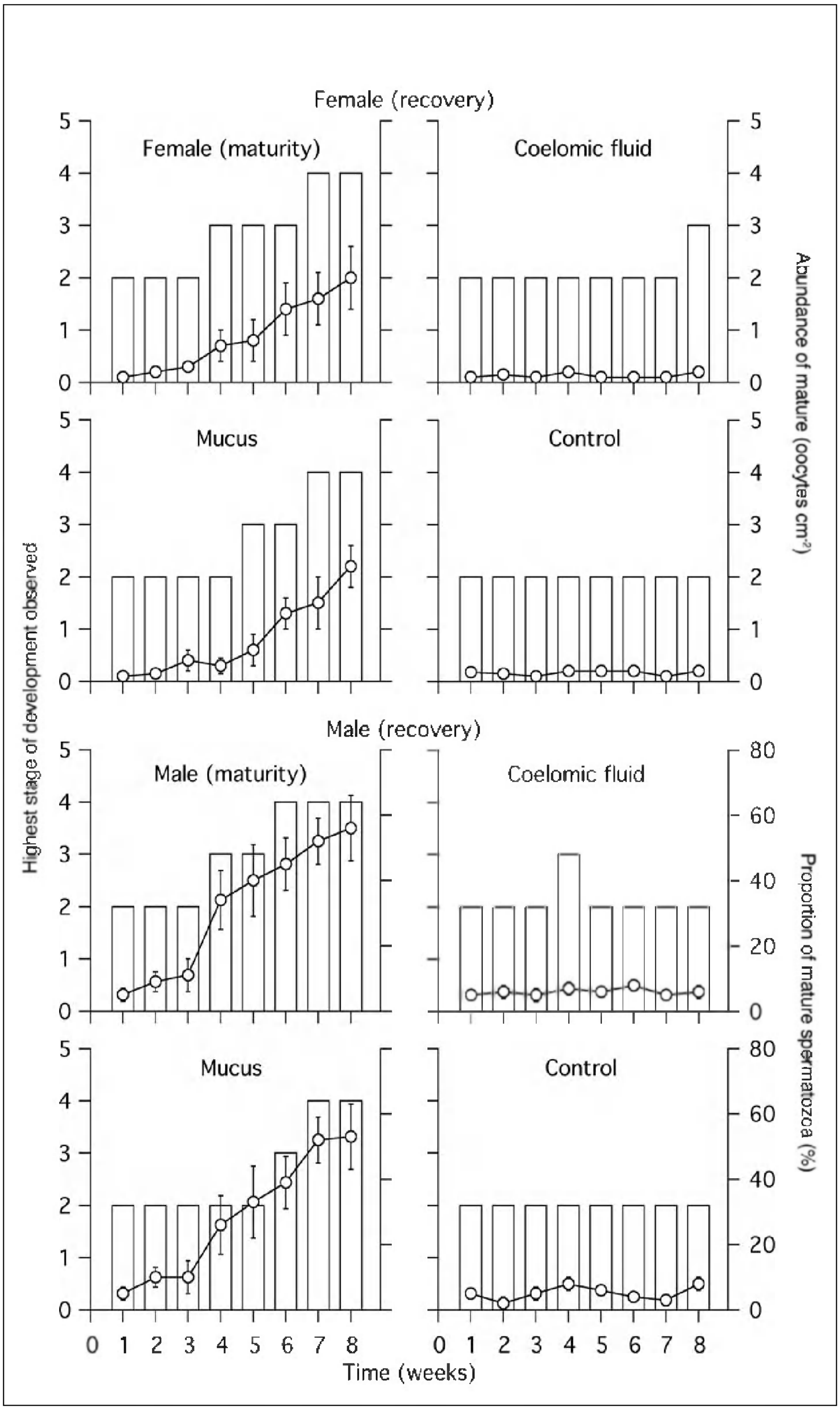

Figure 7. *Gametic development in the gonadal tubules of* Cucumaria frondosa *initially in the recovery stage and submitted to three different sex-specific stimulations: a whole mature individual, mucus and coelomic fluid from a mature individual. The highest stages of development observed are presented as histograms and the number of mature oocytes or the proportion of mature spermatozoa as lines. The gametic stages observed in both sexes were divided into (1) post-spawning; (2) recovery; (3) growth; (4) advanced-growth; and (5) maturity. Control experiments were performed using individuals without the stimulation. The vertical lines represent the confidence interval (95 %) (from Hamel and Mercier, 1999).*

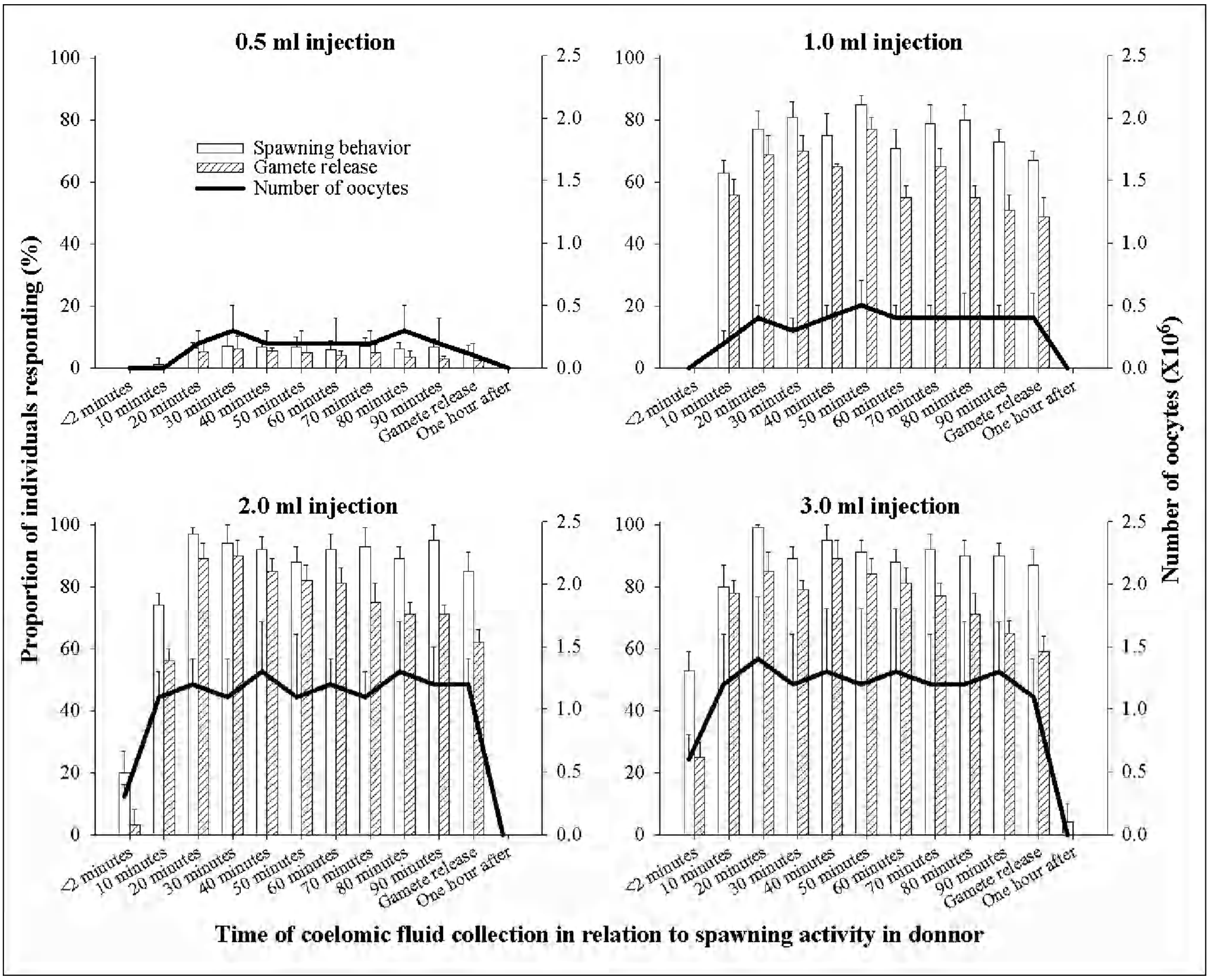

Figure 8. *Effect of the amount of PCF injected and the time of collection in donor on the proportion of female* Bohadschia argus *that exhibit spawning behaviour and gamete release, and on the mount of oocytes spawned. The data are presented as mean ± SE (n=4-11). Each experiment was repeated with three different batches of sea cucumbers (from Mercier and Hamel, 2002).*

Although the ability of PCF to induce spawning has been clearly established, including its efficiency when spread in the water column, the path of its transmission and true function in natural spawning events is not fully understood. Theoretically, the PCF and/or the chemically active substance(s) it contains are trapped inside the coelomic cavity and cannot spread outside. However, Doignon *et al.* (2003) recently observed that the coelomic content of *Holothuria tubulosa* is purged seasonally. He proposed that the coelomic purge would be an indirect result of the host's spawning as holothurians make use of powerful muscle contractions to expulse their gametes. This behaviour would increase the pressure on the peri-cloacal end of the individual and set off the discharge of the coelo-cloacal ducts, carrying the coelomic contents away to the environment. This reasoning could even explain how the use of sperm collected from spawning individuals has been found to induce other individuals to spawn: the presence of PCF in the semen may well be the real trigger.

The next results show that the active PCF is neither sex-specific nor species-specific with the holothurians tested (Table 1). However, PCF from echinoids and asteroids did not induce spawning in sea cucumbers.

Interestingly, the time of collection in the donor and the amount of PCF injected have been found to have an impact on the stimulation of the spawning posture and the gamete release. For instance, PCF collected just 1h after gamete release had lost its effectiveness. Thus PCF apparently acts as a carrier of one or more short-lived molecules of a sexual nature during spawning.

Table 1. *Effect of PCF from different echinoderms on female* Bohadschia argus, *using 2 ml aliquots collected from donors having displayed spawning behaviour for 20 min. Data for spawning induction are presented as Mean ± SE (n = 4-11). Spawning success estimated with the gonadal index (GI) and the amount of oocytes spawned (n = 15 males and 15 females) (from Mercier and Hamel, 2002).*

DONOR SPECIES	SPAWNING INDUCTION	SPAWNING SUCCESS		
	Proportion of spawning individuals (%)	**GI before spawning**	**GI after spawning**	**Oocytes spawned ($X10^6$)**
Sea cucumbers				
Bohadschia marmorata				
Male	69.1 ± 14.4	19.6 ± 6.5	7.6 ± 3.3	0.7 ± 0.4
Female	83.9 ± 8.4	20.3 ± 4.5	6.5 ± 2.5	0.9 ± 0.6
Holothuria atra				
Male	78.3 ± 11.6	18.7 ± 4.7	5.2 ± 4.9	1.2 ± 0.1
Female	86.5 ± 10.3	12.6 ± 6.1	3.1 ± 2.1	1.1 ± 0.8
Holothuria leucospilota				
Male	66.7 ± 12.1	20.1 ± 3.6	7.7 ± 3.5	0.9 ± 0.8
Female	54.6 ± 19.9	22.1 ± 7.6	7.2 ± 2.9	0.7 ± 0.1
Sea urchin				
Diadema savignyi				
Male	0	13.2 ± 5.3	-	-
Female	0	17.7 ± 7.1	-	-
Sea star				
Archaster typicus				
Male	0	20.0 ± 4.1	-	-
Female	0	14.2 ± 3.5	-	-

The pooled data from studies in conspecific holothurians of both sexes showed that the best spawning success was obtained when 2 or 3 ml of PCF was injected. Furthermore, for a given amount of PCF sampled from a donor 20 min after the beginning of spawning behaviour or anytime later until gamete release was also more effective (Table 2).

The fact that 1 ml of PCF induced a good proportion of individuals to display the spawning posture, but with a smaller amount of oocytes actually being broadcasted, compared to 2 or 3 ml injections, suggests that the chemical plays a double role by triggering gamete release. This could mean that the chemical is a single compound that its concentration in PCF increases from the first sign of spawning to reach a maximum ca. 20 min later and that a threshold concentration is needed to induce a complete response.

Conclusions and applications for aquaculture

Chemical communication during maturation

Summary of results:

- Gametogenesis initiated by increasing day length developed normally when individuals were transferred to an environment in which the temperature and photoperiod were held constant and food was withheld.
- Individuals collected from an aphotic zone showed gonadal indices and histological development of gametes that were synchronous with those of populations found in the shallow photic zone.
- Laboratory experiments showed that gametic synchrony was less for individuals maintained separately under natural environmental conditions than it was for individuals kept in groups.

- Gametogenesis was successfully initiated in immature individuals by exposure to more developed individuals.

Recommendations:

- When maintaining broodstock for multiple spawning trials, several individuals of both sexes must be kept together in large groups to optimize synchronous maturation and readiness to spawn.
- During broodstock collection or fisheries, some shallow water populations need to remain untouched to allow them to mature simultaneously and ensure sustained recruitment in nearby fished areas.
- Shallow water populations also need to be protected to allow the transfer of environmental cues to deep water populations and ensure synchronous spawning events. Otherwise the deeper population could degenerate progressively.
- During stock enhancement procedures, quantities of sea cucumbers released in a given area must take in account the requisite of a minimal density for successful natural breeding to occur.

Table 2. *Spawning induction in male and female* Bohadschia argus. *Data as Mean ± SE (n= 4 to 11). The perivisceral coelomic fluid (PCF) was collected from donors having displayed spawning behaviour for 20 min. The same experimental condition was repeated at least three times (from Mercier and Hamel, 2002).*

Injection	Sex (receiver)	Spawning behaviour (%)	Time before first sign of behaviour (min)	Gamete release (%)	Total duration of response (min)	Spawning success		
						GI before spawning	GI after spawning	Oocytes spawned (X 10^6)
PCF from spawning male								
0.5 ml	Male	7.2 ± 1.5	67.5 ± 5.9	5.7 ± 2.3	80.2 ± 12.3	11.6 ± 2.3	9.7 ± 1.9	-
1 ml	Male	81.1 ± 3.3	60.3 ± 7.7	75.4 ± 7.2	82.3 ± 8.4	15.9 ± 5.7	12.4 ± 3.4	-
2 ml	Male	94.3 ± 3.1	59.5 ± 2.6	92.1 ± 9.4	72.1 ± 7.3	21.3 ± 6.1	5.2 ± 3.9	-
3 ml	Male	92.7 ± 4.4	50.1 ± 1.7	90.4 ± 4.7	70.7 ± 9.6	14.6 ± 4.6	2.4 ± 1.1	-
PCF from spawning female								
0.5 ml	Female	49.5 ± 5.5	74.6 ± 12.3	35.3 ± 9.1	83.5 ± 7.9	13.5 ± 3.5	11.3 ± 0.7	0.3 ± 0.1
1 ml	Female	71.7 ± 9.3	65.1 ± 20.2	44.1 ± 6.3	79.3 ± 6.6	18.3 ± 4.8	12.6 ± 4.7	0.7 ± 0.1
2 ml	Female	84.5 ± 6.4	59.3 ± 5.8	79.2 ± 5.4	69.5 ± 5.4	14.9 ± 4.4	3.2 ± 1.9	1.1 ± 0.2
3 ml	Female	74.5 ± 3.1	61.3 ± 7.7	71.9 ± 6.3	71.3 ± 7.6	12.5 ± 6.7	2.9 ± 1.5	1.4 ± 0.5
PCF from spawning male								
0.5 ml	Female	36.3 ± 11.2	72.2 ± 9.4	22.7 ± 6.4	91.3 ± 8.1	20.4 ± 5.5	18.1 ± 3.5	0.1 ± 0.1
1 ml	Female	65.2 ± 3.9	75.2 ± 10.1	56.5 ± 8.4	81.2 ± 7.3	15.1 ± 3.6	11.5 ± 2.7	0.5 ± 0.2
2 ml	Female	80.8 ± 1.2	61.1 ± 5.3	71.3 ± 7.1	83.2 ± 6.4	18.5 ± 7.3	1.7 ± 1.3	1.6 ± 0.4
3 ml	Female	92.4 ± 2.8	62.1 ± 8.7	84.7 ± 5.2	78.3 ± 5.5	17.4 ± 5.1	2.1 ± 1.0	1.3 ± 0.2
PCF from spawning female								
0.5 ml	Male	21.9 ± 9.9	74.3 ± 4.1	9.3 ± 3.2	83.2 ± 9.3	10.5 ± 6.4	9.1 ± 1.7	-
1 ml	Male	62.4 ± 3.4	69.2 ± 3.1	48.0 ± 7.2	83.3 ± 6.7	15.3 ± 4.1	11.6 ± 4.2	-
2 ml	Male	89.4 ± 6.7	31.4 ± 3.3	87.3 ± 3.6	59.1 ± 9.2	13.7 ± 6.4	4.4 ± 2.8	-
3 ml	Male	100 ± 0	30.3 ± 2.0	100 ± 0	57.4 ± 4.7	19.3 ± 7.5	5.7 ± 2.1	-

Spawning induction

Summary of results:

- Perivisceral coelomic fluid (PCF) appears to carry short-lived molecules of a sexual nature during the spawning behaviour up to gamete release.
- Mature non-spawning individuals can be triggered to spawn either by injection of or physical contact with PCF collected from spawning congeners (with success up to 100 % and 31 %, respectively).

Applications:

- Transfer of PCF becomes a tool for maximizing the release of gametes and specifically increasing the number of spawning females, since male PCF can be used to induce females and vice versa.
- A minimum of PCF (2-3 ml) collected in pre-spawning individuals after ca. 20 min. has to be injected to ensure optimal gamete release in receivers being stimulated.
- Release of PCF in seawater surrounding mature individuals can induce them to spawn.
- Individuals are not harmed by the procedure and can thus be kept as broodstock for further spawning.
- A species that spawns easily could be used to induce spawning in another more delicate species to spawn.

