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Managing sea cucumber fisheries with an ecosystem approach

Cover photograph:
Underwater photograph of an adult brown sea cucumber *Isostichopus fuscus* (Ludwig, 1875) at Santa Cruz, Galápagos Islands, Ecuador; courtesy Steven W. Purcell.

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Preparation of this document

This paper was prepared from outcomes of the FAO Technical Workshop on "Sustainable Use and Management of Sea Cucumber Fisheries" held in Puerto Ayora, Galápagos Islands, Ecuador, from 19 to 23 November 2007. The main goal of the workshop was to define the structure and contents of a manual aimed at assisting fisheries managers in deciding regulations and processes for the better management, conservation and sustainable exploitation of their sea cucumber fisheries. The group of experts convened for this purpose consisted of Jun Akamine, Poh Sze Choo, Chantal Conand, Eduardo Espinoza, Kim Friedman, Ruth Gamboa, Jean-François Hamel, Alex Hearn, Jeff Kinch, Alessandro Lovatelli, Priscilla C. Martínez, Annie Mercier, María Dinorah Herrero-Pérezrul, Steven Purcell, Verónica Toral-Granda, Sven Uthicke, Marcelo Vasconcellos and Matthias Wolf. The workshop produced a table of "minimum" and "recommended" regulatory measures and management actions advised for fisheries, depending on the status (abundance and sizes) of wild stocks, scale of fishing activities and technical capacity of the management agency. Working groups at the workshop also canvassed brief points on the definitions, uses, limitations and ways of implementing each measure and action. The draft document produced during the workshop was later developed into the present technical paper by Steven Purcell. This document benefited greatly from editorial comments from Kevern Cochrane, Sven Uthicke, Jean-François Hamel, Annie Mercier, Chantal Conand, Kim Friedman, Jeff Kinch and Veronica Toral-Granda.

The Government of Japan is thanked for generously providing the financial support for the workshop and preparation of this technical paper through the Trust Fund Project GCP/INT/987/JPN on "CITES and commercially-exploited aquatic species, including the evaluation of listing proposals".

Abstract

Sea cucumbers are important resources for coastal livelihoods and ecosystems. At least 60 species are fished from more than 40 countries and most of the harvests are processed then exported to Asian markets. Sea cucumbers generally appear to have slow rates of population turnover and are easily harvested in shallow waters in the tropics. With retail prices of up to USD300–500 per kg (dried), exploitation has often been indiscriminant and excessive. Overfishing in recent years has led to local extinction of high-value species in some localities and prompted closures of many national fisheries to allow stocks to recover and to allow more sustainable management plans to be established. Apart from a few developed countries, only a small number of sea cucumber fisheries are currently being managed sustainably.

Sea cucumber fisheries differ greatly in the scale of the fishing activities, status of stocks and the capacity of the management agency. Consequently, some management measures will be appropriate in some fishery scenarios but not others. This document presents a logical framework to assist fishery managers in choosing an appropriate suite of regulatory measures and management actions and elaborates on the uses, limitations and ways to implement them.

This document contains five main sections. The first provides an overview of the biology and ecology of sea cucumbers, the international market for beche-de-mer market, types of sea cucumber fisheries and their global status (i.e. population abundance). The second section summarizes fisheries management principles and approaches, with an emphasis on the ecosystem approach to fisheries (EAF). The third section provides the "roadmap", by way of instructions, flow diagrams and tables, to lead fishery managers along the path of choosing management measures appropriate to their fishery. The fourth and fifth sections discuss the application of each regulatory measure and management action – with *Examples and lessons learned* boxes to illustrate management problems and potential solutions from various fisheries.

Improved management of sea cucumber fisheries is an imperative. It will be best achieved by applying an EAF, in which multiple regulatory measures and management actions are applied in full consideration of the sea cucumber stocks, the ecosystems in which they live and the socio-economic systems that drive exploitation. The commitment of governments, fishery managers and scientists to develop, apply and strictly enforce EAF will be crucial to sustaining sea cucumber populations for current and future generations.

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Abbreviations and acronyms

ACIAR	Australian Centre for International Agricultural Research
AIMR	Arnavon Island Marine Reserve (Solomon Islands)
AMCA	Arnavon Marine Conservation Area (Solomon Islands)
BC	British Columbia (Canada)
BFAR	Bureau of Fisheries and Aquatic Resources (Philippines)
CC	Consultative Committee
CCC	Coral Cay Conservation
CCRF	Code of Conduct for Responsible Fisheries
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
COFI	Committee on Fisheries
CPUE	Catch per Unit of Effort
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEH	Department of Environment and Heritage (Australia)
DoF	Department of Fisheries
DPI&F	Department of Primary Industries and Fishery (Australia)
EAF	Ecosystem Approach to Fisheries
FAO	Food and Agriculture Organization of the United Nations
FMC	Fishing Monitoring Certificate
FPA	Fisheries Prohibited Area
GBR	Great Barrier Reef (Australia)
GBRMP	Great Barrier Reef Marine Park (Australia)
GIS	Geographical Information System
GMR	Galápagos Marine Reserve
GNPS	Galápagos National Park Service
GPF	Governor Permitted Fishery
GPS	Global Positioning System
Harvest MAC	Harvest Fisheries Management Advisory Committee (Australia)
IHSM	Institut halieutique et des sciences marines (Madagascar)
IMA	Inter-Institutional Management Authority
IQs	Individual Quotas
ITQs	Individual Transferable Quotas
IUU	Illegal, Unreported and Unregulated
IVQs	Individual Vessel Quotas
MAC	Management Advisory Council
MASMA	Marine Science for Management (project of WIOMSA)
MFMRD	Ministry of Fisheries and Marine Resources Development (Kiribati)
MMC	Merchant Monitoring Certificate
MPA	Marine Protected Area
MSE	Management Strategy Evaluation
MSY	Maximum Sustainable Yield
NBMP	National Beche-de-mer Management Plan (Papua New Guinea)
NFA	National Fisheries Authority (Papua New Guinea)
NGO	Non-Governmental Organization
NMAC	National Management Advisory Committee
ONETH	Organisation nationale des exploitants des trépangs et holothuries (Madagascar)

PMAC	Provincial Management Advisory Committee
PMB	Participatory Management Board
PROCFish/C	Pacific Region Oceanic and Coastal Development Project – Coastal Component
QBFP	Queensland Boating and Fisheries Patrol
QPWS	Queensland Park and Wildlife Service
RAP	Representative Areas Program
SAR	Special Administrative Region
SCUBA	Self Contained Underwater Breathing Apparatus
SFA	Seychelles Fishing Authority
SFAC	Sea-area Fishery Adjustment Commission (Japan)
SLG	Special Law of the Galápagos
SMR-PAMB	Sagay Marine Reserve-Protected Area Management Board (Philippines)
TAC	Total Allowable Catch
TAD	Transport Authorization Docket
TROM	Target Resource-Orientated Management
TURF	Territorial Use Rights in Fisheries
UAE	United Arab Emirates
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UVC	Underwater Visual Census
VMS	Vessel Monitoring System
WIO	Western Indian Ocean
WFC	WorldFish Center
WIOMSA	Western Indian Ocean Marine Science Association

Executive summary

Sea cucumbers fulfil an important role in marine ecosystems and support fisheries that provide a significant source of employment and income to coastal peoples. From both an ecological and socio-economic perspective, the long-term sustainability of sea cucumber fisheries is of great importance to coastal communities. Unfortunately, sea cucumber stocks have been overfished in many countries as a result of ever-increasing market demand, uncontrolled exploitation and/or inadequate fisheries management.

