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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

ACKNOWLEDGEMENTS

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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CONTENTS

Session II - Resources management

Session III - Aquaculture advances

Sea cucumbers: a compendium of fishery statistics

Sea cucumber specimen preservation for taxonomic identification

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.