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Mariculture of sea cucumber in the Red Sea - the Egyptian experience

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Abstract

Severe overfishing of sea cucumbers has occurred in most countries of the world. Even though they were abundant along 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 is harvested in large numbers. This paper summarizes 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 and both segments are able to regenerate their gonads. If successful, there is some potential to use this technique in hatcheries with minimum costs.

Keywords: Red Sea, *Actinopyga mauritiana*, reproductive biology, asexual reproduction

红海海域的海参养殖——埃及的经验

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摘要

世界上许多国家均存在着过度捕捞海参的现象。位于红海沿岸的埃及，在二十世纪九十年代中期海参资源还相当丰富，而现在海参资源量明显减少，一些种类濒于灭绝。作为“达尔文启动计划”的一个部分，人工繁殖海参幼苗的放流研究由埃及苏伊士运河大学的海洋科学系进行。该项研究是为恢复海参资源所采取的一项措施，最终目的是希望通过该项计划增加海参的总量。产自红海的一个最重要的海参种类是白底辐肛参（*Actinopyga mauritiana*）。此种海参在世界上具有很高价值，而且需求量很大。本文简介了此种海参的受精方法，并对其解剖学和生物学的形态特征作了概括的描述。结果显示，在繁殖季节之外，无性繁殖方法是增加养殖数量的最为实际的选择。这种方法可以降低白底辐肛参的死亡率，而且切为两段的海参均可再生性腺。用此技术具有以最小成本培育海参苗种的潜力。

关键词：红海、白底辐肛参、繁殖生物学、无性繁殖

Introduction

Increased demand for beche-de-mer and worldwide declines in stocks of tropical sea cucumbers has encouraged aquaculture, stock restoration and enhancement programs for holothurians (Conand and Byrne, 1993; Battaglene and Bell, 1999). However, reliable techniques for induced spawning in holothurians have been developed for relatively few species. The most commonly produced sea cucumber species at present are temperate sea cucumber *Apostichopus* *japonicus* and the tropical species, *Holothuria scabra*. The juvenile production technique for these two species has been established in China, Japan, India, Indonesia and the Solomon Islands, among other (James, 1996; Battaglene and Bell, 1999; Battaglene *et al*., 1999).

Worldwide, *Actinopyga mauritiana* is highly valued, in great demand and is harvested in large numbers. This species, widely known as surf redfish, is amongst the most widespread and important holothurians in the Egyptian Red Sea and Gulf of Aqaba. *Actinopyga mauritiana* is locally called "cajeno" and is generally considered a low value beche-de-mer species. However, due to overfishing of high value species worldwide (Conand and Byrne, 1993) it is likely to become more important in tropical fisheries in the near future. Adults are dried and processed for their gummy meat (muscular body wall), which is exported primarily to China PR, Hong Kong SAR (China) and Singapore. The meat is high in protein, low in fat and believed to be an aphrodisiac. Literature evidence supports the fact that *A. mauritiana* does indeed contain compounds of potential biological activity (Stonik and Elyakov, 1988).

Actinopyga mauritiana is very common throughout the Indo-West-Pacific region (Conand, 1993). In the Red Sea, the species is usually found in subtidal and intertidal areas. It is very abundant in sandy areas, sea grasses and sand lagoons in the coral reef. The species is distributed over a wide range of depths from the reef flat to 30 m deep, but the majority of the individuals are found in between 5-10 m deep.

Few studies have been carried on the reproductive biology of *Actinopyga mauritiana* (Conand, 1993; Hopper *et al*., 1998; Ramofafia *et al*., 2001). The information on its reproductive mode is important for the sustainable management of the fishery and aquaculture of this species.

While sea cucumbers can reproduce sexually, the ability to reproduce asexually by transverse fission has been known to occur in eight aspidochirotide species (Uthicke, 1997), and may be artificially induced in several others (Reichenbach *et al*., 1996). Fission is a seasonally occurring event in *Holothuria atra* (Conand and De Ridder, 1990; Chao *et al*., 1993; Uthicke, 1997), *H. parvula* (Emson and Mladenov, 1987), *H. edulis* and *Stichopus chloronotus* (Uthicke, 1997). All fissiparous species also reproduce sexually by broadcast spawning of gametes during distinct spawning seasons (Conand, 1993). However, cloning by transverse fission is an important means of maintenance of population size in several echinoderm species (Emson and Wilkie, 1980; Ottesen and Lucas, 1982) including sediment-feeding sea cucumbers of the order aspidochirotida (Chao *et al*., 1993; Conand, 1996; Uthicke, 1997, 1998). The goals of the present study are first, to describe gonad development in *A. mauritiana* in the Red Sea and second, to evaluate the potential of asexual propagation through induced transverse fission as a simple, cost-effective method for population-size maintenance.

Materials and methods

Sampling sites

To study the reproductive biology of *Actinopyga mauritiana*, twenty specimens were collected monthly at Al-Gemsha Bay from December 2002 to September 2003. The bay is located in the Northern sector of the Red Sea (Figure 1), about 20 km from Hurghada (27º 66' 56" N: 33º 51' 45" E). The area of the bay is about 40 km² characterized by soft bottom habitat of sea grass beds dominated by *Halophila stipulacea* and *Halodula uninervis*. The depth of the bay ranges between 0.5 and 9 m, with a mean depth of 6 m. Animals were collected by SCUBA diving. Due to the dwindling animals stocks in the bay, the specimens for the asexual reproduction trial were collected from Nuwibaa on the Gulf of Aqaba (28º 43' 35" N: 34° 37' 22" E).

Figure 1. *Map of the Egyptian section of the Red Sea showing the sampling sites of* Actinopyga mauritiana.

Gonad dissection and processing

Total length was measured immediately on site to the nearest 0.5 cm to minimize the expected changes in the animal's size during transit. In the laboratory, total weight to the nearest 0.1 g was measured for each specimen and then all the animals were dissected. Gonads were removed, sexed, weighed to the nearest 0.01 g and preserved in 7 % formalin. The body wall weight was obtained, which is more representative than the total weight. The latter includes the coelomic fluid and digestive tract contents which causes considerable variability (Conand, 1989). For each animal, the gonad index (GI) was determined as:

$$GI = (Wg / Wb) \times 100$$

Where Wg is the wet gonad weight and Wb is the body wall weight.

The gonads' macro- and microscopic features were used to assess maturity stages following previous studies (Sewell, 1992; Tuwo and Conand, 1992; Ramofafia *et al*., 2001). These were wet gonad size, gonad colour and consistency, and presence of gametes in squash preparations. Based on these criteria, a four stage maturity scale was determined: Stage I, premature or recovery; Stage II, maturing; Stage III, mature; and Stage IV, post-spawning. Each gonad was examined and assigned to one of these stages. These four maturity stages were verified by histological examination. A sub-sample of 5 animals (representing the available size range) was taken from each monthly sample for histology. Small sections of gonad tubules were dehydrated, embedded in paraffin, sectioned (5 µm thick) and stained with haemotoxylin and eosin (H/E). Based on the staining response for H/E each gonad was assigned a gametogenic stage. The histological stages of gametogenesis were based on those used in previous studies of sea cucumber gonads (Tuwo and Conand, 1992; Ramofafia *et al*., 2000). Diameters of 30 oocytes from each of the different stages of vitellogenesis (pre-, mid-, and late vitellogenic stages) were also measured.

Asexual reproduction trial

This study was undertaken at a commercial private hatchery located on the Suez Canal coast. *Actinopyga mauritiana* were collected from Nwuibaa and transported to the hatchery in 1 000 litre lidded plastic containers. During the transportation time, the water was aerated. At the hatchery, the animals were placed in 10 m^3 concrete tanks with running seawater. The bottoms of the tanks were covered with a thin layer of sand. Before starting the experiment all animals were allowed to adapt to the new habitat for one week. To determine the potential of *A. mauritiana* to reproduce asexually, 180 individuals were used in this trial. They were separated into two size groups, each group was held in separate tank to assess the effect of size on the ability of the individuals to reproduce asexually. The first group contains 100 individuals ranging in length from 5 to 15 cm and weighing from 50 to 200 g. The second group contained 80 individuals ranging in size from 15 to 28 cm and weighing from 220 to 570 g.

In order to force asexual division, each sea cucumber was fitted with a rubber band across the mid-body. This was found to be efficient in the case of some tropical Pacific species (Reichenbach and Holloway, 1995). After the individuals had completely divided, the anterior ends were moved to separate tanks from the posterior ends. The tanks were monitored daily and the mortality rate was recorded. The experiment was maintained for three months and terminated when the internal organs, except the gonads, of all the divided halves had regenerated. Sacrificing some animals and scanning with ultrasound were two methods used to monitor the regeneration of the internal organs. The percentage of survival was calculated for each size group as following:

$$\text{Survival percentage } S\% = [(A+P)/2T]*100$$

Where (A+P) corresponded to the number of the anterior and posterior ends, respectively, and (T) to the total number of specimens that had undergone fission.

Results

Sex ratio

A total of 244 *Actinopyga mauritiana* were collected from Al-Gemsha Bay. Of the individuals sectioned (102 sexed and 142 unsexed), 53 individuals (52 %) were females, and 49 individual (48 %) were males. The unsexed individuals either carried unidentified gonads or had no visible gonads. The females and the males are more or less equal in proportion, giving a sex ratio of 1:1.

Maturity scale

Four stages of sexual maturity for *Actinopyga mauritiana* were defined according to the gross morphology and microscopic development in the gonads (Plates 1 and 2). The maturation process was similar morphologically and histologically. Table 1 summarizes the mean dimensions of the gonadal tubules and oocytes diameter at various maturity stages.

Stage I – premature or recovery.

Immature gonads could not be sexed by microscopic examination of the preparations. Sex could only be identified by histology. The tubules were white and unbranched fine thread-like tubules. Abundant pre-vitellogenic oocytes lined the germinal epithelium of the ovary (Plate 1A). Immature testes were characterized by the presence of spermatogonia and developing spermatocytes along the germinal epithelium (Plate 2A).

Stage II – Maturing

The tubules were longer, thicker and branched. Sex could be determined microscopically by the presence of developing gametes. Ovaries and testes were more whitish. Active vitellogenesis, with oocytes growing from early to later stages of vitellogenesis, was observed (Plate 1B). Growing testes developed numerous infolds of the germinal layer with columns of spermatocytes (Plate 2B).

Stage III – Mature

Tubules were bulging and their colour changed from whitish to off-white in males and orange in females. Oocytes were tightly packed and filled the entire tubule lumina (Plate 1C). Oocytes were not attached to tubule walls, which still held oogonia. At this stage, most oocytes were mature. They had a very wide, clearly visible nucleus. Mature testes were fully packed with spermatozoa. Spermatozoa appeared in the form of thick granules in the tubules lumina (Plate 2C).

Stage IV– Post-spawnimg

Tubules were flaccid and more or less empty, but a considerable part of the tubule volume was still occupied by undischarged gametes. Undischarged oocytes at various stages of deterioration were noted in females. Undergoing atresia (yellowish clusters) was observed (Plate 1D). Spawned testes still contained spermatozoa and exhibited a renewal of spermatogenesis with spermatocytes present along the germinal epithelium. Lumen became spacious and contained debris and phagocytes (Plate 2D).

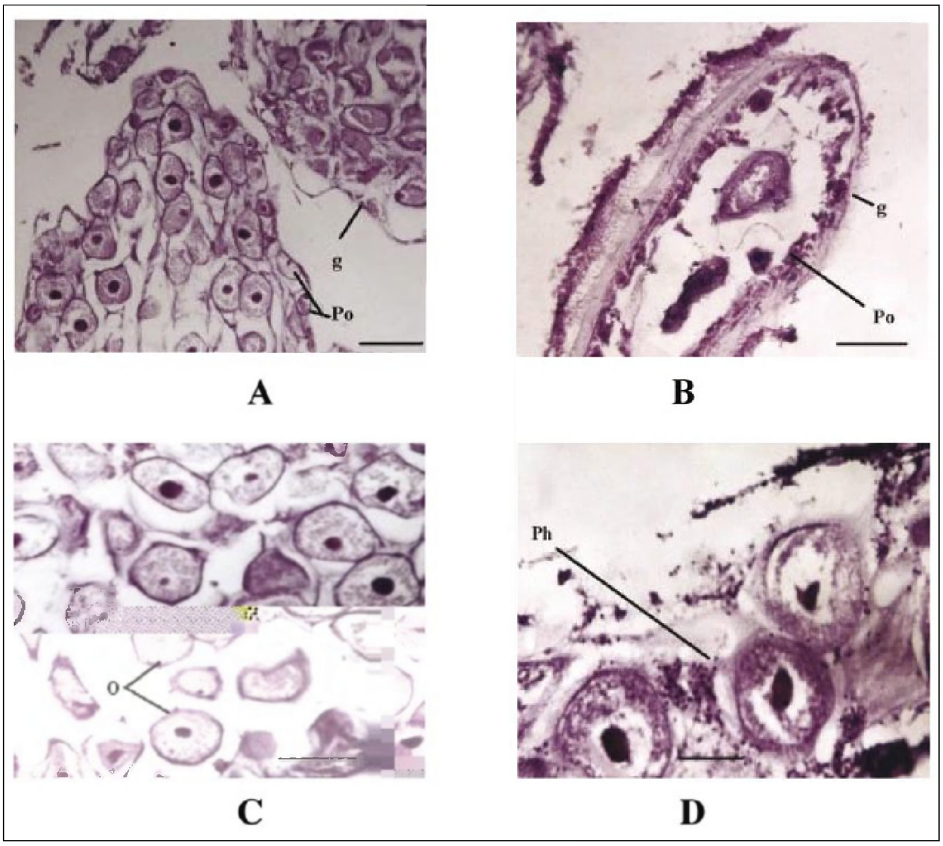

Plate 1. *Development for* A. mauritiana*: (**A**) Stage I, premature or recovery; (**B**) Stage II, maturing; (**C**) Stage III, mature; (**D**) Stage IV, post-spawning. **g**: gonad wall; **o**: ripe oocytes; **ph**: phagocytes; **po**: previtallogenic oocytes. Scale bars represent 100µm.*

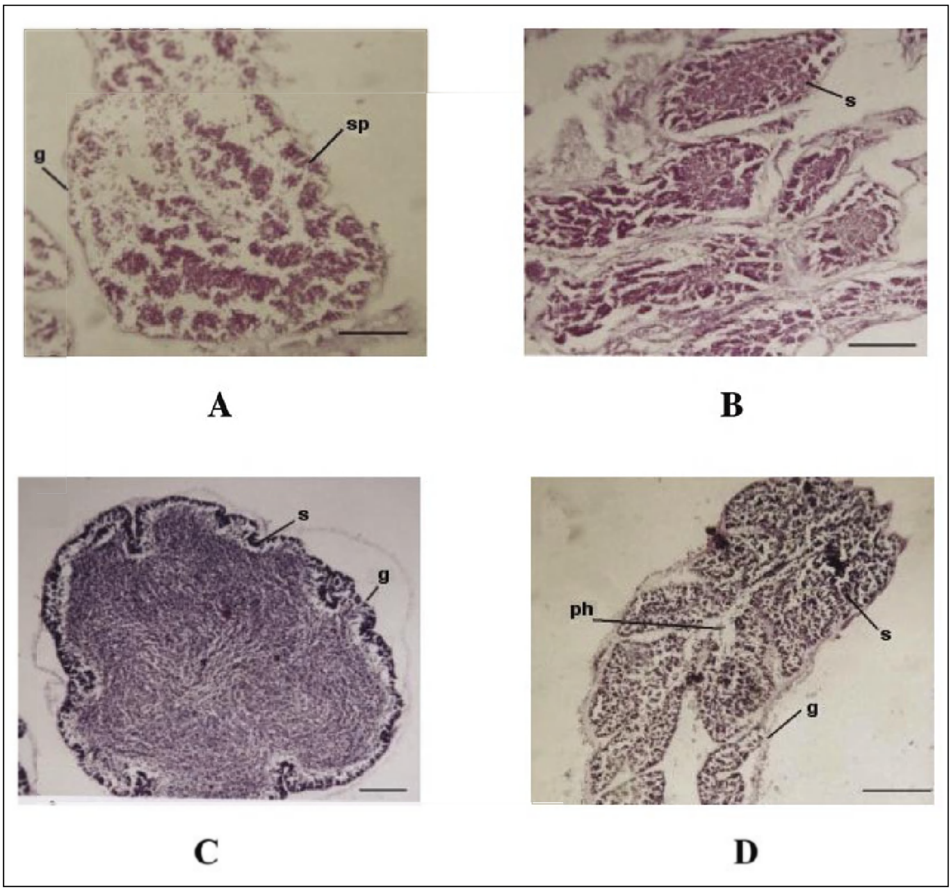

Plate 2. *Microscopic stages of male gonad development for* A. mauritiana*: (**A**) Stage I, premature or recovery; (**B**) Stage II, maturing; (**C**) Stage III, mature; (**D**) Stage IV, post-spawning. **g**: gonad wall; **ph**: phagocytes; **sp**: spermatogenesis; **s**: mature spermatozoa. Scale bars represent 100µm.*

Table 1. *The mean size of male (M) and female (F) gonadal tubules and oocytes diameters for* A. mauritiana *at different stages of development.*

Stage	Gonad tubules						Oocyte diameter (µm)
	Length (cm)		Weight (g)		Diameter (mm)		
	M	F	M	F	M	F	
Premature or recovery	3.00 ±0.50	2.50±0.40	0.15±0.20	2.51±0.70	0.23±0.01	0.13±0.26	19.60 ±0.37
Maturing	3.50 ± 0.20	4.50± 0.30	5.20±0.45	15.80±0.89	0.42±0.06	0.50±0.04	32.90 ± 0.03
Mature	9.80 ±0.40	12.00± 0.50	15.60±0.98	45.00±0.65	0.53±0.03	0.87±0.02	107.20 ± 0.43
Post-spawning	6.50 ± 0.44	7.30±0.30	8.50±0.84	18.35±1.65	0.45±0.06	0.60± 0.03	84.00 ± 0.91

Size at maturity

Figure 2 illustrates the relationship between the gametogenic stages (I, II, III, IV) and the length of the sea cucumber. This figure (based on 53 females and 49 males taken throughout the sampling period) indicates that the size at first maturation for female and male *Actinopyga mauritiana* occurs at similar sizes (23 and 22 cm for females and males, respectively).