The status and present management of sea cucumber fisheries was recently reviewed in five large regions of the world (Toral-Granda, Lovatelli and Vasconcellos, 2008) (Section 2.3 and 2.4). Tropical fisheries contribute most to global captures and involve many species (often 10 to 35) with varied ecological and biological traits. These fisheries are often artisanal or small-scale, typified by fishers gleaning on sandflats or free-diving on shallow reefs and have operated for more than a century, albeit in a boom-and-bust fashion. In many developing countries, fishing by women and children is significant. Sea cucumbers are sometimes eaten locally, whereas the majority are boiled, dried and exported to the distribution hubs in Asia.

Overexploitation in many tropical fisheries has left stocks depleted and fishers have shifted to low-value species, leading to serial depletion. The collapse of breeding stocks has led to recent moratoria (fishing bans) being placed in fisheries of Costa Rica, mainland Ecuador, India, Mayotte (France), Panama, Papua New Guinea, Solomon Islands, mainland Tanzania, Tonga, Vanuatu and Venezuela. Fisheries agencies of tropical countries often lack the technical capacity and resources to develop and adapt complex management regulations and/or to enforce them stringently.

In contrast, most sea cucumber fisheries in temperate waters are industrialized, recent, single-species and involve large boats with sophisticated gear to harvest from deep waters. They also have the benefit of greater technical capacity in the management agencies.

In addition to these disparities, fisheries in each region differ in the governance structure of the management systems. Because sea cucumber fisheries differ on so many levels, it is impossible to prescribe a "one-size-fits-all" solution to improve their sustainability. What is needed, therefore, is clearer information about the utility of various management tools and a framework for deciding which of them to choose for a particular fishery scenario.

A workshop of the Food and Agriculture Organization of the United Nations (FAO) in the Galápagos in November 2007 brought together scientists, sociologists and fishery managers to canvass guidelines for improved management of sea cucumber fisheries. As an output of that workshop, this technical paper is designed to help develop improved and effective management strategies. The Code of Conduct for Responsible Fisheries (CCRF) calls on managers to use the best scientific information available and implement a precautionary approach in the absence of insufficient data (Section 3.1). An ecosystem approach to fisheries (EAF) should be applied, whereby the stock is managed with objectives to also preserve ecosystem integrity and biodiversity and to address the value and use of the resource by a range of stakeholders (Section 3.3).

This technical paper provides decision support through a logical framework, or "roadmap", for planning the most appropriate regulatory measures and actions for implementing management, given the characteristics of the fisheries (Section 4). The regulatory measures and actions include a range of controls and various ancillary measures from stock surveys and socio-economic surveys to strategies that support local-scale management. Lessons from a diverse array of fisheries illustrate uses and limitations of the proposed regulatory measures and actions.

The roadmap directs managers to firstly categorize their fishery based on the scale of the fishing activities, status of stocks and the capacity of the management agency (Section 4). Simple indicators can be used to gauge the stock status in the absence of underwater (fishery-independent) stock surveys. This categorization leads to recommended sets of regulatory measures and actions for implementing management, which are each explained in separate sections. The formal process of developing this paper, through the Galápagos workshop, established a set of best-practice management measures applicable to most fisheries. It also identified situation-specific measures that may be used in some cases (Section 8.3).

Besides the external factors, the life-history traits of holothurians make them especially vulnerable to overfishing, which poses a great challenge to fishery management (Section 2.1). They can have low or infrequent recruitment, high longevity and density-dependent reproductive success. Most sea cucumber fisheries fall in the class of "S-Fisheries": small-scale, spatially-structured, targeting sedentary stocks (Section 3.5). Classical fisheries models to estimate maximum sustainable yields (MSY) of stocks are not applicable in these types of fisheries (see Section 5.4).

The most important actions for fisheries managers are sociological in nature, pointing that management of sea cucumber fisheries must embrace social science more strongly than in the past. This can be achieved with greater involvement of stakeholders and capacity building of local-level institutions (Sections 6.2.1, 6.2.2 and 6.6).

Fisheries with healthy or fully-exploited stocks of sea cucumbers should apply a broad suite of management regulations and actions, in harmony with an EAF. Agencies with adequate capacity for developing management plans and enforcement should strive for best practice by adopting all recommended regulatory measures and actions for implementing management, where appropriate (Section 4). Agencies with modest capacity should at least apply a minimum set of the most important and simple of these. Regardless of whether the fishery type is industrialized or small-scale, the management plan should comprise at least the following minimum regulations (i.e. regulations imposed on fishers, processors and traders) and actions (by the manager):

Regulations	– Minimum legal size limits (Section 5.1) – Gear limitation (Section 5.2) – Permanent Marine Reserves, excluded from fishing (Section 5.7.1) – Place-based or user-based access rights to fish (Sections 5.3 and 5.7.3) – Licensing, monitoring and reporting along the market chain (Section 5.5)
Actions	– Conduct fishery-independent stock surveys (Section 6.1.2) – Conduct fishery-dependent surveys of catch and effort (Section 6.1.3) – Conduct socio-economic surveys (Section 6.1.4) – Educate and communicate with stakeholders (Section 6.6) – Improve the quality of processing through training (Section 6.7)

Some regulatory measures, such as rotational fishing closures and individual transferrable quotas (ITQs), will be easiest to implement in fisheries with relatively few fishers and strong capacity for planning, monitoring and compliance (Sections 5.7.2 and 5.4). Quotas have been difficult to enforce in developing countries (Section 5.4). ITQs have merit for building greater sense of responsibility in fishers for the sustainability of stocks but, again, encounter limitations in developing countries with thousands of village-based fishers. Alternatives such as territorial use rights in fisheries (TURFs) for whole fishing communities may be a solution (Section 7.7.3).

Fully-exploited fisheries need more regulations, and managers need to take more actions, to circumvent the depletion of breeding stocks. The additional measures include gear limitations, the establishment of management advisory committees and support to institutional arrangements for local-scale management (Sections 5 and 6). Management agencies with greater technical capacity and human resources should apply further regulations and carry out more actions, specific to the fishery scenario. The uses, constraints of implementation and alternatives of these complimentary measures are discussed at the end of this technical paper (Section 8.3).

Depleted fisheries need to be managed quite differently in order to restore breeding populations. Moratoria (fishing bans) should be imposed across the fishery and trade should be closely monitored (Section 5.6.2). Managers also need to monitor stocks and communicate with actors along the market chain. Restocking should only be considered as a last resort to rebuild breeding populations and only for agencies with the technical capacity to develop and conduct responsible restocking programmes (Section 6.8). Recent sea ranching and sea farming programmes may improve wild fisheries by routinely creating dense breeding populations in coastal habitats.

International agreements to control the trade of sea cucumbers have advantages and disadvantages (Section 6.3.2). The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) may be beneficial for deterring illegal fishing and trade of sea cucumbers and for conserving threatened species. CITES listing could also help in standardizing trade names and codes. Lack of political will is a major impediment to CITES listing and endorsement from countries. The key concerns are that CITES listing of sea cucumbers would raise administrative costs of monitoring and reporting and would spur exporters to trade illegally.

There are many gaps in our current knowledge of sea cucumber biology and fisheries. Nonetheless, this technical paper stresses that uncertainty should not prevent the development of operational management strategies that aim to maintain or rebuild the productive capacity of sea cucumber fisheries. Management must also preserve the biodiversity values of fishery ecosystems and safeguard the long-term social and economic benefits to local communities. Fisheries are connected to ecosystems on one end and to socio-economic systems on the other. Commitment of collaboration, constructive dialogues among responsible partners, and participation of fishermen and local communities in the management process are essential to the long-term sustainability of sea cucumber fisheries.

This paper is intended for a wide audience of users: fishery managers, policy officers, development and enforcement agents, educated fishers and special interest groups, and therefore have minimal technical details. Those who wish to know more about the technical details should consult the references cited herein.

Background

From ancient times, fishing has been a major source of food for humanity, a source of cultural identity and a provider of employment and economic benefits to those engaged in this activity. However, it was realized that living aquatic resources need to be properly managed if their contribution to the nutritional, economic and social well-being of the growing world's population was to be sustained.

The 1982 United Nations Convention on the Law of the Sea provided a new framework for the better management of marine resources. The new legal regime of the oceans gave coastal States rights and responsibilities for the management and use of fishery resources within the areas of their national jurisdiction, which cover 90 percent of the world's marine fisheries.

World fisheries have become a dynamically developing sector of the food industry and many States have taken advantage of new opportunities by investing in modern fishing fleets and processing. It became clear, however, that many fisheries resources could not sustain an often uncontrolled increase of exploitation.

Clear signs of overexploitation of stocks, modifications of ecosystems, significant economic losses, territorial disputes among fisher groups and international conflicts on management and trade threatened the long-term sustainability of fisheries and their contribution to food supply. Therefore, the nineteenth session of the FAO Committee on Fisheries (COFI), held in March 1991, recommended new approaches to fisheries management. These embraced conservation and environmental, as well as social and economic, considerations. FAO then developed the concept of responsible fisheries and elaborated a Code of Conduct to foster its application.

Subsequently, the Government of Mexico, in collaboration with FAO, organized an International Conference on Responsible Fishing in Cancún in May 1992. The Declaration of Cancún endorsed at that Conference was brought to the attention of the United Nations Conference on Environment and Development (UNCED) Summit in Rio de Janeiro, Brazil, in June 1992, which supported the preparation of a Code of Conduct for Responsible Fisheries.

The twentieth session of COFI in 1993 examined the proposed framework and content for such a Code. The Code was formulated to be interpreted and applied in conformity with the relevant regulations of international laws and conventions. The development of the Code of Conduct was carried out by FAO in consultation and collaboration with relevant United Nations (UN) agencies and other international organizations, including non-governmental organizations (NGOs).

The Code of Conduct for Responsible Fisheries consists of five introductory articles: Nature and Scope; Objectives; Relationship with Other International Instruments; Implementation, Monitoring and Updating and Special Requirements of Developing Countries. These introductory articles are followed by an article on General Principles, which precedes the six thematic articles on Fisheries Management, Fishing Operations, Aquaculture Development, Integration of Fisheries into Coastal Area Management, Post-Harvest Practices and Trade, and Fisheries Research. As mentioned, the Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas forms an integral part of the Code.

The Code is voluntary. However, certain parts of it are based on relevant rules of international law. The Code also contains provisions that may be or have already been given binding effect by means of other obligatory legal instruments amongst the Parties.

The twenty-eighth session of the Conference in Resolution 4/95 adopted the Code of Conduct for Responsible Fisheries on 31 October 1995. The same Resolution requested FAO *inter alia* to elaborate appropriate technical guidelines in support of the implementation of the Code. This technical paper has been developed in this context.

1. Foreword

The conservation and management of sea cucumbers are of paramount importance because these animals fulfil an important role in marine ecosystems and are a significant source of income to many coastal communities worldwide (Conand, 1990; Conand and Byrne, 1994). The current grave status (see Glossary) of sea cucumber stocks in numerous countries can be attributed to three broad causes: rampant exploitation, ever-increasing market demand and inadequacy of fishery management. The unique life history traits of holothurians (e.g. low or infrequent recruitment, great longevity and density-dependent reproductive success) also make these species especially vulnerable to overfishing.

The vulnerability of sea cucumber populations to local extinction and the risk of long-term loss of fishery productivity have prompted several international and regional meetings of expert scientists and fishery managers in recent years. In 2003, FAO hosted a technical workshop, "Advances in sea cucumber aquaculture and management", and published a report with technical papers and recommendations for fishery management (Lovatelli *et al*., 2004). The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) also ran a technical workshop, in 2004 in Malaysia, entitled "Conservation of sea cucumbers in the families Holothuridae and Stichopodidae", providing scientific justification and urging for the immediate need of conservation and sustainable exploitation of sea cucumbers (Conand, 2004, 2006a, 2006b; Bruckner, 2006a). In 2006, the Australian Centre for International Agricultural Research (ACIAR) organized a workshop to produce a simple guidebook to help Pacific fishery managers to diagnose the health of their sea cucumber fisheries and develop appropriate management plans (Friedman *et al*., 2008a). The Western Indian Ocean Marine Science Association (WIOMSA) also funded a Marine Science for Management (MASMA) project to study the biology, socio-economics and management of sea cucumber fisheries to assist Western Indian Ocean countries (Conand and Muthiga, 2007).

A common recommendation from these international meetings is to help improve national fisheries management. Resource managers need prescriptive advice on what management regulations and activities are best for sea cucumber fisheries. Unfortunately, few guidebooks exist at present on managing sea cucumber fisheries, leaving fishery managers with a subjective task of drawing on management principles based on other resources. In addition, sea cucumber fisheries differ greatly in scale, cultural setting, socio-economic structure, fishing methods and in the technical capacity of the management bodies.

To meet these challenges, FAO carried out a global project on sea cucumber fisheries. The major objective was to review the global status of sea cucumber stocks and to provide support tools to improve their conservation and sustainable exploitation (Toral-Granda, Lovatelli and Vasconcellos, 2008). An international workshop was convened in November 2007 in Puerto Ayora, Santa Cruz Island, Galápagos (Ecuador) to identify management measures best suited to sea cucumber fisheries. The present technical paper is the main output of that workshop.

The purpose of this technical paper is to contribute to improved and effective management and governance of sea cucumber fisheries around the world through successful implementation of an ecosystem approach to fisheries (EAF). It presents best-practice management measures applicable to most fisheries and provides examples and situation-specific measures that may be used in some scenarios. Drawing on lessons described in the Regional Reviews of sea cucumber fisheries (Toral-Granda,

Above: Participants of the FAO workshop at the Charles Darwin Foundation Research Station, Galápagos, November 2007

Lovatelli and Vasconcellos, 2008), practical examples are presented across a diverse array of fisheries from tropical and temperate regions. Notably, this technical paper aims to assist fisheries managers in choosing regulations and action plans to maintain and restore the productive capacity and biodiversity of sea cucumber stocks and fishery ecosystems, while considering their role in the livelihoods of fishers.

The technical paper is intended for fishery managers, development and extension agencies, enforcement and trade agencies, policy officers, educated fishers and special-interest groups. It is a decision-support tool for the development of fisheries management plans and strategies for biodiversity conservation. The paper embraces an ecosystem approach to fisheries (EAF) (FAO, 2003) by recognizing the importance of sea cucumbers to rural coastal livelihoods and the socio-economic impacts of management measures. In this context, fisheries management must find a sensible balance between the need to optimize long-term benefits to fishers and the conservation of resource biodiversity. These trade-offs were discussed among the expert biologists, sociologists and resource managers at the Galápagos Workshop.

Aligned with the EAF, the Galápagos workshop evaluated potential actions the agencies responsible for fisheries management, monitoring, surveillance and enforcement may take and the scientific knowledge needed to support management decisions. The technical paper is therefore designed for a wide readership, and not just for fisheries managers. It also provides discussion of the utility of CITES listing for the conservation of threatened or depleted holothurian species.