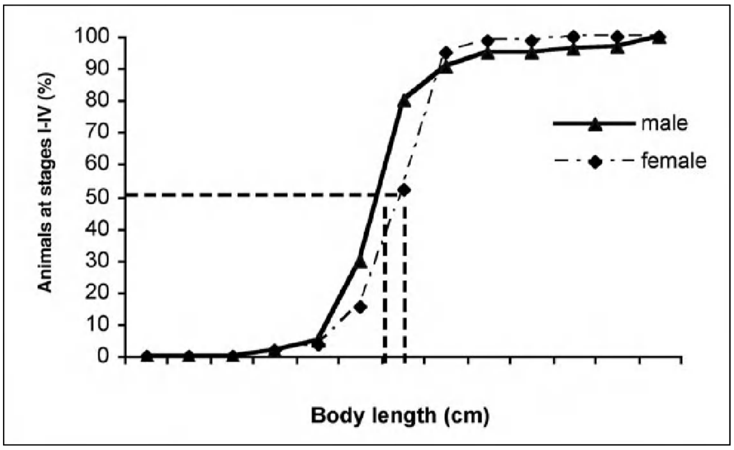

Figure 2. *Size at first sexual maturity of* A. mauritiana.

Monthly variation in maturity stages

To determine the spawning season, the occurrence of mature females and males throughout the period of study was examined. Figures 3 and 4 illustrate the monthly percentage composition of the maturity stages of female and male *Actinopyga mauritiana*, respectively. Most mature females and males (Stage III) were observed between March and August. Meanwhile, the peak incidence of mature males (Stage III) coincided with the peak incidence of spawning females (March to May).

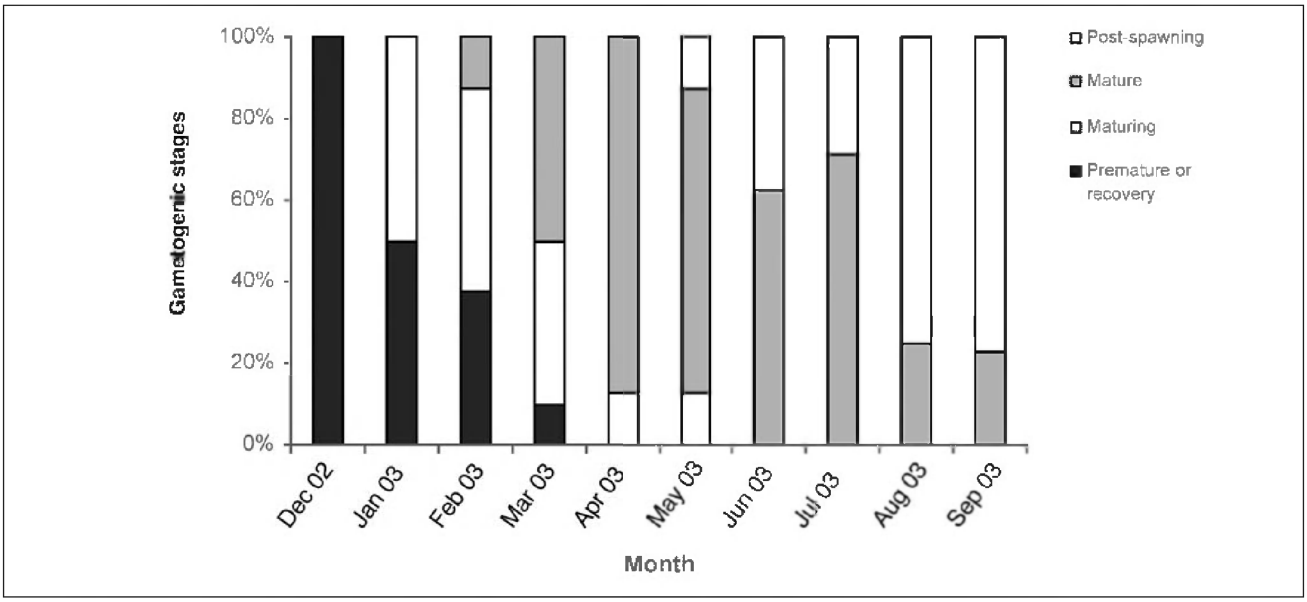

Figure 3. *Monthly variation of gametogenic stages in female* A. mauritiana.

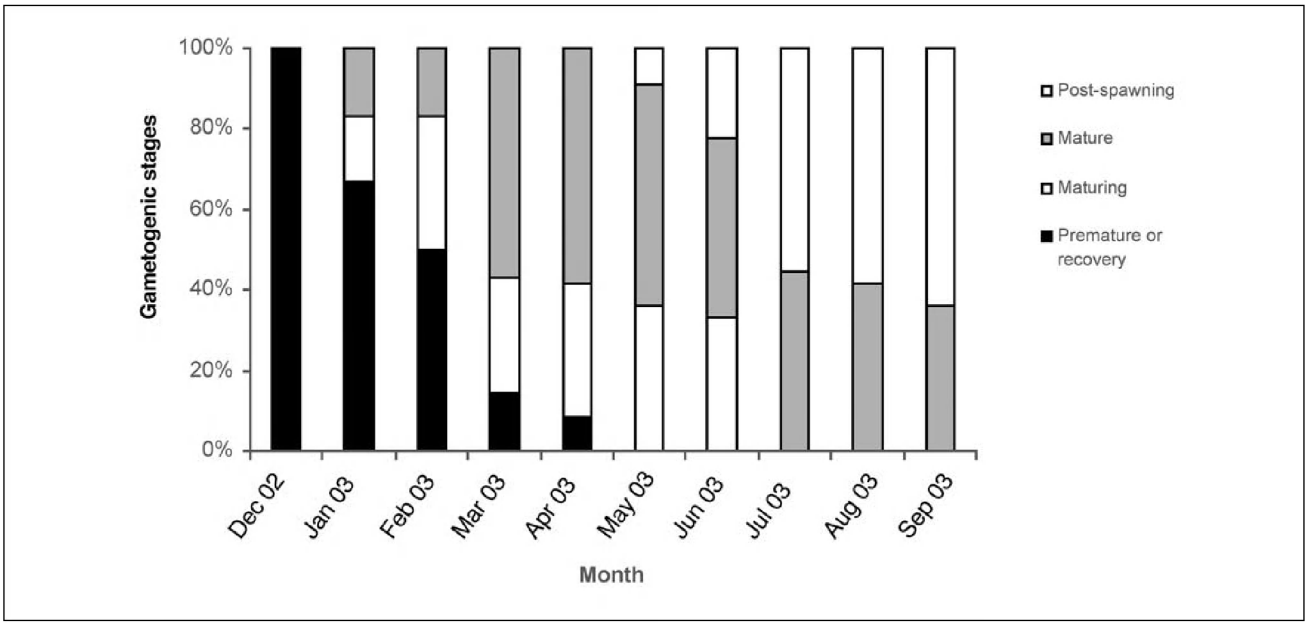

Figure 4. *Monthly variation of gametogenic stages in male* A. mauritiana.

Monthly changes in gonad index

The pattern of maturation indicated by examination of the gametogenic stages (Figures 3 and 4) was supported by the gonad index (GI). The seasonal variation in the GI was pronounced for both sexes (Figure 5). The female and male gonad index increased in March and peaked in April. This coincided with the peak percentage of mature specimens. The GI declined in May and June, then a gradually increased to an intermediate level in July and August. For both sexes, the GI dropped in September. The drop of GI in May and June was due to the presence of specimens with gonad weights that varied significantly from the mean.

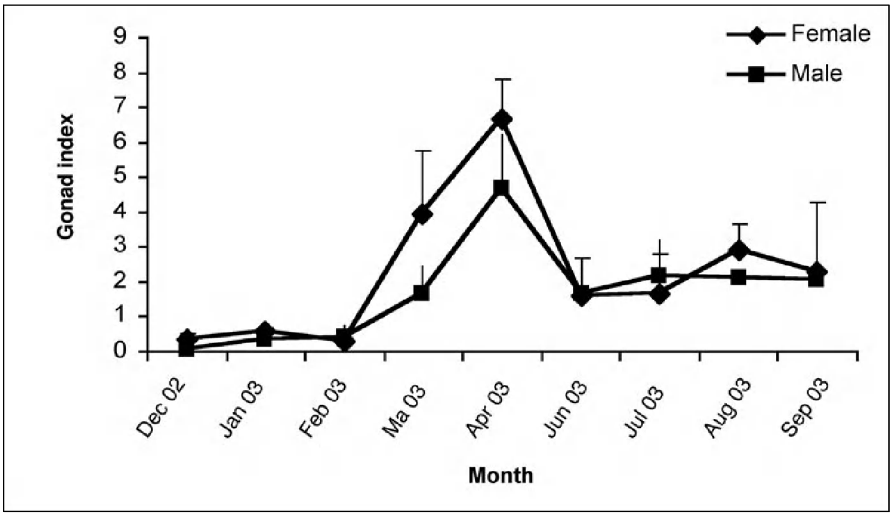

Figure 5. *Monthly variation in means gonad index (GI) for female and male* A. mauritiana.

Asexual reproduction trial

Observation - It is not known whether *Actinopyga mauritiana* is able to reproduce asexually by transverse fission in addition to its sexual mode of reproduction. However this experiment indicates that this species has some capacity to reproduce asexually in response to stressful conditions.

Immediately after the rubber bands were placed in the mid-body of the sea cucumbers, they started to constrict slightly in the middle and showed some swelling in the posterior section (Plate 3A). After one hour, the constriction became slightly more distinct; giving a heart shape to the posterior half (Plate 3B). The anterior and posterior sections slowly rotated in opposite directions resulting in a more distinct construction (Plate 3C). The posterior half of the individual remained stationary while the anterior end continued to move forward. At this point, the body wall at the fission site started to rupture, and some white tissue started to appear in the constriction area. The two body parts remained connected by only a string of tissue for at least four more hours (Plate 3D). The entire process of fission lasted for a whole day. The body wall at the fission site remained a liquid or mucus like consistency for at least six more hours (Plate 3E). After two days, the body wall had its normal consistency and the wounds at both ends were healed and nearly entirely closed (Plate 3F).

Dissections of the posterior and anterior halves of the individual immediately after fissions revealed that most of the intestines, and the respiratory organs (water lungs) were separated equally between the two sections.

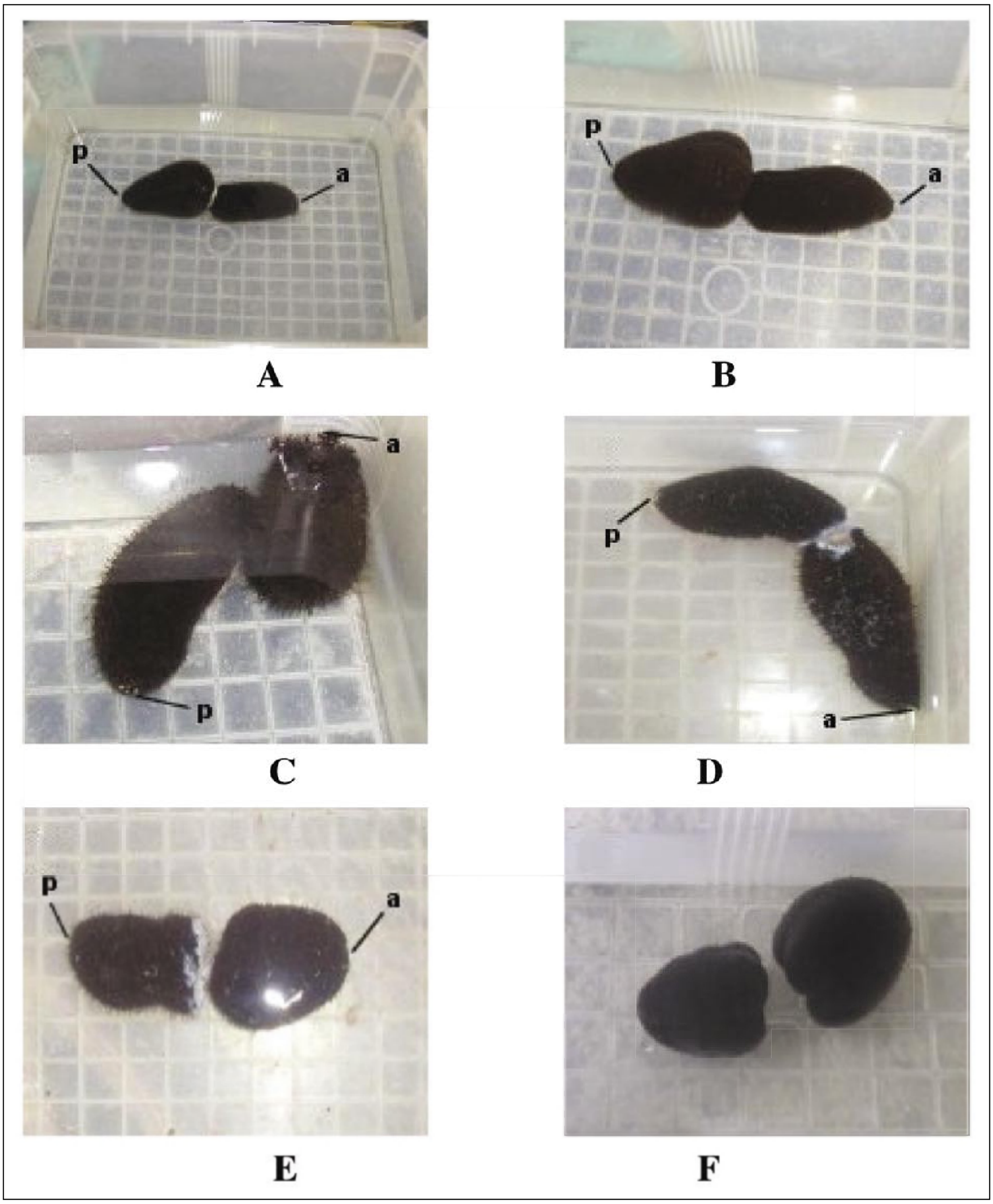

Plate 3. *Photographs showing the process of induced transverse fission in* A. mauritiana. ***a****: anterior part;* ***p****: posterior part.*

Survival rate

The survival rate of the small size group (average length 12 cm and average weight 130 g) was 75 % with 65 % survival of the anterior parts and 85 % survival of the posterior parts (Figure 6). The survival rate of the large size group (average length 19 cm and average weight 330 g) was 58 % with 50 % survival of the anterior parts and 66 % survival of the posterior parts (Figure 6).

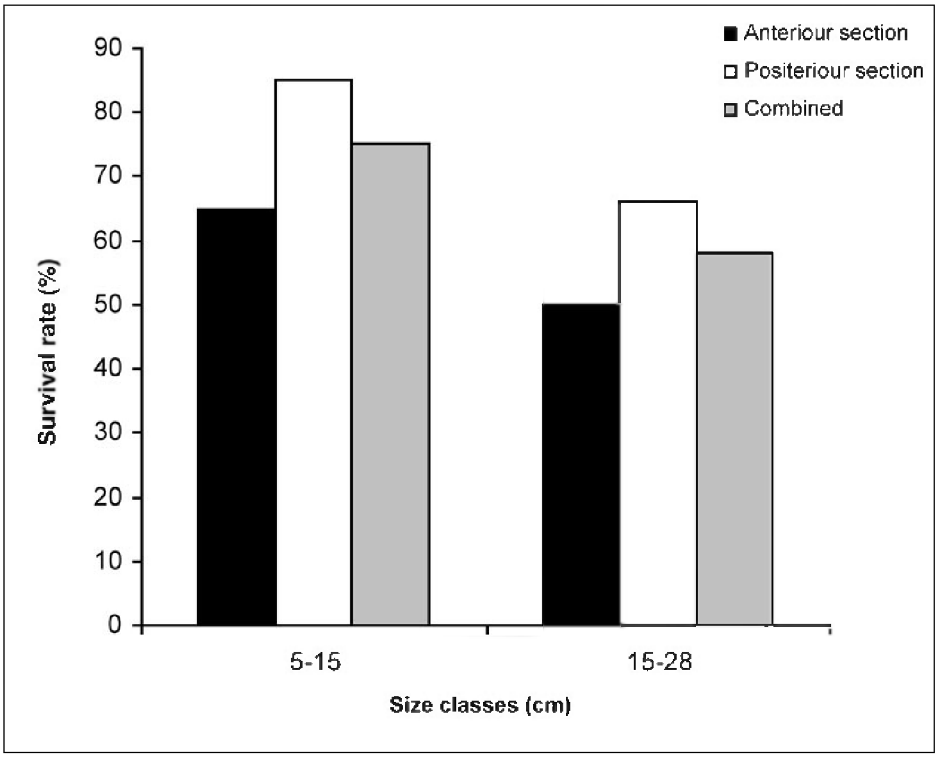

Figure 6. *Survival rate of asexual reproduction experiment for two size groups of* A. mauritiana.

Regeneration rate

Dissection of the sea cucumber on a monthly interval indicated that large individuals of *A. mauritiana* (average length 19 cm and average weight 330 g) were able to regenerate the posterior and the anterior parts into a whole individual, in around 100 days. In contrast, small animals (average length 12 cm and average weight 130 g) were able to regenerate both anterior and posterior parts into whole individuals in around 60 to 80 days. The shortest regeneration time was for the posterior parts of the smallest size class.

Discussion

Reproductive cycle

This species exhibits traits typical of many aspidochirote holothurian species: annual reproductive cycle, gametogenesis occurring in synchrony among sexes, partial spawning and total gonad resorption after spawning.

Size at first maturity was very similar for both sexes. The restricted spawning season for this species (spring and early summer) and the slight variation in temperature during this time (22-25 °C) will give rise to a cohort with minimal growth rate differences between individuals.