Although our understanding of how sea cucumber fisheries should be managed has come a long way in the past decade, much progress is still needed. Whereas Friedman *et al*. (2008a) provide a quick guide for alerting managers to problems in their fisheries and directing them to appropriate regulatory measures and actions, the present technical paper give a comprehensive "roadmap" with more detailed explanations and examples. However, this technical paper is not a completed recipe book. Rather, if needs to be seen as a "work in progress" and represent our current position along the road to developing sustainable management systems for these very important resources.

2. Sea cucumber fisheries

2.1 BIOLOGY AND ECOLOGY

There are six taxonomic orders of holothurians but most commercial species belong to the Aspidochirotida and a few to the Dendrochirotida order (Conand, 2006a). Reviews of the biology and ecology of commercial sea cucumbers are widely available (Conand, 1990; Hamel *et al*., 2001; Conand, 2006a). Only a brief overview is therefore presented here, with particular reference to fisheries management.

Commercial sea cucumbers are predominantly gonochoric; that is, they exist as males or females. However, a few species are known to be hermaphroditic (combining both sexes in the same individual). In most gonochoric species, it is not possible to distinguish males from females by their outer appearance, but sea cucumber populations generally present 1:1 sex ratios. The majority of sea cucumbers are broadcast spawners, releasing sperms and oocytes (unfertilized eggs) directly into the water column. Females can release thousands to millions of oocytes in a single spawning event. The motile sperm cells (spermatozoa) have to swim to find and fertilise the oocytes. Fertilisation success is, therefore, maximized where males and females are relatively close to each other. The release of gametes, i.e. oocytes and sperm, by adults is generally triggered by environmental cues (e.g. certain tidal conditions, lunar phases, temperature fluctuations) and chemical cues from other individuals of the same species. For example, the chemical "signature" of sperm released by males is suspected to be sensed by down-current females, which then release eggs to mix in proximity with the sperm.

Reproductive cycles are variable among species, but most tropical species tend to have a peak in spawning activity around the early summer months (Conand, 1993; Conand, 2008; Kinch *et al*., 2008a). Fewer species, like *Holothuria whitmaei*, spawn primarily in the cooler months of the year. Some commercial sea cucumbers can spawn several times per year or periodically every month, such as *Isosticopus fuscus* in Ecuador (Mercier, Ycaza and Hamel, 2007) and *Holothuria scabra* in the Solomon Islands (Hamel *et al*., 2001). Temperate species, like *Cucumaria frondosa* in Canada, usually spawn once a year in spring or early summer (Hamel and Mercier, 1996) (Figure 1). In addition to sexual reproduction, about 10 species reproduce asexually by dividing in the middle of the body; both halves re-grow necessary organs and form clones of the original individual. This mode of reproduction by *transverse fission*, as it is called, may or may not occur in different seasons than sexual reproduction among the various species (Uthicke, 1997; Conand, 2006a).

The oocytes of most commercial species of sea cucumbers are small, generally under 200 µm in diameter, and more or less neutrally buoyant when released in the water column (Mercier, Hidalgo and Hamel, 2004; Agudo, 2006). However, commercial species from temperate regions may possess large yolky buoyant oocytes that can measure up to 1 mm in diameter (Hamel and Mercier, 1996). In the case of tropical species with small oocytes, fertilized eggs will develop quickly into free-swimming larvae, sometimes in less than one day. These larvae will feed on microalgae until metamorphosis (whereas dendrochirotid sea cucumber species can have non-feeding, or "lecithotrophic", larvae) (Figure 2). The larvae spend a couple to several weeks in the water column before transforming to the final larval stage that can settle on various substrata, depending on the species (e.g. rocks, dead corals, algae, seagrass or sediments).

FIGURE 1

Spawning in sea cucumbers. Left: a female *Cucumaria frondosa* spawning in captivity. The orange, tightly packed, cylinders of oocytes have been expelled and will be fertilised externally by sperm released from males. Right: a male *Bohadschia marmorata* stands erect in a tropical seagrass bed and releases sperm, which disperses into the water column

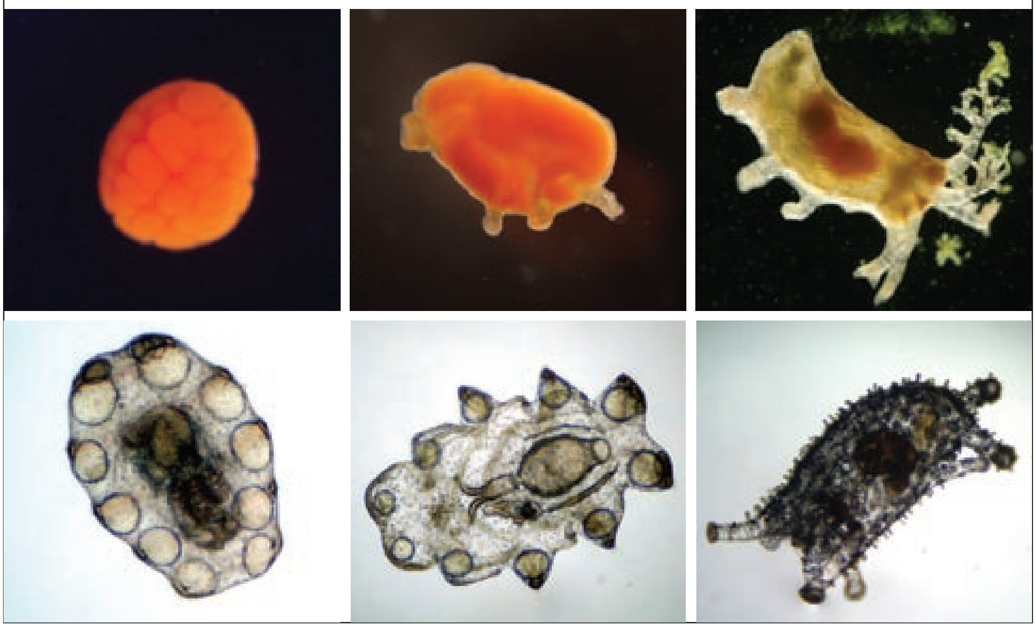
PHOTO: A. MERCIER AND J.-F. HAMEL

PHOTO: A. DESURMONT

The ecology of sea cucumber larvae is poorly understood (Conand, 2006a), but it is likely that their movement in the water column, particularly vertically, mediates their dispersal to new sites. Genetic studies indicate that large-scale larval dispersal exists for some species (Uthicke and Benzie, 2000). But evidence suggests that dispersal is relatively restricted for some other species, resulting in genetic differences in populations over relatively short distances (Uthicke and Benzie, 2001; Uthicke and Purcell, 2004). Some species are therefore more likely to provide larvae to renew populations on distant habitats, while other species seem to self-recruit and supply larvae to neighbouring sites. For reasons not yet clear, even populations of species

FIGURE 2

Embryonic and larval development of sea cucumbers. Upper photos: the dendrochirote sea cucumber *Cucumaria frondosa*. Upper left: the blastula stage, 0.9 mm, just 40 h after fertilisation. Upper centre: the pentactula larval stage, 1.3 mm long, 4–5 weeks after fertilisation. Upper right: a juvenile, 2.5 mm long, 3 months old. Lower photos: the aspidochirote sea cucumber *Isostichopus fuscus*. Lower left: the doliolaria larval stage, ca. 0.6 mm long. Lower centre: ventral view of a fully developed auricularia larval stage, ca. 1 mm long. Lower right: newly settled juvenile, measuring 1.5 mm in length



PHOTOS: J.-F. HAMEL AND A. MERCIER

with widely dispersing larvae can be slow to recover from moderate to high rates of exploitation (Uthicke, 2004; Uthicke, Welch and Benzie, 2004). For the Pacific black teatfish *Holothuria whitmaei*, a fishing rate of just 5 percent of virgin biomass per year still lead to depletion of breeding stocks (Uthicke, 2004). Evidence from other populations that have failed to recover from heavy fishing pressure also stresses that sea cucumbers are prone to "extirpation" (local extinction of stocks) and management measures should curtail fishing to conservative rates.