The size of gonadal tubules and oocytes diameters were correlated to gametogenesis and corresponded well to the descriptive maturity stages assigned to this species. This supports previous work on the same species in which the size of gonadal tubules was recommended as adequately reflecting the maturation process (Ramofafia *et al.*, 2001).

The data on gonad index, tubule morphology and gonad histology indicate that *Actinopyga mauritiana* has an annual reproductive cycle in the Red Sea and that gametogenesis occurs in synchrony in both sexes. In general, the period of peak reproductive activity is between spring and summer. An annual reproductive cycle with a summer spawning season has also been recorded for this species in Solomon Islands (Ramofafia *et al.*, 2001), New Caledonia and Guam (Conand, 1993; Hopper *et al.*, 1998).

Spawning in *Actinopyga mauritiana* is partial with mature and spawned tubules evident in dissected specimens during the breeding season. Furthermore, histology revealed that not all gametes were released from spawned tubules and that re-initiation of gametogenesis occurred in these tubules. It is not known whether unspawned tubules will eventually release their gametes. Partial spawning has been documented for the same species (Ramofafia *et al.*, 2001) and for *Holothuria fuscogilva* (Ramofafia *et al.*, 2000) in the Solomon Islands and has also been observed in other holothurians (Sewell, 1992; Hamel *et al.*, 1993).

This study showed that there was a period during the reproductive cycle in which the gonads were absent. This suggests that total resorption of the gonads may happen. The resorption of gonad in spawned individuals again supports the observations in previous studies on the same species (Ramofafia *et al.*, 2001) and as also observed in *H. fuscogilva* (Ramofafia *et al.*, 2000).

Asexual reproduction

Most holothurian species which have adopted asexual reproduction follow the "twisting-and-stretching" mode of fission (Emson and Wilkie, 1980): the anterior and posterior sections slowly rotate in opposite directions, resulting in a constriction of the body. This process had not been previously observed in *Actinopyga mauritiana.* Rubber bands placed mid-body of the individuals may provide an effective yet simple technique to induce transverse fission. Asexual reproduction in *A. mauritiana* did follow the twisting-and-stretching mode, as described for species of the genus *Holothuria* (Emson and Wilkie, 1980), which may take up to several hours. The mechanical properties of the body wall of many holothurians are well described for *S. chloronotus* (Motokawa, 1982, 1984). Connective tissue in holothurians (and other echinoderms) is named "catch-connective-tissue" (Motokawa, 1984) or "mutable collagenous tissue" (Wilkie, 1984). These tissues may contract or expand nearly instantaneously without the action of muscles, probably under the control of the nervous system (Wilkie, 1984). *Actinopyga mauritiana* appears to be another good example of a species with these properties. It appears that in addition to asexual reproduction, another important function of the catch connective tissue is to aide rapid wound healing.

The overall trend in the fission study was that higher survival rates were seen in the smaller size group and that the posterior ends had better survival and regeneration rates than the anterior ends. This was observed previously in other holothurians (Reichenbach *et al.*, 1996). The ability of the posterior parts to obtain oxygen needed for more energy may be a crucial factor in the process. This may be supported by the presence of the origin of the respiratory trees in the posterior part. On the contrary, the anterior part will obtain its oxygen through diffusion across the body until the respiratory trees are regenerated.

Out of the spawning season, asexual reproduction appears as the most practical option for increasing the stock of *A. mauritiana.* This study indicates that the survival and regeneration rate in small size individuals is higher (75 % survival and 60 days to regenerate) when compared with the larger individuals (58 % survival and 100 days to regenerate). Uthicke (2001) suggested that the body size of sea cucumber could have an effect on the likelihood of asexual reproduction taking place. This also agrees with previous studies on temperate water species, in which a sea cucumber takes from 30 to 120 days to regenerate (Byrne, 1985).

This possible application of asexual propagation of *A. mauritiana* would have to be carefully considered. At the simplest level, it may offer a good means of increasing the broodstock of cultured animals, thereby reducing the pressure on the natural environment. However, this will only be applicable if both the anterior and posterior sections are able to regenerate reproductive organs. These have not been observed in the current study.

Conclusions

Actinopyga mauritiana is commercially important for the production of beche-de-mer, a dried body wall product. Depletion of wild stocks and interest in aquaculture of this species prompted the current investigation of aspects of their biology essential for artificial culture. *A. mauritiana* has an annual reproductive cycle. Gametes are spawned from early spring through to summer with increased spawning activity in spring. Spawning coincided with the spring plankton bloom in the Red Sea, increasing day length and seawater temperature. This suggests that food supply, photoperiod and temperature should be tested as triggers for artificial spawning of broodstock in culture. Although, in nature asexual reproduction has not been observed in *A. mauritiana*, it is induced readily in the laboratory. The overall trend was that the survival rate increased in smaller individuals. The implications of this for the management of *A. mauritiana* populations and the fishery will require careful consideration. In the first instance, further research is required on the possible influence of fission on sexual reproductive activities and genetic alterations of culture and wild populations.

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

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Abstract

This 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. Sea cucumbers were subjected to thermal stimulation during March-May, the major breeding peak, and also during November-December, the minor breeding peak. The males released sperm within three hours of stimulation and were followed by females spawning 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. The next day early 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 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 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 which is beneficial both to prawns and sea cucumbers. In recent years the prawn farming industry in India has been rocked by disease and legal problems. The culture of sea cucumbers in prawn farms comes as a bonus for the prawn farmers.

Keywords: Broodstock, larval rearing, juvenile rearing, prawn farming

印度糙海参（*Holothuria scabra*）的人工育苗和养殖技术的研究

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摘要

本文介绍印度产的糙海参（*Holothuria scabra*）的育苗和养殖技术。第一次的育苗成功是1988年，由印度东南沿海的上第考林水产研究所完成的。个体大而健康，未受伤的个体被选作亲本。亲本被暂养在育苗场1吨的水池里。将亲本采集地的海泥铺在池底供海参潜伏。每天更换海水，海泥每两周更换一次。3-5月间采用温度诱导容易奏效，是产卵的高峰季节，而11-12月份是产卵的低谷。在温度诱导后的3小时内，雄性先排精，大约1小时后雌性也开始产卵。受精卵用新鲜的海水洗后，在750升的水池内放30万粒卵。第二天早晨，受精卵发育到早期耳状幼虫。幼虫的饵料系等鞭金藻。第十天幼虫变态为樽形幼虫。在体形上樽形幼虫小于耳状幼虫。它们活跃地游动，但不摄食。3天后，部分樽形幼虫变态为五触手幼体。 此阶段幼体

的饵料是角毛藻和扁藻。此时仍然每天交换海水，但是池底无须每天清洗，因为有藻类饵料沉积在池底。两个月后，幼参体长达到20毫米。在育苗池内培育的幼参被分别放养在位于卡拉帕（Karapad）湾、法里努卡（Valinokkam）湾和港口内的1吨的水池、长方形网箱、维纶网围、塑料网围和混凝土圈内。最好的生长记录是养在靠近土第考林的虾池内的幼海参。众所周知，虾池内的残剩饲料在虾池内造成富营养化，污染水体。海参是以有机碎屑作为食物的。虾池内所养的海参不会对对虾产生不利影响，相反，海参为虾池清除掉过多的残饵，有助于对虾的生长。因此，海参与对虾养在同一池塘内形成生态互利的关系。近年来，对虾养殖业由于受到疾病的危害和法律的限制一直是踌躇不前。在虾塘内养殖海参为对虾养殖带来了实惠。

关键词：亲本、幼虫培养、幼参培养、对虾养殖

Introduction

According to the latest report of the Food and Agriculture Organisation (FAO) on world capture fisheries, production of sea cucumbers during 2001 was 18 900 tonnes (Vannuccini, 2004). India exported 50 tonnes of processed sea cucumber in 1989, valued at US$ 0.2 million. At present, the Government of India has completely banned collection, processing and export of all species of sea cucumbers from India as a conservation measure. According to Hornell (1917) the beche-de-mer industry in India is an ancient one, having been introduced by the Chinese more than one thousand years ago. Since sea cucumbers do not offer resistance at the time of capture and also do not make any attempts to escape, the resource is over exploited in many parts of the world. A classic example of this case is the beche-de-mer industry in the Maldives, which developed in 1985 with a modest export of 31 kg. Within 5 years the resource was in danger of over exploitation (Joseph and Shakeel, 1991; Joseph, 1992). James and James (1994a,b) wrote on the needs for conservation and management of sea cucumbers in India. A new resource of sea cucumber, *Actinopyga echinites*, was exported for the first time from India in 1989 and by 1992 this resource had become scarce (James and Badrudeen, 1995). Another species, *A. miliaris*, was collected for the first time in 1992 and, within 2 months, more than 0.6 million specimens were caught. James and James (1994) published a handbook on Indian sea cucumbers to facilitate identification of commercially important sea cucumbers from India. James and Ruparani (1999) gave an account of new resources of beche-de-mer and the management of these resources in India. In order to replenish the natural populations, hatchery technology for juvenile production and sea ranching was developed by the Central Marine Fisheries Research Institute in India.

The Chinese and Japanese are pioneers in the aquaculture of the sea cucumber, *Apostichopus japonicus*. Apart from these two countries some work has been completed on the production of sea cucumbers by the Koreans and the Russians. James *et al.* (1988) produced juveniles of *H. scabra* for the first time in 1988 at Tuticorin in India. Following this same technology, juveniles of this species have been produced in Australia, Indonesia, New Caledonia, Maldives, Solomon Islands and Viet Nam in recent years.

Hatchery production

Apostichopus japonicus juveniles were produced more than 60 years ago in Japan (Inaba, 1937) and were successfully reared (Imai *et al.*, 1950). Subsequently, Shuxu and Gongchao (1981), Li (1983) and Shui *et al.* (1986) reported on the breeding and culture of this species in China. In recent years there have been several authors from China and Japan who have worked on the artificial breeding of this species. James *et al.* (1988) produced *Holothuria scabra* juveniles for the first time in India. Since 1988 this species has been bred in captivity on a number of occasions (James 1993a, 1997, 1998; James and James, 1993; James *et al.* 1994a, b). Chen and Chan (1990) reported on the larval development of *Actinopyga echinites* and James *et al.*, (1993) reported on the spawning of *A. mauritiana*, while Asha and Rodrigo (2001) and Asha and Muthiah (2002) reported on spawning and larval rearing of *Holothuria spinifera* in India.

Collection of broodstock

Large and healthy broodstock specimens (Figure 1) were collected from the commercial catch destined for processing. Most individuals were collected by divers in shallow waters up to a depth of 10 m. The diving season for sea cucumbers is from October to March in the Gulf of Mannar and from March to October in Palk Bay.

Maintenance of broodstock

After collection, individuals were brought to the hatchery and stocked in one tonne tanks (Figure 1). Usually 15-20 specimens were stocked in an area of 2 m^2. The bottom of the tank was covered with mud from the natural habitat to a thickness of 15 cm to allow the broodstock to bury themselves. The water in the holding tanks was changed each morning and the mud at the bottom of the tanks changed every fortnight. Before use, the tanks were thoroughly cleaned with bleaching powder and put out in the sun to dry.

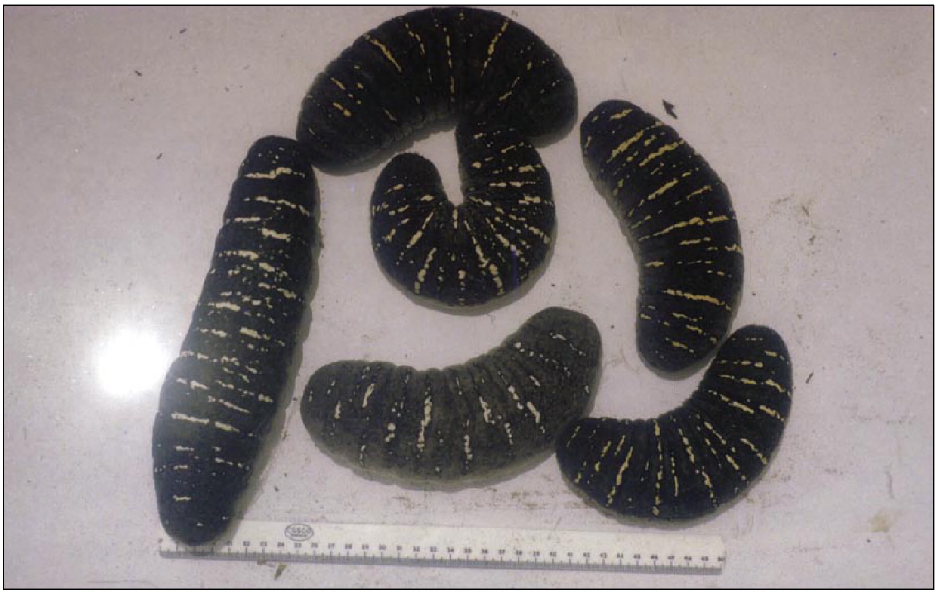

Figure 1. *Broodstock of Holothuria scabra.*

Thermal stimulation

Best results for thermal stimulation were obtained only during the breeding peaks (March-May) of the sea cucumbers. The temperature of the water was raised by 3-5 °C by slowly adding hot seawater and stirring uniformly. Usually 20 specimens were introduced into the tanks at 10:00 hrs. By 13:00 hrs the males had released sperm by raising the anterior end (Figure 2). One hour or so after the males had released sperm, the females started releasing the oocytes. Simultaneously, several males in the tank were still releasing sperm. It is better to keep only one male spawning in the tank, otherwise the over-abundance of spermatozoa clouds he water.

Figure 2. *A mature* Holothuria scabra *male in the act of spawning.*

Spawning behaviour

In sea cucumbers the sexes are separate but it is not possible to separate the males and females from an external examination in most species. In the case of *H. scabra*, only a microscopic examination of the gonads reveals whether the specimen is a male or a female. However, it is possible to distinguish them at the time of spawning since the spawning behaviour of the males and females is different. Typically, males spawn first, followed by females. The male first lifts the anterior end (Figure 2) and exhibits swaying movements just like a snake. After exhibiting such movements for some time the males start releasing the sperm in a fine white stream from the gonopore situated at the anterior end and in the mid-dorsal position. When a male starts releasing the sperms it continues for nearly 2 hours. Meanwhile the ripe females start reacting, possibly to the presence of sperm released in the water. The anterior ends of females become bulged due to the pressure created inside the gonopore by the accumulation of oocytes. The female releases the oocytes which settle down on the bottom of the tank. Sometimes the same females spawn for a second or even third time; this is mainly observed in large specimens. The oocytes are ejected out through the single gonopore. They are ejected out in a powerful jet reaching a distance of about one metre, helping in the dispersal over a wide area. The gametes are released as a light yellow mucus-like substance.

Fertilization

The fertilization is external and takes place in the water column. The oocytes are fertilized quickly as they make contact with the spermatozoa. After the oocytes and sperm are released in the water, the sea cucumbers are removed from the tank. The eggs are washed in fresh seawater several times to remove the excess spermatozoa. Excess spermatozoa can reduce the rate of fertilization and cause the development of deformed embryos.

Early development

Large females can release about one million oocytes. About 0.7 million eggs were stocked in 750 litres of water. The eggs were spherical, white and visible to the naked eye and were found floating in the water. The diameter of the oocytes ranged from 180 to 200 µm. After fertilization the eggs underwent cleavage and developed into the dipleurula stage with eggs ranging in length from 190 to 250 µm. The dipleurula transformed into early auricularia larva after 24 hours. They are 430 µm long and 280 µm wide at this stage.

The early auricularia larvae have a buccal cavity, ciliary bands, a cloaca and an anus and they actively feed. They were fed on the microalgae, *Isochrysis galbana,* and a mixed culture dominated by species of *Chaetoceros* spp. and *Skeletonema* spp. As days passed the auricularia (Figure 3) became more and more transparent and the lateral projections also became prominent. On each side of the late auricularia larva, four lateral projections were seen and at the end of each projection there was a hyaline sphere. The oesophagus and the pear-shaped stomach were well demarcated. Right and left stomatocoel were clearly seen. The ciliary bands showed a number of pigment spots. The length of the late auricularia larvae varied from 660 to 1050 µm (with an average of 860 µm) and the width was 240-690 µm (with an average of 500 µm). Some of the auricularia larvae remained small.

A few of the late auriculariae transformed into doliolariae (Figure 4) on the tenth day. The doliolariae were barrel-shaped with five hyaline spheres on each side. Later, the first two tentacles developed at the anterior end. Their length varied from 420 to 570 µm (with an average of 485 µm) and 240-390 µm in breadth (average of 295 µm).

On the thirteenth day, some of the doliolariae transformed into pentactula larvae (Figure 5). The body of the pentactula was tubular with five tentacles at the anterior end and with one short stumpy tube foot at the posterior end which helps in locomotion. The anal opening was distinct. The length varied from 330 to 750 µm (average of 307 µm). By the eighteenth day the tube feet and tentacles became distinct. Two long tube feet developed at the posterior end. At this stage the length of the juveniles was 550-720 µm (average of 656 µm) and the width varied from 210 to 320 µm (average of 262 µm). The pentactulae had the habit of moving to the edge of the tank, remaining just below the surface of the water. They soon settled down on the bottom of the tank.

Figure 3. Sea cucumber auricularia stage.

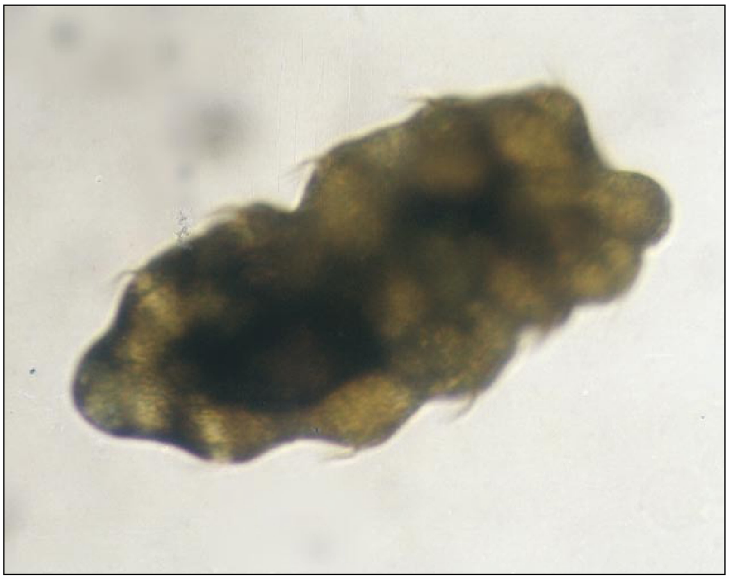

Figure 4. Sea cucumber doliolaria stage.

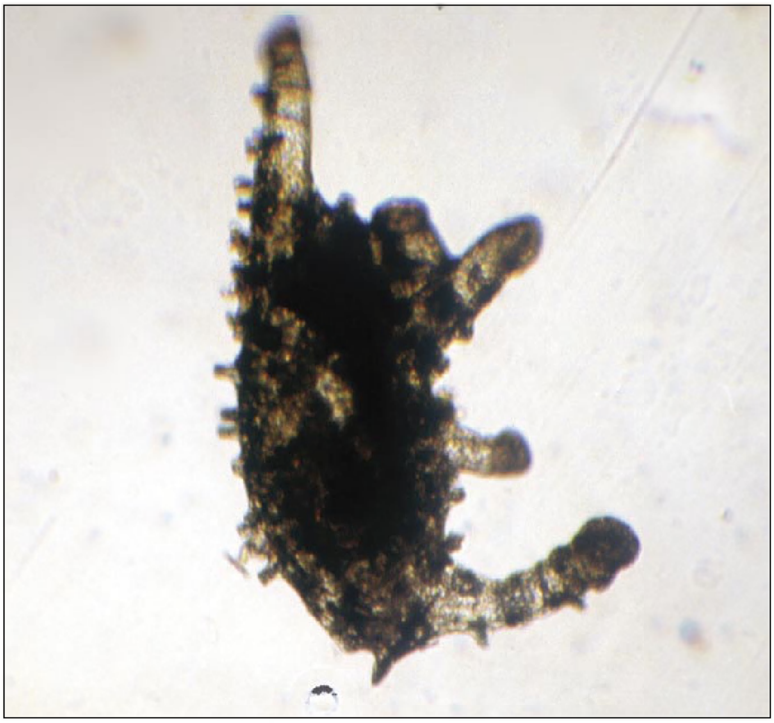

Figure 5. Sea cucumber early juvenile stage.

Rearing of the post larvae

Preparation of the rearing tanks

All rearing tanks used in breeding, especially new tanks must be scrubbed clean and filled with seawater for 20 days. During this period the water in the tanks is repeatedly changed. Before the tanks are used, they are then scrubbed and filled with seawater containing 40 ppm bleaching powder and then washed clean with filtered seawater.

Rearing density

Strict control over the rearing density of the larvae (i.e. the number of larvae per ml of water) is maintained. At present there are two methods used to rear the larvae: still water rearing and flowing water rearing. Auricularia larvae during their early and middle stages concentrate at the surface of the water. If the density of the larvae is high, they will form agglomerations and sink to the bottom of the tank resulting in their death. Rearing density, therefore, should be controlled to ensure better survival rates. The desirable density of auricularia is 300-700 per litre. In a one tonne tank filled with 750 litres of water, 0.3 million auriculariae can be reared.

Selecting and counting of larvae

After the embryos are transferred to rearing tanks, they develop into auricularia larvae in about 30 hours. Healthy larvae occupy the surface layer of the water while deformed larvae and dead embryos are found in the lower layer of the water column or on the bottom of the tank. A sample can be removed for counting the larvae. Samples can be taken separately from the two ends and the middle of the tank using 250 ml beakers. The sample is stirred and a 1 ml aliquot is taken with a pipette and placed on a plankton counting chamber to assess the number of larvae. Two more samples are taken and the average of three counts is taken as an indication of the density of the larvae. When the auricularia larvae are in the early stage of development, they should be reared at a density of about 500 larvae per litre. The development of the auricularia can be divided into three stages: early, middle and late.

Water management

During their development, the larvae eject faeces and consume dissolved oxygen constantly. Some of the larvae will die. These, together with excess food, will produce harmful substances such as hydrogen sulphide and ammonia. In addition, bacteria reproduce rapidly with the rise of temperature. Poor water quality directly affects the normal development of the larvae. Therefore proper water management and sanitation is essential, including regular cleaning of the tanks and frequent changing of water. Sediment and deformed larvae at the bottom of the tank have to be siphoned out preferably on a daily basis.

During water changes a sieve (80 µm mesh size) is used to prevent loss of eggs and/or larvae. While the water is being changed, it is advisable to constantly stir the water lightly around the tank. This will prevent damage to the larvae during the water change as without stirring the larvae would be forced into the sieve causing mechanical injury.

Larval feeding and feeding rates

High quality microalgae and proper feeding schedules are key factors in the successful rearing of sea cucumber larvae. Early auriculariae possess a well formed alimentary tract and must be fed. Ingestion by these larvae consists of conveying the suspended particles of food into the alimentary canal through the mouth parts by the swaying of peristomial cilia. The effectiveness of *Isochrysis galbana*, *Dunaliella salina*, *Dicrateria* spp. and mixed diets consisting of all the above mentioned microalgae was tested. The best growth rates and lower mortality were observed when larvae were first fed *I. galbana* and supplemented with mixed cultures, chiefly consisting of *Chaetoceros* spp., four or five days later. Unicellular algae were given twice a day but the amount given depended on the particular stage of the larvae. In general, a concentration of 20 000 to 30 000 cells per ml was maintained in the rearing tank. The amount of food given should be increased or decreased depending on the abundance of food observed in the stomach of the larvae. This can be visually assessed everyday before feeding.

Environmental factors

Monitoring of the environmental factors is important since the larvae and the juveniles are sensitive to environmental changes.

Temperature

At Tuticorin, the temperature of the seawater ranged from 26 to 30 °C. The optimum temperature for rearing of the larvae was found to be 27-29 °C. The temperature of the water should be recorded twice a day - once in the morning and once in the afternoon.

Dissolved oxygen

Dissolved oxygen (DO) levels vary with water temperature. The higher the temperature the lower the DO level. At Tuticorin, the normal DO level was around 5-6 ml per litre. Constant aeration was provided to the larval tanks throughout the day to make sure the oxygen level did not decrease. For a 1 tonne tank, two aerators are generally provided, one at either end.

pH

Under normal conditions the seawater is alkaline with a pH of 7.5-8.5. Tests have shown that the larvae adapt to a fairly wide range of pH. However when the pH rises above 9.0 or drops below 6.0, the movements of the larvae weaken and the growth stops. Therefore the pH of the water must be maintained between 6.0 and 9.0.

Salinity

Salinity of normal seawater at Tuticorin ranges from 31 to 34. The lethal critical salinity is 12.9, whereas the optimum salinity for larval development ranges from 26.2 to 42.7. In this range the higher the salinity the quicker the development. Extreme salinity levels adversely affect the normal development of embryos and larvae, resulting in a large number of deformed larvae and death.

Ammoniacal nitrogen

The ammoniacal nitrogen content of seawater is very low. The main sources in breeding tanks are the metabolites of the larvae, excess food and decomposing organisms. Accumulation of ammonia in concentrations above 500 mg/m^3 can be harmful for the larvae. The larvae can develop normally with ammoniacal nitrogen in the range of 70 to 430 mg/m^3 of water.

Rearing of juveniles

The pentactula settles when food is sufficient and also when a hard substratum is available. If these two conditions are not satisfied the pentactula continue to swim in the tank for long periods.

Types of settling bases

Two types of settling bases have been tried. Rough surface tiles were used in the first case. Filtered seawater was circulated in the tanks continuously for four or five days in good sunlight. Tiles were suspended in the water. After settlement of benthic algae on the tiles, the tiles were taken inside the hatchery and suspended in the tanks holding the doliolaria larvae. The hard surface and available food induced the doliolaria to metamorphose into pentactulae and subsequently settle on the tiles. One disadvantage with tiles of this type is that the benthic algae can die and easily come off after four or five days particularly in shady conditions.

An alternative settling method is to use polythene sheets that are kept in the tank filled with seawater. An algal extract, usually *Sargassum* spp. that has been filtered through a 40 µm sieve, is added to the tank. The algal extract sticks to the polythene sheets. The seawater is changed daily and fresh algal extract added in small quantities. After four or five days the polythene sheets become covered with a fine coat of algal extract and this serves as a good settling base for the larvae.

Juvenile diet

Newly metamorphosed juveniles have limited swimming ability and their tentacles are short. Seaweeds like *Sargassum* spp. and *Halimeda* spp. were tried as food. Protein rich *Sargassum* spp. and the sea grass, *Syngodium isoetifolium*, have been found to be suitable feed for the juvenile sea cucumbers. The algae are cut into small pieces and then grounded into a fine paste which is then filtered using a 40 µm sieve. After one month of growth, the paste is filtered through an 80 µm sieve. This filtered extract is given to the juveniles twice a day, in the morning and evening. The juveniles were found to feed actively on the settled algal extract and grew well.

Density of settled juveniles

When the larvae develop into juveniles they begin to crawl on the substrate with most of them remaining on the settlement plates. Fifteen days after settlement they can be clearly seen with the naked eye. At this stage the number of juveniles should be estimated. The sampling area of each tank must account for over 5 % of the total surface area. In order to achieve increased survival rate, it is necessary to maintain the settling density at the optimum level between 200 and 500 juveniles/m^2. Higher densities and insufficient food will adversely affect growth and survival. Juveniles reach 20 mm in length after two months (Figure 6) and 40 mm after four months (Figure 7).

Figure 6. *Two-month old hatchery produced sea cucumber juveniles.*

Figure 7. *Four-month old hatchery produced sea cucumber juveniles.*

Predators and their control

Predation

Harpacticoids and other copepods and ciliates are the main predators of slow moving auricularia larvae. The predators usually attack the auricularia causing injuries and eventually killing them. They also harm the juveniles by reproducing rapidly in the rearing tanks and thus competing for food. Algal extracts of *Sargassum* spp. given for the juveniles are often found in the alimentary track of the copepods.

Predator control

The effectiveness of various chemicals was tested for the control of Harpacticoids and other copepods. Harpacticoids are sensitive to organic phosphorous and thus Dipterix, Kogor and other chemicals containing organo-phosphorous are effective. It was found that Harpacticoids can be killed with 2 ppm Dipterix in two hours with no harmful effects on the juveniles. The Dipterix solution should be evenly sprinkled into the tank and the water changed completely after two hours otherwise the chemicals may affect the juveniles.

Sea ranching

As stated in the introduction, a sea cucumber resource can quickly become over exploited since the animals do not make any attempts to avoid collection and do not have any effective defensive mechanism. This has made the sea cucumbers very vulnerable and natural populations have dwindled alarmingly as a result of overfishing. The juveniles produced in the hatchery are used for sea ranching in natural beds of sea cucumbers so that the natural population can be replenished. Trials are currently being conducted to test the effects of sea ranching in a particular area. James (1993b) provides details of sea ranching of sea cucumbers.

Future prospects

Studies conducted in India showed that the sea cucumber juveniles and young adults of *Holothuria scabra* grow relatively fast in prawn farms by making use of the feed waste. The growth of the sea cucumber juveniles is three times faster when they are grown in the prawn farm without affecting the normal prawn farming activities. If juvenile *H. scabra* are produced in good numbers it is advisable to release them directly into the farm at the rate of 30 000 juveniles/hectare. The growth rate is expected to be better when freely grown in the prawn farm rather than in a confined space like a concrete ring. The juveniles are expected to reach harvestable weight at the end of one year.

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Sea cucumbers:
a compendium of fishery statistics

Sea cucumbers: a compendium of fishery statistics

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Introduction and methodological remarks

This compendium is a reduced version of the support document distributed at the Workshop on Advances in Sea Cucumber Aquaculture and Management (ASCAM), held in Dalian, Liaoning Province, China on 14-18 October 2003. The aim of this review is to present relevant fisheries statistics available on sea cucumbers in the FAO FIDI databases, namely statistics on capture fisheries production and foreign trade. With few exceptions, the statistics cover the 1991-2001 period. One of the main functions of the Fishery Information, Data and Statistics Unit (FIDI) is to collect, analyse, interpret and disseminate information relating to fisheries. FAO fisheries data are usually obtained from national offices and, whenever possible, are checked using other sources. When official data are unavailable to FAO or considered unreliable, estimates are provided.

Several methodological remarks must be made before reading this compendium. Total production of sea cucumbers is probably higher than indicated in this review due to several reasons. No aquaculture production of sea cucumbers has been reported to FAO by national offices. Another factor to be taken into account is the risk of the incorrect inclusion, by some countries, of their production of farmed sea cucumbers under their reporting of sea cucumber capture statistics. Furthermore, there were countries that did not separately identify their production of sea cucumbers (farmed or caught in the wild), but they included it in more generic groups from which is not possible to identify the exact volume of sea cucumbers produced. This is, for example, the case of a large producer such as China, which does not identify production of sea cucumbers separately in their reporting to FAO. Another major problem lies in trade statistics. There are countries that record and report their trade of sea cucumbers in a specific group called "sea cucumber" (in fresh or chilled; frozen; dried, salted or in brine forms), but there are many others that report this trade in a more generic group named "sea cucumber and other invertebrates" (fresh or chilled; frozen; dried, salted or in brine; canned; preparations). It is, therefore, not possible to determine the exact amount of sea cucumbers included in this generic group and, therefore, the exact volume of sea cucumber traded internationally. In this review, trade of these two main groups is shown separately and it is important to bear in mind that sea cucumbers may represent only a small fraction in the "sea cucumber and other invertebrates" group.

FAO FIDI fisheries statistics are accessible to external users, as downloadable databases, together with a retrieval and analytical software, at: http://www.fao.org/fi/statist/FISOFT/FISHPLUS.asp. For more detailed information on the concepts, composition, coverage and methodologies followed for the compilation of statistics on capture fisheries production, aquaculture production and fishery trade, please refer to the FAO Yearbooks of Fishery Statistics or contact the FAO Fishery Information, Data and Statistics Unit, Fisheries Department, Viale delle Terme di Caracalla, 00100 Rome, Italy; Email: FIDI-Inquiries@fao.org; Fax: +39 06 57052476.

Standard symbols

0	more than zero but less than half the unit used	**nei**	not elsewhere included
-	none; magnitude known to be nil or zero	**F**	FAO estimate
...	data not available; unobtainable	**%**	Percentage

Reference

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Capture fisheries production of sea cucumbers

World capture fisheries production of sea cucumbers increased from 4 300 tonnes in 1950 to a peak of 23 400 tonnes in 2000, subsequently decreasing to about 18 900 tonnes in 2001 (Figure 1). In this past year, two main groups of species of sea cucumber were reported: sea cucumbers nei (*Holothurioidea*) with 10 730 tonnes and Japanese sea cucumber (*Stichopus japonicus*) with 8 130 tonnes. Japan was the top producer of sea cucumbers caught in the wild with more than 7 200 tonnes in 2001, representing a 10 % increase compared to 1991, followed by Indonesia (3 250 tonnes), the USA (1 800 tonnes) and Papua New Guinea (1 450 tonnes).

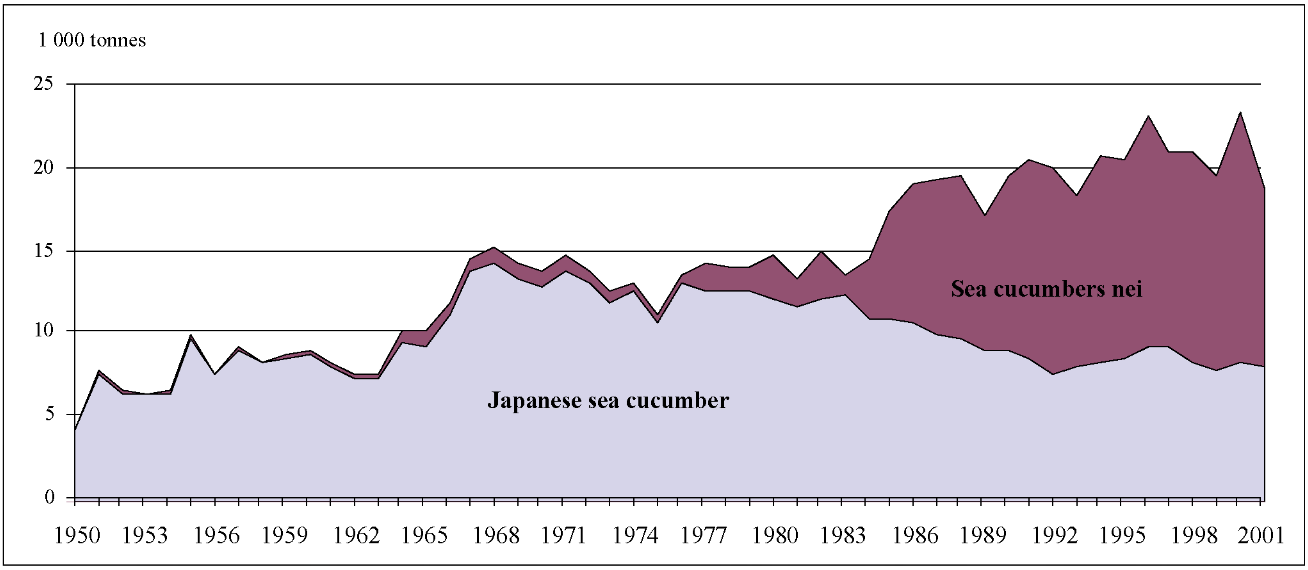

Figure 1. *Capture fisheries production of sea cucumbers by species. Source: FAO, Fishstat Plus (v. 2.3), Capture Production 1950-2001.*

In 2001, 66 % of world production of wild caught sea cucumbers originated from Asia, followed by Oceania (16 %), North and Central America (12 %, showing the strongest increase in production) and Africa (5 %) (Figure 2).