Growth in sea cucumbers has been difficult to assess (Conand, 1990) because they are not amenable to conventional tagging methods (Purcell, Blockmans and Nash, 2006). However, some growth rates in the wild are available from studies using modal progression analysis, genetic fingerprinting, and the release and monitoring of juveniles. Some species, like the sandfish *Holothuria scabra* are relatively fast growing when young (Purcell and Kirby, 2006), reaching the size at first maturity (~180 g) in a year or so but take another couple years to reach an acceptable market size (Purcell and Simutoga, 2008). Similarly, Shelley (1985) estimated growth to be 14 g month^{-1} for *H. scabra* and 19–27 g month^{-1} for *Actinopyga echinites*. Uthicke (1994) found modest weight gain in *Stichopus chloronotus* of 70–80 g year^{-1}, and Franklin (1980) showed that their growth slows once individuals become large. Growth of other species like *H. whitmaei* appears slow, in the order of 80–170 g yr^{-1}, and large animals can shrink during certain periods (Uthicke and Benzie, 2002; Uthicke, Welch and Benzie, 2004). A study of *A. echinites* in southern Japan (Wiedemeyer, 1992) also found slow weight gain of small juveniles. It may thus take some species many years to reach commercial sizes. For example, the cold-temperate species *Cucumaria frondosa* from the North Atlantic was estimated to reach commercial size after 10 years (Hamel and Mercier, 1996).

Longevity has been estimated at 10–15 years for *Actinopyga mauritiana*, *A. echinites* and *Thelenota ananas* but only 5 years or so for *Stichopus chloronotus* (Conand, 1989). The results of Uthicke *et al.* (2004) led them to suggest that *H. whitmaei* are rather long-lived, potentially in the range of several decades. Field studies therefore indicate that many populations turnover relatively slowly and may not support high rates of fishing or be amenable to rotational harvest-closures that require fast growth of animals after pulses of harvesting.

Sea cucumbers are rather sluggish, in terms of their rates of displacement and can be regarded as "sedentary". Some migration from settlement habitats to adult habitats has been reported for some species (Reichenbach, 1999; Hamel and Mercier, 1996; Hamel *et al*., 2001). The limited long-term displacements of sea cucumber, compared to highly mobile species like fishes, give advantages to using marine reserves and no-take zones to protect breeding populations as sources of egg supply for fishing grounds. Marine reserves can be relatively small but in a network if the intended resources do not migrate in and out of the reserves easily (Sale *et al*., 2005). Work using a DNA fingerprinting technique shows that only few Pacific black teatfish migrated 90 m between study sites during one year (Uthicke, Welch and Benzie, 2004). Field measurements of various sized animals and subsequent modelling suggest that sandfish *H. scabra* will mostly remain within a few hundred metres of their settlement locations over a 10–year time span (Purcell and Kirby, 2006). These studies suggest that marine reserves need not be very large for protecting breeding populations of sea cucumbers for long periods. If simply for sea cucumbers and other sedentary or sessile invertebrates, no-take reserves of perhaps 50–300 hectares (0.5–3 km^2) could be sufficient.

Most of the commercial sea cucumbers are deposit feeders that consume detritus, bacteria and diatoms mixed with sediments on the seabed (Conand, 2006a) (Figure 3). Those species on hard reef surfaces "mop up" the particulate organic matter that coats rocks and benthic vegetation (Figure 3). Just a few commercial species are suspension feeders (Hamel and Mercier, 2008a). Holothurians are therefore a low-food chain group and help to recycle detritus. Some species bury in sediments and are so believed

FIGURE 3

Sea cucumbers feeding on organic detritus and microalgae. Left: *Holothuria coluber* with cream-coloured tentacles extended, feeding on detritus in sediments. Right: *Pearsonothuria graeffei* with black tentacles extended to collect microalgae and detritus on a hard reef surface

to help oxygenate upper sediment layers and play a role in bioturbation (Purcell, 2004a; Wolkenhauer *et al.*, 2009).

Sea cucumbers are prey to a vast array of predators (Francour, 1997). In particular, invertebrate predators like sea stars, crabs and some gastropods are often reported as the culprits of mortalities. A short-term study on released sandfish shows that juveniles are prone to being eaten readily by a range of fishes (Dance, Lane and Bell, 2003). Some birds, turtles and marine mammals are also believed to eat sea cucumbers on occasion. However, some species develop passive or active mechanisms of defence (e.g. *Holothuria atra*, *Holothuria leucospilota*, *Cucumaria frondosa*) that have proved to be efficient predator deterrents.

2.2 BECHE-DE-MER MARKET

Sea cucumbers have been eaten by Chinese and other Asians for centuries for their curative and dietary properties (Conand, 1990, 2006a, 2006b). They were recorded as a tonic food as early as the Ming Dynasty (1368–1644 AD) (Chen, 2004). Foods are often first used by Chinese to treat ailments and disease, before powdered or chemical medicines. Many Asians believe that sea cucumbers can help reduce joint pain and arthritis, help restore correct intestinal and urinary function, reinforce the immune system and can treat certain cancers (Chen, 2004). To a lesser extent, sea cucumbers may also be eaten as aphrodisiacs. They are rich in protein and contain mucopolysaccharides and chondroitin sulphate, known in western medicines as treatments for arthritis and joint ailments. This correspondence with western medicine gives credit to the use of sea cucumbers in traditional Asian dietary medicines.

In the past, sea cucumbers were eaten by Asians wealthy enough to afford them for health treatments, or served as delicacies during festive periods such as the Chinese New Year. More recently, Chinese and other Asians have started to eat sea cucumbers more regularly, owing to increased affluence and greater disposable income for luxury foods (Figure 4). This increased demand is the primary cause of inflated prices of sea cucumbers globally and the driver of increased exploitation of stocks.

The main import markets are traditionally China, Hong Kong Special Administrative Region (SAR), Singapore and Taiwan Province of China. Recently, the United Arab Emirates (UAE) has also become important. All of these markets are also major re-exporting centres (Conand, 2004, 2006b, 2008). China, Hong Kong SAR is the major world market. Although China is the main consuming country, sea cucumbers are also appreciated in Southeast Asian countries and by Asians residing abroad (Ferdhouse, 2004).

FIGURE 4
Left: sea cucumbers served as a sauced dish in China. Right: wartless variety "Namako" (*Apostichopus japonicus*) from Kobe, Japan

PHOTO: S.W. PURCELL

PHOTO: J. AKAMINE

Fresh or live animals are called sea cucumbers or holothurians, but they are usually gutted, boiled and dried before being exported to Asian markets. It is the dried body wall that is called "*beche-de-mer*", meaning "spade of the sea", or "*trepang*" or "*haishen*". Once purchased, beche-de-mer is reconstituted by gentle boiling then eaten in sauced dishes or soups. Sea cucumbers are also used in Malaysia in a wide range of products including oral jellies, body creams, shampoo and toothpaste (Choo, 2008a). Because they are a luxury food item and one that apparently delivers curative benefits, it is unlikely that the global market will wane over time, particularly if consumer affluence in China continues to rise.