The bulk of the sea cucumber production was caught in the Pacific Ocean, in particular in the Northwest Pacific (43 %) and in the Western Central Pacific (32 %).

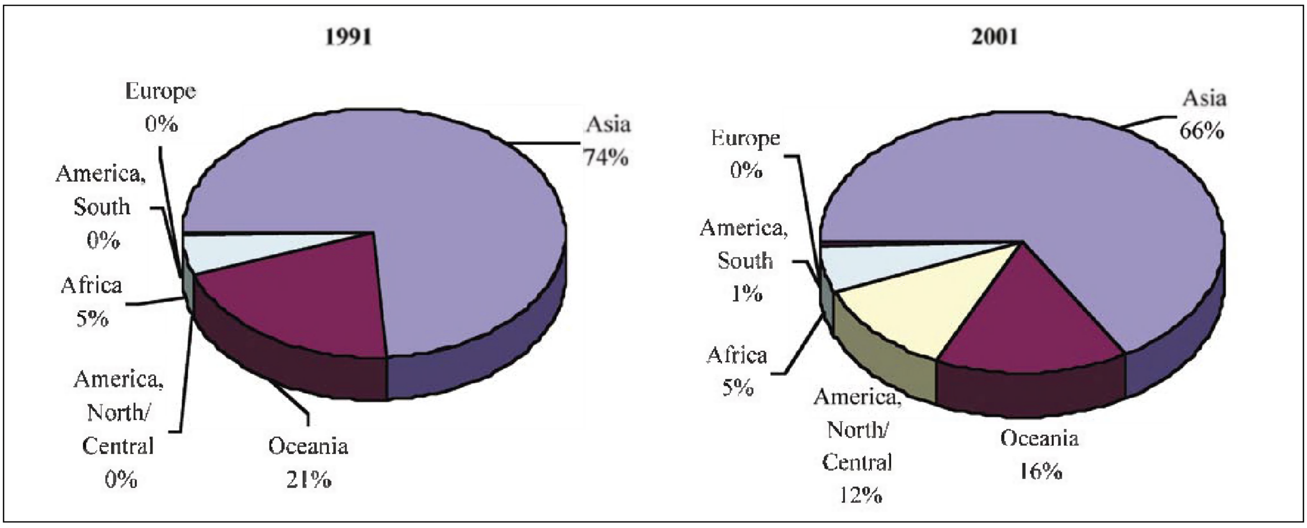

Figure 2. *Capture fisheries production of sea cucumbers by continent. Source: FAO, Fishstat Plus (v. 2.3), Capture Production 1950-2001.*

Exports of sea cucumbers and other invertebrates

In 2001, exports of "sea cucumbers" were more than 5 300 tonnes (Figure 3), with a value of US$ 30.9 million. This represented a 43 % decrease in volume terms and a 25 % decline in value terms compared to 1991. In 2001, 84 % of the volume and 90 % of the value of these exports consisted of cured sea cucumbers (Figure 3). In volume terms, China Hong Kong SAR was the leading exporter in 2001, with 3 900 tonnes, followed by China (650 tonnes) and the Solomon Islands (270 tonnes). China Hong Kong SAR was also the main exporter in value terms in 2001 with US$ 22.7 million, followed by Sri Lanka (US$ 1.9 million) and Taiwan Province of China (US$ 1.8 million) (Figure 4).

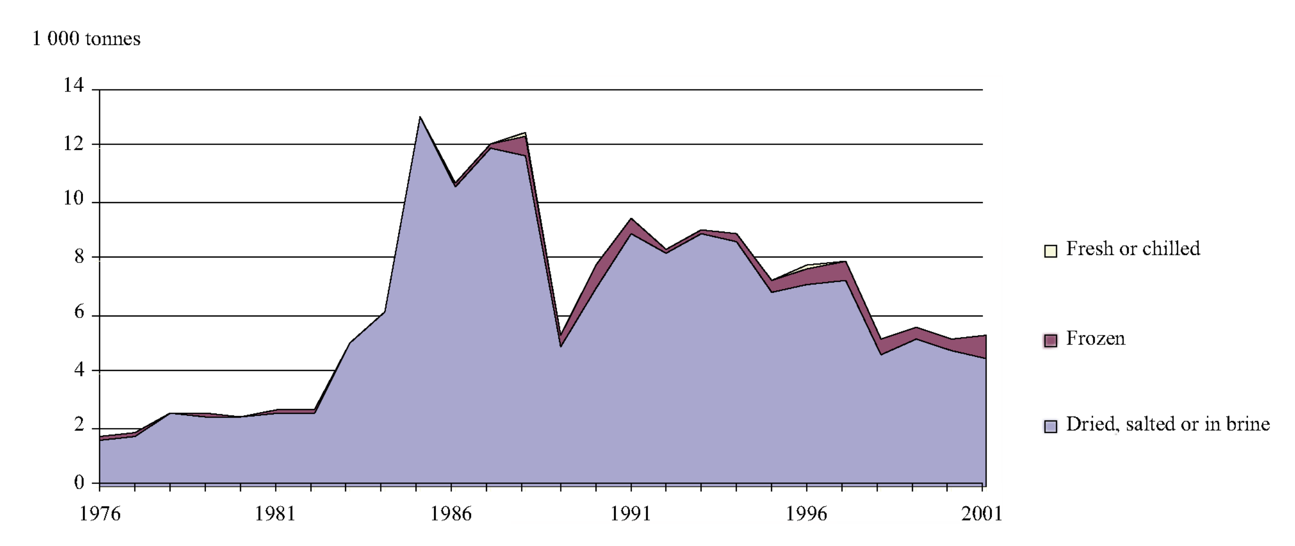

Figure 3. *Exports of "sea cucumber" by product form. Source: FAO, Fishstat Plus (v. 2.3), Commodities trade and production 1976-2001.*

In 2001, exports of "sea cucumber and other inverterbrates" were 20 700 tonnes, worth US$ 85.6 million. In 2001, 93 % of the volume and of the value of these exports were represented by sea cucumber in prepared and preserved form. In volume terms, Spain was the top exporter in 2001 with 10 000 tonnes, followed by Indonesia (2 600 tonnes) and the Republic of Korea (2 500 tonnes). In value terms, the Republic of Korea was the leading exporter in 2001 with US$ 32.4 million, followed by Spain (US$ 24.4 million) and France (US$ 5.2 million). As mentioned in the methodological remarks, these data may include other species, other than sea cucumbers.

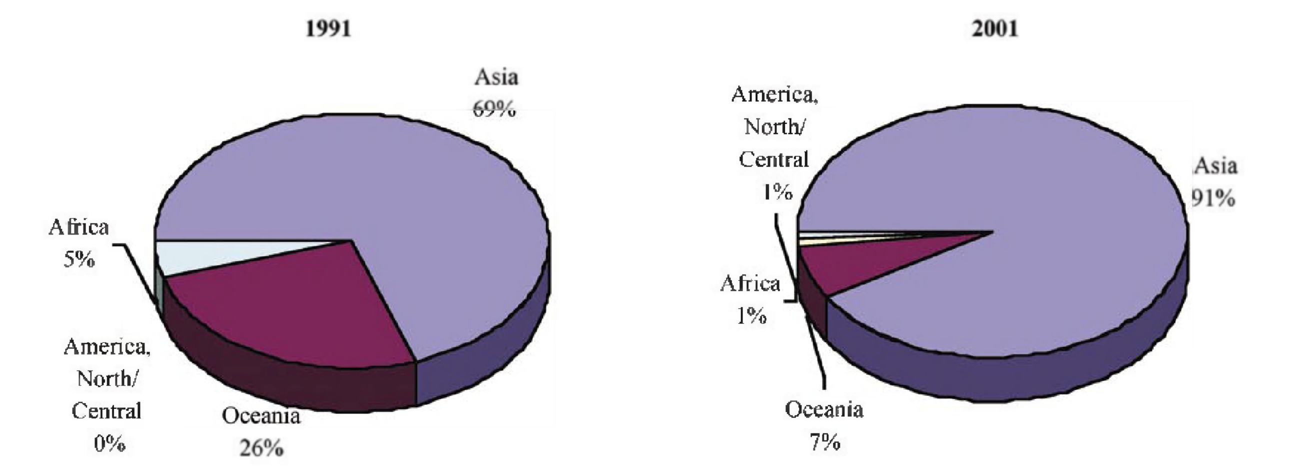

Figure 4. *Exports of "sea cucumbers" by continent in value. Source: FAO, Fishstat Plus (v. 2.3), Commodities trade and production 1976-2001.*

Imports of sea cucumbers and other invertebrates

In 2001, imports of "sea cucumbers" amounted to 7 300 tonnes, worth US$ 56.7 million (Figure 5). China Hong Kong SAR was the leading importer in volume and value terms with 4 400 tonnes (US$ 50.4 million), followed by China (2 060 tonnes) and Taiwan Province of China (700 tonnes). In value terms, China Hong Kong SAR was followed by Taiwan Province of China (US$ 4.0 million) and China (US$ 1.2 million) (Figure 6). In 2001, the bulk (68 %) of sea cucumbers imported (quantity) consisted of products in dried, salted or in brine form, followed by frozen (31 %) and limited quantities of fresh or chilled sea cucumbers. Cured fish also held the greatest share in value terms (95 %)

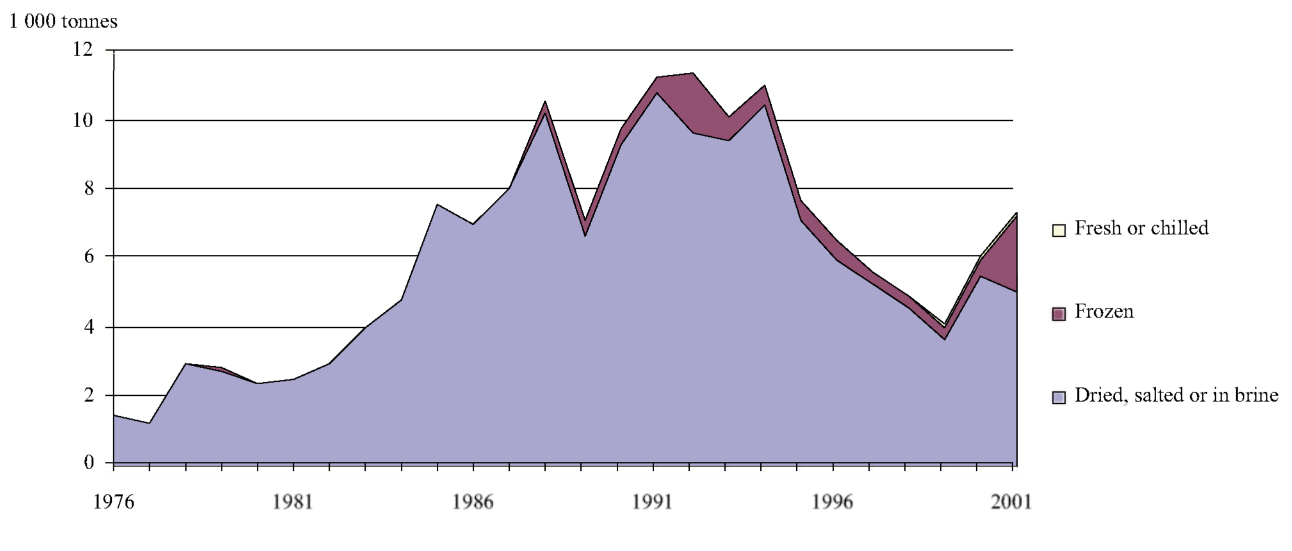

Figure 5. *Imports of "sea cucumbers" by product form. Source: FAO, Fishstat Plus (v. 2.3), Commodities trade and production 1976-2001.*

In 2001, imports of "sea cucumber and other inverterbrates" reached more than 29 000 tonnes, worth US$ 87.2 million. In 2001, 49 % of the volume and 55 % of the value of these exports were in prepared and preserved form. In volume and in value terms, France was the top importer in 2001 with 9 000 tonnes (US$ 26.9 million), followed by the Republic of Korea (6 400 tonnes; US$ 16.4 million) and Spain (4 300 tonnes; US$ 10.7 million). As remarked for exports, these data may also contain other species, other than sea cucumbers.

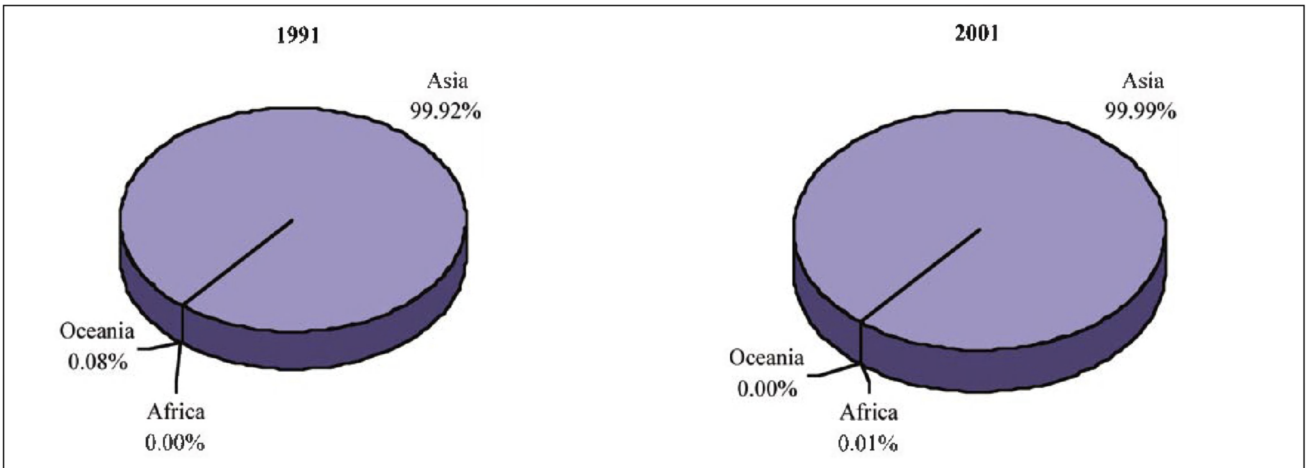

Figure 6. *Imports of "sea cucumbers" by continent in value. Source: FAO, Fishstat Plus (v. 2.3), Commodities trade and production 1976-2001.*

Tables

***Table 1**. CAPTURE fisheries production of sea cucumbers by species and country in tonnes.*

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Japanese sea cucumber (*Stichopus japonicus*)											
Japan	6 591	6 072	5 996	6 106	6 602	7 226	7 160	6 952	6 662	6 957	7 229
Korea, Republic of	2 027	1 583	2 068	2 117	1 892	1 979	2 217	1 439	1 204	1 419	900
Total	*8 618*	*7 655*	*8 064*	*8 223*	*8 494*	*9 205*	*9 377*	*8 391*	*7 866*	*8 376*	*8 129*
Sea cucumbers nei (Holothurioidea)											
Indonesia	2 465	2 113	2 364	3 132	2 562	2 443	3 138	3 058	2 617	3 041	3 250
United States of America	<0.5	481	472	2 141	729	1 779	-	2 406	3 732	4 583	1 804
Papua New Guinea	1 746	1 893	1 440	627	1 335	1 788	1 515	2 037	1 185	1 824	1 453
Fiji Islands	589	447	191	400 F	835	850	790	400	880	800 F	824
Philippines	3 535	3 679	3 109	1 497	2 062	2 123	1 191	830	849	730	791
Madagascar	600	423	450	1 800	1 800	1 800	1 800	482	500	500	500
New Caledonia	1 240	1 090	777	798	480	776	565	402	493	615	489 F
Mexico	-	-	-	-	-	-	-	271	234	426	481
Tanzania, United Rep. of	426	535	980	1 591	1 460	1 644	1 527	1 800	189	372	340
Maldives	405	119	72	66	94	145	318	85	54	205	226
Egypt	-	-	-	-	-	-	-	-	-	20	139
Sri Lanka	65	65	65	92	100	150	272	203	170	145	120
Chile	-	237	13	4	106	115	1	30	108	1 510	107
Kiribati	-	-	-	-	-	-	136	154	89	64	60
Solomon Islands	622	715	316	285	219	113	203	253	376	48	50 F
Vanuatu	50 F	39 F	40 F	40 F	50 F	50 F	50 F	50 F	50 F	50 F	50 F
Ecuador	29	152	12	12	12	12	15	15	15	15	15
Kenya	78	277	14	41	55	15	41	38	15	30	13
Mozambique	5	-	<0.5	<0.5	6	54	7	2	8	12	12
Spain	-	-	-	-	-	4	4	4	1	9	4
New Zealand	-	-	-	-	4	1	<0.5	-	-	-	2
Tonga	...	...	...	...	...	86	80	90	<0.5	<0.5	<0.5
Palau	5	6	6	6	6	6	7	7	6 F	...	...
Yemen	140	48	-	102	-	-	-	-	1	-	-
Iceland	-	-	-	-	2	-	-	-	-	-	-
Total	*12 000*	*12 319*	*10 321*	*12 634*	*11 917*	*13 954*	*11 660*	*12 617*	*11 572*	*14 999*	*10 730*
Grand total	**20 618**	**19 974**	**18 385**	**20 857**	**20 411**	**23 159**	**21 037**	**21 008**	**19 438**	**23 375**	**18 859**

Source: FAO, Fishstat Plus (v. 2.3), Capture Production 1950-2001.

Table 2. *CAPTURE fisheries production of sea cucumbers by species and country in selected years in tonnes and in percentage.*

	Tonnes						Percentage					
	1951	**1961**	**1971**	**1981**	**1991**	**2001**	**1951**	**1961**	**1971**	**1981**	**1991**	**2001**
Japanese sea cucumber (*Stichopus japonicus*)												
Japan	7 200	7 700	12 000	8 098	6 591	7 229	92.3	92.8	81.6	60.2	32.0	38.3
Korea, Republic of	500	400	1 700	3 589	2 027	900	6.4	4.8	11.6	26.7	9.8	4.8
Total	*7 700*	*8 100*	*13 700*	*11 687*	*8 618*	*8 129*	*98.7*	*97.6*	*93.2*	*86.9*	*41.8*	*43.1*
Sea cucumbers nei (Holothurioidea)												
Indonesia	100	200	500	287	2 465	3 250	1.3	2.4	3.4	2.1	12.0	17.2
United States of America	...	...	-	-	<0.5	1 804	...	...	...	...	0.0	9.6
Papua New Guinea	...	...	-	5	1 746	1 453	...	-	-	0.0	8.5	7.7
Fiji Islands	...	...	<0.5	22	589	824	...	-	0.0	0.2	2.9	4.4
Philippines	...	<0.5	-	80	3 535	791	...	0.0	-	0.6	17.1	4.2
Madagascar	...	...	300	50 F	600	500	...	-	2.0	0.4	2.9	2.7
New Caledonia	...	...	...	826	1 240	489 F	...	-	-	6.1	6.0	2.6
Mexico	...	...	-	-	-	481	...	-	-	-	-	2.6
Tanzania, United Rep. of	...	...	100	26	426	340	...	-	0.7	0.2	2.1	1.8
Maldives	...	...	-	<0.5	405	226	...	-	-	0.0	2.0	1.2
Egypt	...	...	-	-	-	139	...	-	-	-	-	0.7
Sri Lanka	...	...	...	73	65	120	...	-	-	0.5	0.3	0.6
Chile	...	...	-	...	-	107	...	-	-	-	-	0.6
Kiribati	...	...	-	-	-	60	...	-	-	-	-	0.3
Solomon Islands	...	...	<0.5	8	622	50 F	...	-	0.0	0.1	3.0	0.3
Vanuatu	...	...	-	...	50 F	50 F	...	-	-	-	0.2	0.3
Ecuador	...	...	-	...	29	15	...	-	-	-	0.1	0.1
Kenya	...	...	<0.5	12	78	13	...	-	0.0	0.1	0.4	0.1
Mozambique	...	...	-	-	5	12	...	-	-	-	0.0	0.1
Spain	...	...	...	...	-	4	...	-	-	-	-	0.0
New Zealand	...	...	-	-	-	2	...	-	-	-	-	0.0
Tonga	...	...	...	...	...	<0.5	...	-	-	-	-	0.0
Yemen	...	...	-	66	140	-	...	-	-	0.5	0.7	-
Palau	...	...	-	-	5	...	...	-	-	-	0.0	-
Malaysia	...	-	100	300	-	-	...	-	0.7	2.2	-	-
Total	*100*	*200*	*1 000*	*1 755*	*12 000*	*10 730*	*1.3*	*2.4*	*6.8*	*13.1*	*58.2*	*56.9*
Grand total	**7 800**	**8 300**	**14 700**	**13 442**	**20 618**	**18 859**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Source: FAO, Fishstat Plus (v. 2.3), Capture Production 1950-2001.

Table 3. *CAPTURE fisheries production of sea cucumbers by continent in selected years in tonnes and percentage.*

	Tonnes						Percentage					
	1951	**1961**	**1971**	**1981**	**1991**	**2001**	**1951**	**1961**	**1971**	**1981**	**1991**	**2001**
Asia	7 800	8 300	14 300	12 493	15 228	12 516	100.0	100.0	97.3	92.9	73.9	66.4
Oceania	...	...	<0.5	861	4 252	2 928	-	-	0.0	6.4	20.6	15.5
America, North and Central	...	...	-	-	<0.5	2 285	-	-	-	-	0.0	12.1
Africa	...	...	400	88	1 109	1 004	-	-	2.7	0.7	5.4	5.3
America, South	...	...	-	...	29	122	-	-	-	-	0.1	0.6
Europe	...	...	-	-	-	4	-	-	-	-	-	0.0
Grand total	**7 800**	**8 300**	**14 700**	**13 442**	**20 618**	**18 859**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Source: FAO, Fishstat Plus (v. 2.3), Capture Production 1950-2001.

Table 4. *CAPTURE fisheries production of sea cucumbers by fishing area in selected years in tonnes and percentage.*

	Tonnes						Percentage					
	1951	**1961**	**1971**	**1981**	**1991**	**2001**	**1951**	**1961**	**1971**	**1981**	**1991**	**2001**
Pacific, Northwest	7 700	8 100	13 700	11 687	8 618	8 129	98.7	97.6	93.2	86.9	41.8	43.1
Pacific, Western Central	100	200	590	1 394	9 505	5 997	1.3	2.4	4.0	10.4	46.1	31.8
Atlantic, Northwest	...	...	-	-	<0.5	1 504	-	-	-	-	0.0	8.0
Indian Ocean, Western	...	...	400	154	1 654	1 230	-	-	2.7	1.1	8.0	6.5
Indian Ocean, Eastern	<0.5	<0.5	10	207	812	1 090	0.0	0.0	0.1	1.5	3.9	5.8
Pacific, Eastern Central	...	...	...	...	...	442	-	-	-	-	-	2.3
Pacific, Northeast	...	...	-	-	-	300	-	-	-	-	-	1.6
Pacific, Southeast	...	...	-	...	29	122	-	-	-	-	0.1	0.6
Atlantic, Western Central	...	...	-	-	-	39	-	-	-	-	-	0.2
Mediterranean and Black Sea	...	...	...	...	-	4	-	-	-	-	-	0.0
Pacific, Southwest	...	...	-	-	-	2	-	-	-	-	-	0.0
Atlantic, Northeast	...	...	-	-	-	-	-	-	-	-	-	0.0
Grand total	**7 800**	**8 300**	**14 700**	**13 442**	**20 618**	**18 859**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Source: FAO, Fishstat Plus (v. 2.3), Capture Production 1950-2001.

***Table 5**. EXPORTS of sea cucumbers and other invertebrates by product form in tonnes, US$'000 and US$/kg.*

		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Sea cucumbers												
Fresh or chilled	Tonnes	8	3	2	1	5	26	41	13	35	12	27
Frozen	Tonnes	439	198	148	196	403	561	648	465	413	431	833
Dried, salted or in brine	Tonnes	8 998	8 208	8 947	8 685	6 826	7 185	7 257	4 700	5 149	4 726	4 484
Sea cucumbers and other invertebrates												
Fresh or chilled	Tonnes	-	-	-	-	-	0	-	2	-	1	8
Frozen	Tonnes	13	43	53	13	8	26	9	15	22	8	27
Dried, salted or in brine	Tonnes	2 511	2 584	2 483	1 856	1 780	1 751	885	1 658	1 080	1 643	1 353
Canned	Tonnes	4 507	9 940	11 583	11 842	9 115	11 778	10 302	9 829	11 297	13 702	17 875
Preparations	Tonnes	300	199	2 144	1 143	446	1 322	1 005	292	505	921	1 440
Sea cucumbers												
Fresh or chilled	US$'000	76	37	11	9	19	70	72	60	106	98	134
Frozen	US$'000	2 347	1 897	1 274	2 460	3 757	4 863	7 025	4 834	3 203	1 045	2 967
Dried, salted or in brine	US$'000	39 056	37 335	33 066	39 199	28 861	32 109	35 046	21 659	27 401	34 269	27 809
Sea cucumbers and other invertebrates												
Fresh or chilled	US$'000	-	-	-	-	-	1	-	11	-	2	46
Frozen	US$'000	44	194	249	93	55	172	80	49	84	42	84
Dried, salted or in brine	US$'000	7 504	7 489	6 904	5 304	5 838	3 907	3 288	4 481	3 540	5 004	5 844
Canned	US$'000	20 685	32 308	74 090	75 226	48 911	78 827	54 756	36 576	50 960	59 369	76 079
Preparations	US$'000	537	708	1 817	3 401	3 296	4 939	4 882	1 278	2 529	3 134	3 532
Sea cucumbers												
Fresh or chilled	US$/kg	9.5	12.3	5.5	9.0	3.8	2.7	1.8	4.6	3.0	8.2	5.0
Frozen	US$/kg	5.3	9.6	8.6	12.6	9.3	8.7	10.8	10.4	7.8	2.4	3.6
Dried, salted or in brine	US$/kg	4.3	4.5	3.7	4.5	4.2	4.5	4.8	4.6	5.3	7.3	6.2
Sea cucumbers and other invertebrates												
Fresh or chilled	US$/kg	-	-	-	-	-	-	-	5.5	-	2.0	5.8
Frozen	US$/kg	3.4	4.5	4.7	7.2	6.9	6.6	8.9	3.3	3.8	5.3	3.1
Dried, salted or in brine	US$/kg	3.0	2.9	2.8	2.9	3.3	2.2	3.7	2.7	3.3	3.0	4.3
Canned	US$/kg	4.6	3.3	6.4	6.4	5.4	6.7	5.3	3.7	4.5	4.3	4.3
Preparations	US$/kg	1.8	3.6	0.8	3.0	7.4	3.7	4.9	4.4	5.0	3.4	2.5

Source: FAO, Fishstat Plus (v. 2.3), Commodities trade and production 1976-2001.

Table 6. *IMPORTS of sea cucumbers and other invertebrates by product form in tonnes, US$'000 and US$/kg.*

		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Sea cucumbers												
Fresh or chilled	Tonnes	6	5	3	14	5	32	3	18	23	42	33
Frozen	Tonnes	483	1 712	662	610	528	596	353	297	440	484	2 267
Dried, salted or in brine	Tonnes	10 847	9 661	9 437	10 427	7 120	5 969	5 274	4 631	3 616	5 514	4 999
Sea cucumbers and other invertebrates												
Fresh or chilled	Tonnes	6 619	6 202	6 698	5 678	5 483	4 919	4 677	4 553	4 603	4 644	5 489
Frozen	Tonnes	4	4	8	16	6	-	-	-	-	-	-
Dried, salted or in brine	Tonnes	6 297	5 469	5 950	6 186	6 202	7 996	8 176	8 663	8 146	7 377	9 165
Canned	Tonnes	5 364	5 082	7 272	7 925	10 226	10 370	12 184	7 484	9 359	11 657	12 163
Preparations	Tonnes	2 580	3 038	2 861	5 198	2 045	2 634	1 641	1 567	2 435	2 357	2 199
Sea cucumbers												
Fresh or chilled	US$'000	17	13	12	26	16	104	23	10	45	90	219
Frozen	US$'000	2 301	3 850	2 617	2 036	2 071	2 080	1 782	1 404	1 654	2 262	2 504
Dried, salted or in brine	US$'000	56 369	50 569	42 411	51 577	46 420	47 803	42 522	43 206	37 632	59 339	53 999
Sea cucumbers and other invertebrates												
Fresh or chilled	US$'000	19 790	19 698	15 102	11 539	11 436	9 093	8 633	11 165	11 239	10 970	13 833
Frozen	US$'000	33	19	34	93	36	-	-	-	-	-	-
Dried, salted or in brine	US$'000	12 531	12 542	12 749	16 142	19 560	23 645	24 360	20 414	20 355	18 277	25 188
Canned	US$'000	21 521	23 966	32 503	30 782	40 354	41 538	42 782	24 143	30 568	33 799	34 765
Preparations	US$'000	14 916	20 546	18 987	21 987	20 821	21 996	16 140	12 345	14 323	16 544	13 364
Sea cucumbers												
Fresh or chilled	US$/kg	2.8	2.6	4.0	1.9	3.2	3.3	7.7	0.6	2.0	2.1	6.6
Frozen	US$/kg	4.8	2.2	4.0	3.3	3.9	3.5	5.0	4.7	3.8	4.7	1.1
Dried, salted or in brine	US$/kg	5.2	5.2	4.5	4.9	6.5	8.0	8.1	9.3	10.4	10.8	10.8
Sea cucumbers and other invertebrates												
Fresh or chilled	US$/kg	3.0	3.2	2.3	2.0	2.1	1.8	1.8	2.5	2.4	2.4	2.5
Frozen	US$/kg	8.3	4.8	4.3	5.8	6.0	-	-	-	-	-	-
Dried, salted or in brine	US$/kg	2.0	2.3	2.1	2.6	3.2	3.0	3.0	2.4	2.5	2.5	2.7
Canned	US$/kg	4.0	4.7	4.5	3.9	3.9	4.0	3.5	3.2	3.3	2.9	2.9
Preparations	US$/kg	5.8	6.8	6.6	4.2	10.2	8.4	9.8	7.9	5.9	7.0	6.1

Source: FAO, Fishstat Plus (v. 2.3), Commodities trade and production 1976-2001.

Table 7. *Total EXPORTS of "sea cucumbers" by principal exporters in US$'000.*

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
China, Hong Kong SAR	13 244	11 158	13 820	13 978	15 403	18 169	20 115	18 055	16 126	30 128	22 669
Sri Lanka	553	683	415	955	2 028	2 936	6 352	4 260	2 547	-	1 936
Taiwan Province of China	77	239	140	212	812	1 028	844	1 044	1 229	1 525	1 823
Solomon Islands	2 816	3 555	993	783	509	354	664	853	393	253	1 749
China	...	758	490	1 203	-	296	98	99	209	612	845
Thailand	5	-	1	1	48	56	129	160	320	857	432
Yemen	...	...	...	...	...	138	-	-	-	-	374
Cuba	...	...	...	...	...	...	...	...	...	452	351
Seychelles	...	...	...	...	...	...	...	...	...	...	247
Kiribati	...	...	466	559	281	602	199	31	61	79	116
Vanuatu	-	-	-	-	-	123	121	130	33	-	102
Korea, Republic of	237	125	39	33	21	60	47	59	116	165	92
Malaysia	186	144	55	97	142	49	136	1	11	5	84
Mozambique	...	26	-	-	-	116	-	24	20	5	34
Fiji Islands	2 797	3 483	1 169	1 580	3 978	4 071	2 791	1 171	1 379	-	32
Tonga	-	-	-	-	911	719	-	-	-	-	7
Korea, Dem. People's Rep	-	20	-	-	-	15	-	100	3	-	3
United Arab Emirates	...	...	...	...	...	19	70	-	3	161	1
New Caledonia	-	-	925	1 233	1 300	930	...	...	593	1 170	...
Papua New Guinea	5 070	5 005	3 112	1 836	-	-	3 861	-	3 332	-	-
Philippines	3 560	3 216	3 986	4 120	4 803	4 827	4 505	-	3 653	-	-
Maldives	2 003	799	594	431	707	646	728	346	407	...	...
Tanzania, United Rep. of	374	416	502	788	359	438	685	201	262	...	...
Madagascar	1 559	1 497	1 016	2 093	1 254	751	452	-	-	-	-
Marshall Islands	...	...	...	...	...	432	312	-	-	-	-
Viet Nam	-	-	-	1 000	-	139	-	-	-	-	-
Singapore*	8 998	8 141	6 582	10 689	...	...	...	...	...	...	...
Others	-	4	46	77	81	128	34	19	13	-	13
Total	**41 479**	**39 269**	**34 351**	**41 668**	**32 637**	**37 042**	**42 143**	**26 553**	**30 710**	**35 412**	**30 910**

**Data provided from 1995 are based on a different classification which does not identify trade on sea cucumbers separately. Source: FAO, Fishstat Plus (v. 2.3), Commodities trade and production 1976-2001.*

***Table 8**. Total IMPORTS of "sea cucumbers" by principal importers in US$'000.*

	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
China, Hong Kong SAR	35 481	32 378	29 959	35 461	40 898	43 376	38 147	39 565	33 571	55 533	50 430
Taiwan Province of China	5 771	6 817	5 714	5 237	5 792	5 327	5 291	4 549	4 735	4 514	3 979
China	...	1 367	689	380	-	49	3	30	265	793	1 229
Thailand	18	54	37	55	102	90	446	282	417	528	504
Korea, Republic of	4 275	265	327	24	128	154	302	23	68	127	400
Japan	1 324	1 263	635	613	799	350	134	163	121	141	81
China, Macao SAR	40	35	23	33	28	33	-	-	25	22	36
Malaysia	1 176	1 081	761	688	755	564	4	8	34	24	16
Korea, Dem. People's Rep	...	...	...	-	5	-	-	-	91	-	13
Viet Nam	...	...	...	...	...	...	...	...	...	7	13
Brunei Darussalam	-	-	-	-	-	5	-	-	4	-	5
Mali	...	...	...	...	...	...	...	...	...	...	4
Syrian Arab Republic	...	...	...	...	...	...	...	...	...	...	4
United Arab Emirates	...	...	...	...	...	...	...	...	...	...	4
Nepal	...	...	...	...	...	...	...	...	...	...	2
Sudan	...	...	...	...	...	...	...	...	...	...	2
Djibouti	...	...	...	...	...	...	...	...	...	2	-
Fiji Islands	47	196	9	-	-	38	-	-	-	-	-
Marshall Islands	...	...	...	...	...	1	-	-	-	-	-
Singapore*	10 555	10 976	6 886	11 148	...	...	...	...	...	...	...
Total	**58 687**	**54 432**	**45 040**	**53 639**	**48 507**	**49 987**	**44 327**	**44 620**	**39 331**	**61 691**	**56 722**

**Data provided from 1995 are based on a different classification which does not identify trade on sea cucumbers separately. Source: FAO, Fishstat Plus (v. 2.3), Commodities trade and production 1976-2001.*

Table 9. Total EXPORTS of "sea cucumbers and other invertebrates" by principal exporters in US$'000.