The price of beche-de-mer varies greatly among species and also within species depending on the size of the animal and the care in which it was processed. Larger animals generally command a higher price per kilogram than smaller ones. The Japanese sea cucumber, *Apostichopus japonicus*, can fetch more than USD300 kg^{-1} (dried) at retail markets, if the animals are in a perfect, presentable, state (Figure 5). Some tropical species, particularly the sandfish *Holothuria scabra* and golden sandfish *Holothuria lessoni* (Massin *et al.*, 2009) can fetch almost an equivalent price for large, well-processed specimens. However, some low-value species or animals poorly processed would sell for a small fraction of this price.

FIGURE 5
Left: the Japanese sea cucumbers *Apostichopus japonicus* on sale in transparent bins and gift boxes in a market in Dalian, China. Right: price tag on a bin of dried high-quality *A. japonicus*; equivalent to USD460 per kg

PHOTOS: S.W. PURCELL

2.3 FISHERY TYPES

Sea cucumber fisheries are diverse in terms of ecological attributes of species, modes of exploitation, fishery history, socio-economic structures and capacity for management and enforcement (Toral-Granda, Lovatelli and Vasconcellos, 2008). They are often small-scale fisheries in the way the animals are harvested, mainly comprising fishers that collect sea cucumbers by wading or skin diving in shallow waters (Choo, 2008a; Conand, 2008; Kinch *et al*., 2008a) (Figure 6). In developed countries, sea cucumber fisheries are commonly industrialized, with fishing companies owning larger boats operated by teams of fishers, sometimes with sophisticated fishing gear (Bruckner, 2006c; Hamel and Mercier, 2008a) (Figure 7; Section 5.2). Greater and greater fleet capacity has also been an increasing theme for smaller fisheries as prices of beche-de-mer have become lucrative (Toral-Granda, 2008b; Kinch *et al*., 2008a).

FIGURE 6
Artisanal small-scale fisher in Mindanao, Philippines. Women (left) and men (centre) fish from small canoes and gather sea cucumbers in shallow water using only a mask and fins. A sea cucumber fisher in Tomini Bay, Sulawesi, Indonesia, (right) wearing simple, homemade, goggles

PHOTOS: R. GAMBOA (LEFT AND RIGHT)
PHOTO: J. AKAMINE

FIGURE 7
Industrialized fishing in eastern Canada for *Cucumaria frondosa*. Sea cucumbers are collected using a “drag” net (see *Examples and lessons learned* in Section 5.2) then dumped into a sorting tray on the fishing vessel where undersized sea cucumbers and bycatch, like sea urchins and sea stars, are removed and returned to the sea

PHOTOS: L. BARRETT

The problems confronting small-scale and industrial fisheries are different. Small-scale fisheries often comprise a large number of lowincome fishers (see Kinch *et al.*, 2008a,b; Choo, 2008a,b), who collect sea cucumbers out of tradition or as an occupation of last resort in times of economic hardship. In both cases, fishers show great reluctance or inability to cease fishing, even when sea cucumber populations become depleted. These fishers often lack formal education and live in remote areas so that they are hardly known by management agencies, making the job of working with them to implement sustainable fishing practices very difficult (see Conand and Muthiga, 2007; Rasolofonirina, 2007; Kinch *et al.*, 2008b; Choo, 2008b). On the other hand, industrial-scale fishers are more commonly capable to switch to other resources and are easily contactable by fisheries agencies. But their great capital investment in boats and fishing gear means they must continue high rates of exploitation to cover financial loans and operating costs.

Most of the sea cucumber fisheries in the world are multispecies in nature (Toral-Granda, Lovatelli and Vasconcellos, 2008). There are over 60 species known to be exploited commercially and traded around the world (Toral-Granda, Lovatelli and Vasconcellos, 2008; Annex 10.1). Fisheries in the tropics tend to comprise many species (Figure 8). This is particularly true for those in the Western Pacific, Southeast Asia and the Indian Ocean, where 20–30 species can be fished and exported from a single country (Choo, 2008a; Conand, 2008; Kinch *et al.*, 2008a). In contrast, temperate fisheries are more or less mono-specific (Conand, 2004, 2006a; Bruckner, 2006c; Hamel and Mercier, 2008a,b).

The habitats where sea cucumbers are fished also vary widely among various fisheries. Commercial species in the tropics are mostly fished on shallow coral reefs (Figure 9), tropical lagoons and inshore seagrass beds. Those in temperate waters can be found on rocky substrata or soft sediments, mostly in deeper waters (Figure 9). Some species seem to strongly prefer complex reef habitats (e.g. *Actinopyga lecanora*; *Stichopus chloronotus*) or wave-exposed areas (e.g. *Actinopyga mauritiana*), making them accessible only to skindivers. In contrast, species in temperate waters may occur to depths exceeding 50 m (e.g. *Cucumaria frondosa*; Hamel and Mercier, 2008a,b) and are mostly fished with "drag" nets (Figure 7).

The technical capacity and human resources of fisheries agencies also vary widely among sea cucumber fisheries. Developed countries, such as Canada, the United States of America and Australia, have relatively greater capacity to conduct monitoring and analyses on fisheries and biological data and in the development and compliance of fisheries management regulations. Management measures therefore tend to be more sophisticated. In developing countries, capacity constraints limit the ability to develop

FIGURE 8
Left: a mixed catch of sea cucumbers on a fishing boat in the Seychelles. Right: at least six species of dried sea cucumber with a sales receipt in Mindanao, Philippines

PHOTO: R. AUMEERUDDY *PHOTO: R. GAMBOA*

FIGURE 9

Left: a tropical sea cucumber (*Actinopyga mauritiana*) in shallow, complex, coral reef habitat, too inaccessible for fishing with trawl gear. Right: a temperate species (*Cucumaria frondosa*) at depth, on a substrate of coarse sand and shellgrit

PHOTO: S.W. PURCELL

PHOTO: J.-F. HAMEL AND A. MERCIER

or effectively implement complex management measures (e.g. individual transferrable quota schemes) or to conduct rigorous monitoring of fishery stocks. Countries in Asia generally lack management measures and the two largest exporters of sea cucumbers, Indonesia and the Philippines, do not have widespread management systems for their sea cucumber fisheries (Choo, 2008a).

The level of access rights to fishing grounds or specific resources is another factor varying among fisheries. For example, the sea cucumber fishery in western Canada and the Great Barrier Reef in Australia are divided into delineated fishing areas allocated to particular licensed fishing companies (Hamel and Mercier, 2008b; Kinch *et al*., 2008a). The fishers can leave smaller adults while fishing, knowing that they have sole rights to collect them in subsequent seasons. In contrast, open access fisheries such as the Philippines or Madagascar are plagued with the "tragedy of the commons" (Hardin, 1968) whereby fishers even collect small adult and juvenile sea cucumbers because they will be fished by their neighbour if left behind (Choo, 2008b; Conand, 2008).

The wide diversity of sea cucumber fisheries makes it impossible to prescribe a "one-size-fits-all" template for management. There are, nonetheless, some regulatory measures that are appropriate for most fisheries and some actions that all fishery managers should undertake for implementing management (Section 4). Before proceeding to appraise the merits of potential management tools, managers must first set appropriate objectives, in line with precautionary principles and a holistic approach to management, and diagnose the fishery, in terms of its ecological and social attributes (Sections 3.4 to 3.6).

2.4 GLOBAL STATUS

Sea cucumbers are fished worldwide, particularly in tropical regions (Conand and Byrne, 1994; Conand, 2006b; Toral-Granda, Lovatelli and Vasconcellos, 2008). Fisheries exist in warm waters from East Africa to South and Central America, and in temperate waters of the Mediterranean and in the North Pacific and North Atlantic Oceans. Most of these fisheries have existed for centuries, especially those in Asia (Choo, 2008a), the Pacific Islands (Kinch *et al*., 2008a) and the Indian Ocean (Conand, 2008). The Western Central Pacific and Asia are the predominant regions exporting beche-de-mer. Some fisheries are relatively new or in the process of development, such as those in Latin America (Toral-Granda, 2008a), North America and Europe (Hamel and Mercier, 2008a).