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Korea, Republic of	7 679	6 115	51 701	49 741	21 649	42 732	25 894	8 001	17 804	24 576	32 423
Spain	268	638	11 551	13 234	18 048	17 477	13 801	17 480	18 739	19 706	24 429
France	2 164	2 014	710	3 599	3 470	3 899	3 704	4 703	4 790	4 603	5 249
Indonesia	3 997	14 701	6 679	6 034	3 337	4 728	1 684	1 924	2 249	3 788	5 248
Italy	6 239	6 740	2 426	1 722	2 116	4 437	4 935	4 070	4 193	4 946	4 881
New Zealand	-	5	11	4	56	3 547	2 901	2 298	3 326	3 002	2 905
Belgium	400	2 231	413	1 563	536	624	884	777	1 827	1 851	2 305
Jamaica	...	...	...	...	...	...	...	...	...	...	2 300
United Kingdom	-	78	1	860	1 375	1 143	1 043	230	757	809	2 237
Germany	279	328	216	420	437	1 286	693	454	451	1 198	1 170
Bulgaria	...	...	...	...	...	...	...	...	...	...	762
Colombia	...	...	...	99	1 109	168	1 035	652	1 066	1 086	576
Portugal	87	43	16	64	69	113	341	231	293	194	193
Malaysia	6 098	6 459	6 840	4 078	3 316	4 058	1 537	47	434	216	184
Netherlands	139	-	-	190	85	834	1 479	674	116	204	140
Greece	147	55	19	119	185	85	340	57	86	11	112
Romania	...	...	...	19	-	-	99	-	-	99	104
Czech Republic	...	...	...	...	...	43	30	47	63	111	85
Mauritania	...	...	...	...	...	...	...	...	...	...	60
Finland	...	...	...	...	44	24	30	35	13	55	50
Ireland	...	45	-	-	-	-	93	47	205	4	47
Poland	...	...	...	61	-	-	-	22	86	6	30
Vanuatu	...	...	...	...	...	...	...	11	-	-	26
South Africa	-	-	-	-	-	758	440	-	-	-	3
Taiwan Province of China	...	1	244	368	386	31	30	12	7	-	2
Korea, Dem. People's Rep	885	1 080	2 080	1 295	1 252	1 093	1 516	620	483	1 024	-
Philippines	73	117	131	178	169	160	291	-	100	-	-
Uruguay	...	...	...	325	404	537	-	-	-	-	-
Others	315	49	22	51	57	69	206	3	25	62	64
Total	**28 770**	**40 699**	**83 060**	**84 024**	**58 100**	**87 846**	**63 006**	**42 395**	**57 113**	**67 551**	**85 585**

Source: FAO, Fishstat Plus (v. 2.3), Commodities trade and production 1976-2001.

Table 10. Total IMPORTS of "sea cucumbers and other invertebrates" by principal importers in US$'000.

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
France	21 186	21 040	19 052	14 644	17 282	15 739	19 606	20 550	20 094	21 091	26 862
Korea, Republic of	11 528	14 320	21 326	17 626	26 787	27 789	29 788	9 138	13 523	13 841	16 390
Spain	1 404	1 811	3 366	4 012	7 363	6 377	6 796	9 078	6 404	8 413	10 653
Japan	9 570	14 293	12 675	14 196	17 734	15 687	14 144	9 406	11 621	14 005	10 423
Germany	3 192	3 860	2 793	4 272	3 520	4 788	4 195	4 332	6 126	6 137	6 114
Belgium	2 114	2 648	2 980	3 632	3 168	3 644	3 209	2 709	3 320	3 456	3 269
Netherlands	1 668	1 773	154	426	453	4 469	984	537	988	586	2 543
Portugal	944	433	358	734	1 214	1 895	1 596	1 567	1 284	2 571	2 266
Italy	3 523	2 794	1 385	1 173	574	945	1 291	1 059	1 316	2 212	1 895
Taiwan Province of China	3 566	3 394	3 619	3 924	2 148	3 339	2 812	1 876	2 595	2 280	1 711
United Kingdom	207	398	408	2 304	2 373	2 244	1 413	1 606	1 544	752	925
Greece	55	-	119	292	442	207	177	112	273	377	833
Czech Republic	...	...	...	...	...	155	320	197	208	353	498
Malaysia	1 909	1 587	1 775	2 165	2 133	983	393	731	623	649	428
Malta	...	...	...	...	...	...	...	342	346	335	394
Luxembourg	...	...	...	...	...	...	...	...	...	332	356
Israel	...	...	...	...	...	...	...	...	...	...	196
Poland	...	...	...	...	41	-	-	208	106	101	165
New Zealand	13	27	50	38	100	113	193	110	131	130	158
Netherlands Antilles	...	...	...	...	...	...	...	...	81	158	155
Yugoslavia, Fed. Rep. of	...	...	...	...	3	-	-	-	-	-	150
Myanmar	...	...	...	...	...	3	-	-	-	-	137
Bolivia	34	58	62	74	33	73	58	75	115	68	90
Finland	...	...	...	...	250	235	102	108	120	129	86
Romania	...	...	...	34	-	-	-	-	-	54	67
Kazakhstan	...	...	...	...	...	...	...	...	...	64	56
Canada	-	-	1 387	1 901	2 022	3 944	4 569	4 059	5 523	1 116	-
Australia	4 455	4 631	4 555	4 212	-	3 412	-	-	-	-	-
Guadeloupe	854	653	357	913	1 514	60	...	...	...	...	...
Martinique	1 593	1 861	1 737	2 436	1 564	...	...	...	...	...	...
Réunion	471	575	770	911	1 086	...	...	...	...	...	...
Others	505	615	447	624	513	171	269	267	144	380	330
Total	**68 791**	**76 771**	**79 375**	**80 543**	**92 207**	**96 272**	**91 915**	**68 067**	**76 485**	**79 590**	**87 150**

Source: FAO, Fishstat Plus (v. 2.3), Commodities trade and production 1976-2001.

Sea cucumber specimen preservation for taxonomic identification

The Belgian focal point to the global taxonomy initiative and its role in strengthening individual and institutional taxonomic capacity for, *inter alia*, sea cucumbers

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Preamble

Alessandro Lovatelli, in his capacity as Fishery Resources Officer (Aquaculture) of the Inland Water Resources and Aquaculture Service (FIRI), FAO Fisheries Department, as well as principal editor for the present ASCAM proceedings, asked us to devote some words on how sea cucumbers should be optimally preserved for taxonomic identification. It is with pleasure that we respond to his request and take advantage of the opportunity to frame this preservation protocol in the broader context of capacity building in taxonomy and collection management. This will be done by briefly outlining the history and scope of the Global Taxonomy Initiative (GTI) as well as Belgium's contribution to it.

CBD, GTI and the Belgian contribution to it all

The United Nations Convention on Biological Diversity (CBD) was adopted at the 1992 Earth Summit in Rio de Janeiro, Brazil. Conservation of biodiversity, sustainable use of its components and fair and equitable sharing of the benefits arising from the use of genetic resources, the three goals of the CBD, became prime points on the political agenda of contracting parties (188 Parties in May 2004). However, through the Conference of the Parties (COP), it was quickly recognized that the standing capacity to identify and monitor biodiversity are, and will continue to be, the limiting factors that allow successful and effective implementation of the three CBD objectives (see also Article 7 of the Convention text).

Taxonomy and collection management were recognized to be important keys. The Global Taxonomy Initiative (GTI), one of the cross-cutting issues established by the COP, is the operational vehicle that must ensure that a satisfying amount of taxonomic capacity is installed, and this in all parts of the world, including the mega-diverse countries of the South where the paucity of taxonomic capacity is striking. As such, the GTI tends to remove or at least severely reduce the so-called "taxonomic impediment" - in other words, the knowledge gaps in our taxonomic system (including those associated with genetic systems), the shortage of trained taxonomists and curators, and the impact these deficiencies have on our ability to conserve, use and share the benefits of our biological diversity. More information on the GTI is available at: http://www.biodiv.org/programmes/cross-cutting/taxonomy/.

Belgium fully endorses the operational programme of work of the GTI (COP decision VI/8) and has designated the Royal Belgian Institute of Natural Sciences as National Focal Point to the GTI. This Focal Point approaches Belgium's GTI obligations by being: (i) an information centre; (ii) a facilitation centre, (iii) a partnering centre and, (iv) a tutoring centre.

Belgium has chosen to be pro-active in ensuring maximal implementation of the operational programme of work of the Global Taxonomy Initiative. The Belgian National Focal Point, in close cooperation with other Belgian Institutes such as the Royal Museum for Central Africa and the National Botanic Garden, and funded by the Belgian Development Cooperation, has designed an operative strategy that aims at constructing positive feedback-loops in capacity building for taxonomy and collection management, *inter alia*, for sea cucumbers.

The core of the Belgian approach is embedded in building transparent bilateral and multilateral synergies that not only promote scientific partnerships, collection valuations and optimal resources utilizations, but also envisages maximal supply of information and tuition. The *modus* to attain this goal is twofold:

- the first approach adopts a top-down tactic: established taxonomists from the Focal Point identify important taxonomic impediments and tackle these by carrying out an *in situ* research project that incorporates clear-cut capacity human and/or institutional capacity building;
- the second approach works bottom-up: interested parties from developing countries identify key taxonomic or collection management needs. Through an external call for proposals, the Focal Point, in close cooperation with other competent Belgian taxonomic bodies, makes available its expertise, collections and collection-based information to meet the need.

Mr Lovatelli's request for an adequate preservation protocol for holothuroids complements this dichotomous approach by addressing a most crucial issue: i.e. how to expedite taxonomic research without wasting precious natural resources. Hence, we hope that the protocol below can serve as an important drive to identify and monitor this ecologically and economically important group.

Building a representative sea cucumber collection and the protocol to preserve specimens for taxonomic identification

1. *Legal framework* - Prior to commencing with the construction of a reference collection, make sure that you possess all the necessary legal authorisations to sample in the region. When specimens need to be transported (e.g. to specialists for identification), wrap them in alcohol impregnated cotton. Pack in sealable plastic bags and add a little more alcohol. Pack in one or two additional plastic bags so that no alcohol can leak out. Make sure that, prior to such transport, you respect all international agreements, as some airline companies will not transport samples in alcohol. If this is the case, overseas transport by ship is your only alternative.
2. *Getting specimens* - In the past, holothuroid specimens were gathered by handpicking in the intertidal zone or by dredging in deeper waters. With the advent of SCUBA diving, selective sampling at greater depth in shallow waters became feasible. This technological innovation greatly augments the effectiveness of sampling. Moreover, SCUBA diving allows observation of a species *in situ*, thus greatly improving our understanding of the ecology of the species. As such, information on life habitus, natural habitat, and even abundance can be obtained. Upon collection, individuals are best kept separate from each other, for instance by using plastic bags. Such physical separation of live specimens minimises potential antagonistic reaction between any two individuals (e.g. expulsion of Cuvierian tubules, auto-evisceration) and thus greatly augments the taxonomic value of the specimens. When and wherever possible, sampling should be done both at night as well as during the day, as it has been well documented that some species appear only during the night. Sampling in as many representative habitats as possible (for instance on the outer reef, but also in the associated coral reef lagoon as well as in the adjacent seagrass bed and mangrove forest) significantly increases the completeness of the survey. Moreover, as holothuroids often have a fugitive behaviour, turning stones and sieving substrate (especially for individuals smaller than 1 cm) frequently exposes additional specimens.
3. *Number of specimens required* - Although there is no rule as to the number of specimens that needs to be collected per species, it is important to realize that at least two to three specimens per species will be needed to ensure a reliable identification of the species. Identification of holothuroids depends to a large extent on the shape, the size and the distribution of the ossicles in the different body parts. As it is documented that during growth ossicle assemblage in some species can drastically change, specimens belonging to different size classes may present different ossicles. Whenever possible, it is thus strongly recommended that growth series of a single species (encompassing at least one small, one medium and one large individual) are collected. Only such growth series will enable competent taxonomists to assess intraspecific variation and as such avoid unnecessary splitting. If you have collected a large number of specimens belonging to the same

species, it is ideal to deposit the voucher material in different museums. In this way, not only can your work be built upon in further studies, but you will benefit from partnerships with these museums. The same rule of thumb applies to eventual new species; distributing paratypes over different museums will not only ensure that the species is fully available for further study, it will also stimulate museums to work in partnership with you in the future.

4. *Relaxation / anaesthetisation of collected specimens* - Holothuroid specimens, at all times, should be adequately anaesthetized prior to preservation as otherwise the preservative will cause contraction and, at times, even evisceration of the specimen that then renders the specimen unfit for taxonomic purposes. Several methods exist to relax a holothuroid, but the most commonly used one today is anaesthetization with magnesium chloride (Epson salts as available in virtually every drug store can also be utilized). The animals are left to expand and extend their tentacles in a container of seawater, and then magnesium chloride ($MgCl_2$) is added till the concentration is roughly 5 %. The animals should be left in the anaesthetizing solution until they cease to respond to probing, but they should not be allowed to die in the anaesthetic as tissue breakdown by autolysis can set in very quickly (for instance this is often the case with holothuroids from the family Stichopodidae; here placing the container in a fridge can help slow down autolysis). A well relaxed holothuroid, with its tentacles and, if present, tube feet fully extended, will greatly facilitate a taxonomist's job. At this stage in the protocol, making pictures of the specimen will help with later description.

5. *Preservation of collected specimens* - When the animals are adequately anaesthetized the specimens can be place in a fixative fluid. Here again several fixatives can be used, but it should be remembered that the most important taxonomic characters of a holothuroid are its calcareous ossicles. Such ossicles can dissolve if the solution is acid (pH below 7). An acid preservative like unbuffered formalin[1] (10 %) will quickly dissolve the ossicles in the different body parts. The preservation protocol commonly utilised is the following: (i) preserve for 1 to several days in 10 % buffered formalin solution, (ii) replace the formalin with a buffered alcohol[2] solution of 70-80 %; (iii) after a couple of days, refresh the alcohol with a 70 % buffered alcohol solution for permanent storage. When dealing with large and/or stout specimens, it is generally useful to also inject in step (i) concentrated buffered formalin in the coelomic cavity (this can be done with a hypodermic needle; use a volume of approximately 1/10 th of the estimated volume of the coelomic cavity).

6. *Sea cucumbers as micro-ecosystems* - Holothuroids can be seen as micro-ecosystems as they often are host to a diverse assemblage of symbionts which range from turbellarian worms living in the coelomic cavity, scaled polychaetes foraging on the epidermis, crustaceans and molluscs between the tentacles and around the anus, and even fish living in the respiratory trees (making echinoderms the only invertebrates that host a vertebrate). Upon relaxation and preservation it is little trouble to also collect and properly label these associates.

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[1] Formalin usually can be purchased as a 40 % aqueous solution of the gas formaldehyde (a 10 % formalin solution thus equals a 4 % formaldehyde solution). To make 10 % formalin solution one adds 9 parts of seawater to 1 part commercial formalin. Formaldehyde solutions tend to be acidic; to neutralize gently add saturated borax solution ($Na_2B_4O_7$ or $Na_2B_4O.4H_2O$) until the pH is around 8 (use indicator sticks).

[2] The alcohol used for preservation is ethanol. This does not have to be pure ethanol, which can be expensive. For routine preservation (i.e. not for preserving tissue intended for molecular studies, here pure ethanol should be used) alcohol in the form of methylated spirits is commonly used. To buffer the alcohol, gently add saturated borax solution until the pH is around 8 (use indicator sticks).

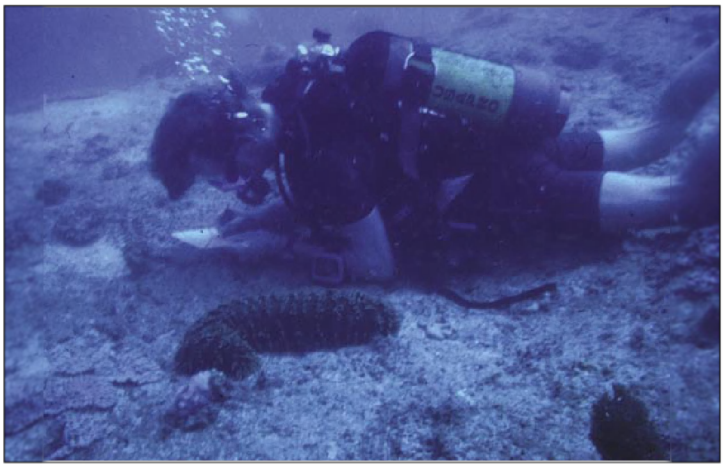

Figure 1. *Left: making notes on* Thelenota ananas *(Jaeger, 1833) as found in the Mombasa Marine National Park, Kenya. (Photo: B. Van Bogaert).*

Figure 2. *Relaxation and preservation of sea cucumber specimens.* ***(a)*** *specimens are kept separate from each other using plastic bags – pictured is a specimen of* Bohadschia subrubra *(Quoy & Gaimard, 1833) collected in the field (make sure the bags contain enough seawater);* ***(b)*** *field lab with separate containers for relaxation and preservation;* ***(c)*** *relaxation and anaesthetization with approximately 5% magnesium chloride (some extra magnesium chloride salt is added as the animal showed no signs of relaxation after 1 hour);* ***(d)*** *specimens of* Neostichopus grammatus *(H.L. Clark, 1923) - packed for temporarily storage in 70-80% alcohol (note that the alcohol extracts the coloration pigments) (Photo: I. Tallon).*

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The utilization of sea cucumbers, including for human consumption, has been steadily growing over the years. Up-to-date information on the present status of world sea cucumber resources and utilization is presented with special focus on countries such as China, Ecuador, Indonesia, Japan, Malaysia and the Philippines that have been heavily engaged in the industry for decades. Information from other countries such as Cuba, Egypt, Madagascar and the United Republic of Tanzania, relative newcomers to the sector, is also provided, indicating to some extent the growing interest with regard to the exploitation of holothurians for the demanding Asian markets. Details on the technical advances made in the artificial reproduction and farming of selected commercial species are presented. This document includes the recommendations formulated during the FAO Fisheries Department Workshop on Advances in Sea Cucumber Aquaculture and Management held in Dalian, China, in October 2003, along with the technical papers presented. The report will be useful to those international and regional development organizations and national governments who wish to prioritize their activities concerning sea cucumber conservation and exploitation.

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