The total volume of global harvests is difficult to collate for many reasons: not all countries declare sea cucumbers separately in trade statistics of marine invertebrates; some countries import and re-export; and some animals are exported as salted or frozen, representing about half of the original whole animal weight, whereas most others are exported dried, representing roughly 5–10 percent of the live animal weight (Ferdhouse, 2004; Conand, 2006b). Including catches of sea cucumbers in countries where they are eaten, the total global catch of sea cucumbers is in the order of 100 000 tonnes of live animals annually (considering that some trade statistics are not dried animals; c.f. Vannuccini, 2004). At the beginning of the new millennium, about 6 000 tonnes of processed (i.e. mostly dried) animals were exported to Asian markets, worth over USD130 million (Vannuccini, 2004).

Countries in Southeast Asia and the Pacific are traditionally the main sources of wild-caught sea cucumbers (Conand, 1990; Ferdhouse, 2004). A decade ago, the leading exporters were Indonesia, the Philippines, Papua New Guinea, Japan, Republic of Korea, the United States of America, Solomon Islands, Fiji Islands, Madagascar, Australia and New Caledonia. However, this appears to have changed radically in recent years as some fisheries have been depleted and others have developed or are expanding (Toral-Granda, Lovatelli and Vasconcellos, 2008).

Recent reviews of sea cucumber fisheries from around the world suggest that many are overexploited, some are depleted and a few are nascent fisheries with relatively healthy stocks (Toral-Granda, Lovatelli and Vasconcellos, 2008). In the Indian Ocean, more than half of the sea cucumber fisheries are considered overexploited (Conand, 2008). Excessive fishing has caused local extinction of breeding populations of some species and a collapse of other stocks in Egypt (Hasan, 2005) and depleted stocks to oblige a complete moratoria on fishing in India (Conand, 2008). Moratoria on fishing have been set in mainland Tanzania and Mayotte (France).

Throughout much of Asia, fisheries have been overexploited and populations are severely depleted for high-value species such as *Holothuria fuscogilva*, *H. whitmaei*, *H. scabra* and *Thelenota ananas* (Choo, 2008a). Field surveys indicate that some high-value species have also been fished to reproductive extinction in some regions of Indonesia, Viet Nam and the Philippines (Choo, 2008a,b). Fishery managers in Asian countries confront difficult challenges to deal with the sheer number of fishers, their poverty and dependence on aquatic resources, and limited technical capacity and human resources for implementing sustainable management.

In the Western Central Pacific, the vast majority of countries have exported sea cucumbers in recent years. Catches have dwindled to insignificant levels in most Polynesian countries (Kinch *et al.*, 2008a). Although Papua New Guinea was recently exporting hundreds of tonnes of beche-de-mer each year, the catch shifted to low-value species in recent years and there is compelling evidence from field surveys that stocks of high-value species have been fished to local extinction in some localities (Kinch *et al.*, 2008b). Overfishing prompted the recent closure of national fisheries in Vanuatu and Solomon Islands, which had both exported large volumes for the past two decades (Kinch *et al.*, 2008a). In 2009, depleting breeding stocks prompted a national moratorium to close the entire sea cucumber fishery of Papua New Guinea, a country traditionally among the top three global exporters of beche-de-mer. Six fisheries operate in Australia, but several valuable species are currently banned from fishing due to overexploitation, even from within the World Heritage-listed Great Barrier Reef Marine Park.

Fisheries in Latin America and the Caribbean started in the past two decades and have mostly been unsustainable (Toral-Granda, 2008a). One exception is the lucrative sea cucumber fishery in Cuba which, by all accounts, remains sustainable. After some years of heavy fishing, moratoria were imposed in fisheries of Costa Rica, mainland Ecuador, Panama and Venezuela. In Mexico, stocks of the valuable *Isostichopus fuscus* were fished to about 2 percent of the pre-fishing biomass (Toral-Granda, 2008a). In the World Heritage-listed Galápagos Islands, *I. fuscus* has been overexploited and the fishery has been the centre of aggressive demonstrations by fishers over stricter management regulations (Toral-Granda, 2008b).

Temperate sea cucumber fisheries of the Northern Hemisphere are commonly based on one of about five or six key species (Hamel and Mercier, 2008a). Temperate fisheries exist in the United States of America, Canada, Iceland, the Russian Federation, Japan and recently in parts of Scandinavia. Fisheries for species within the genus *Parastichopus* involve divers and have been active for almost 40 years. Those for *Cucumaria* species use "drag" nets from ships and are recent or in an exploratory phase (Hamel and Mercier, 2008a). Exploitation rates are increasing but fishery managers are mostly employing conservative measures. Some stocks are sizeable, like those of the temperate-polar *Cucumaria frondosa* in eastern Canada, and novel processing methods have been pioneered to use organs and muscle bands as well as the body walls of the animals, to countervail its low value as beche-de-mer (Hamel and Mercier, 2008b).

Of particular note, aquaculture in China for the cold-water *A. japonicus* has boomed in the past 15 years (Chen, 2004). Mass production of this species through aquaculture of juveniles in hatcheries and growout of adults in ponds and on artificial reefs currently rivals the total global wild captures in volume (Figure 10). Surprisingly, this does not seem to have dampened prices of the wild-caught tropical species.

FIGURE 10

Left: a commercial diver ready to collect sea cucumbers from artificial reefs in front of a hatchery for *A. japonicus* in Dalian, China. Right: *A. japonicus* harvested by the diver from an artificial reef previously stocked with cultured juveniles

PHOTO: J. AKAMINE

PHOTO: S.W. PURCELL

3. Fisheries management principles and approaches

3.1 THE CODE OF CONDUCT FOR RESPONSIBLE FISHERIES

Through partners in fisheries management, the FAO developed the Code of Conduct for Responsible Fisheries (1995). Although the Code is not legally binding, it sets out a list of principles for behavior and practices towards responsible stewardship of marine resources and their environments. (Note, though, that some principles of the Code reiterate those that may have been given a binding effect in international agreements or other legal instruments). It advocates the principles to be followed by all actors in all fisheries, from fishers to processors, exporters, biologists and managers.

The Code urges managers to take actions to ensure that resource values, e.g. the abundance and diversity of marine animals, are maintained for future generations. It covers recommendations for the behaviour and actions of States (and centralized management agencies) pertaining to, but not exclusive of, the following:

- proper management of marine resources,
- collection of data and provision of advice,
- exercising a precautionary approach to resource use and management,
- implementation and enforcement of management measures,
- controls over fishing practices,
- development of aquaculture and caution to translocation of stocks,
- actions to ensure proper post-harvest processing of marine animals,
- monitoring and control of international trade of marine products, and
- support for all aspects of research needed to understand and manage stocks.

Specific references are made to articles of the Code later in this paper. Nonetheless, some general recommendations are pertinent to sea cucumber fisheries and worth highlighting, and are paraphrased below:

- States are urged to prevent overfishing and excess fishing capacity and to ensure that fishing effort is commensurate with the productive capacity of the resources.
- Conservation and management decisions should be made using the best scientific information available, and managing institutions should take responsibility to conduct or promote research into all aspects needed for responsible management.
- States (or managing institutions) should also monitor fishing activities regularly and use results from analyses of fishery-dependent data in management decisions.
- Through education and training of fishers, States (or fisheries agencies) should promote awareness of responsible fishing practices and processing methods that add value to their catch in environmentally responsible ways and in order to minimize discard.
- The rights of indigenous and small-scale fishers should be respected and protected.
- States should ensure compliance with, and enforcement of, conservation and management measures.
- The capacity of developing countries in applying various articles of the Code should be taken into account.

3.2 THE PRECAUTIONARY APPROACH

There are a couple indisputable tenets about fisheries that underlay the precautionary approach. Fishing activities impact resource stocks and can reduce populations to low levels at which reproduction becomes ineffective. Fishing activities can also affect the environment, albeit indirectly in some sea cucumber fisheries, and one cannot assume that these impacts will not lead to long-term change.

The precautionary approach recognizes that undesirable changes in fisheries systems, like depletion of certain stocks, are usually only restored slowly (FAO, 1996). Therefore, where the impacts of fishing on the resource or environment are uncertain, managers and decision-makers should err on the conservative (or "precautionary") side or fisheries management to avoid situations where the productive capacity of the resource, or the health of the environment, is diminished. The precautionary principle thus assumes that a conservative "duty of care" is exercised in fisheries management (Grafton, Kompass and Hilborn, 2007). A key principle in the precautionary approach is that "*The absence of adequate scientific information should not be used as a reason for postponing or failing to take conservation and management measures*" (FAO, 1995).

Fishery managers should also take the following actions:

- Develop management plans that indicate which management measures are to be applied and the circumstances under which the measures should be changed, i.e. "decision control rules" (FAO, 1996; Hindson, *et al*., 2005).
- Take necessary corrective measures, without delay, in cases where the resource or environment has been impacted by fishing activities, giving priority to restoring the stocks to productive levels.
- Set in place mechanisms for adapting regulatory measures in the light of unexpected events. Establish legal or social management frameworks for fisheries.
- Define the objectives of the fishery and set measurable targets in a precautionary manner, e.g. by setting fishing mortality lower than the level required for the maximum sustainable yield (MSY) of the stock (FAO, 1996).
- Ensure that the harvesting and processing capacity is commensurate with the sustainable levels of the resource and that fishers report on their activities.

The precautionary approach urges States (i.e. fishery managers) to take into account uncertainties related to the size and productivity of the stocks (FAO, 1995). For sea cucumbers, this is particularly important because there is yet clear scientific evidence to reliably predict the productivity of most species and populations. The studies from which we can gain some understanding of the dynamics of sea cucumber populations (e.g. Uthicke, 2004; Uthicke, Welch and Benzie, 2004; Hearn *et al*., 2005; Lincoln-Smith *et al*., 2006; Skewes *et al*., 2006) point towards sporadic, or infrequent, recruitment and/or low productivity for many species. Therefore, managers should not use management tools that assume regular recruitment of sea cucumbers or that stocks will recover quickly if fished down.

3.3 THE ECOSYSTEM APPROACH TO FISHERIES

Ecosystem approach to fisheries (EAF) arose from the global awakening to the shortcomings in managing fisheries by focusing primarily on the resource (i.e. fish or sea cucumbers) or so called "target resource-orientated management" (TROM). The broad purpose of the EAF is to accommodate societal expectations and needs into management without threatening the options for future generations to gain from the goods and services of resource ecosystems (FAO, 2003). The EAF strives to find a satisfactory balance between *ecosystem conservation*, which focuses on protecting biophysical components and processes of ecosystems, and *fisheries management* that focuses on providing food and income for people's livelihoods by managing fishing activities.

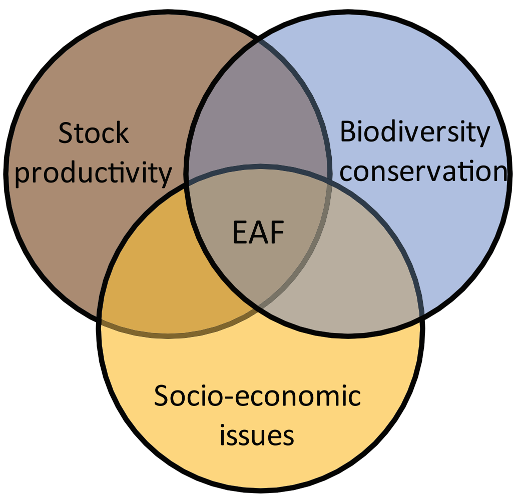
The EAF requires consideration of the potential direct and indirect effects of fishing on the dynamics of the ecosystem and potential cumulative impacts from different fisheries. But this does not mean that fishery managers must understand the structure and function of entire ecosystems to implement effective ecosystem-based management (Jennings, 2004). What it does mean is that a variety of factors influencing the stocks and their resilience to human impacts (e.g. fishing, habitat degradation and other threats to marine ecosystems such as climate change and ocean acidification) should be considered in decision-making about regulatory measures and actions. The ecosystem approach to fisheries is somewhat of a misnomer because it goes much further than just expanding management considerations to marine ecosystems. Rather, the EAF attempts to deal with fisheries in a holistic way through the recognition of wider economic, social and cultural benefits that can be derived from fisheries resources and their ecosystems (FAO, 2003) (Figure 11).

In small-scale fisheries, like sea cucumber fisheries, Andrew *et al.* (2007) stress that humans must be considered within fishery ecosystems rather than apart from them. A common theme to the concept of EAF is to include fishers and other "actors", in the decision-making process and implementation of fisheries management. Conand (1990, 2006b) noted that sea cucumbers are important to the livelihoods of coastal fishers, particularly in developing countries, so socio-economic issues in these fisheries should be recognized and incorporated into management. By considering humans (especially fishers, processors, exporters) in ecosystem management, appropriate incentives can be devised to stop the "race-for-fish" and reduce other problems of classical "top-down" fisheries management (Hilborn, 2004). In this sense, the EAF promotes institutions for co-management and community-based management of marine resources (discussed in Section 6.2.1).

The ecosystem approach to fisheries is a set of guiding principles and commitments. Operationalizing the fundamental concepts within the ecosystem approach, i.e. putting it into action, has proven difficult (Andrew *et al.*, 2007). As Jennings (2004) put it, "*the success of an ecosystem approach will depend on whether these high-level and somewhat abstract commitments can be turned into specific, tractable and effective management actions*". Making the EAF operational requires managers to identify broad and specific objectives, set measurable reference points (e.g. certain minimum densities for sea cucumber populations), develop rules about how to apply and adapt fishery

FIGURE 11

The ecosystem approach to fisheries involves the overlap of several key management objectives



regulations and objectively evaluate the performance of management plans through monitoring (FAO, 2003; Sections 3.4 and 3.5). All of this needs to be done with greater involvement of stakeholders (e.g. Sections 6.2.2 and 6.6) and capacity building of local institutions (Section 6.2.1).

3.4 MANAGEMENT OBJECTIVES, INDICATORS AND REFERENCE POINTS

The path to failure in fisheries, and fisheries interventions, is often paved with the initial ambiguity over the objectives of management. Objectives are statements of the intended outcomes of the fishery management plan (FAO, 2003; Hindson, *et al*., 2005). A management plan may have, for instance, six to twelve overarching objectives. Defining objectives helps to align choices for regulatory measures and actions undertaken by management institutions and affixes the "goalposts" for judging management success.

The Code of Conduct for Responsible Fisheries (FAO, 1995) outlines that objectives should provide safeguards for fisheries stocks, the socio-economic interests of fishers and other stakeholders, and the integrity of the ecosystems. Hindson *et al*. (2005) provide a practical step-by-step guide for developing a management plan and setting objectives, indicators and reference points. Some common objectives are discussed briefly below in the context of sea cucumber fisheries.

1. *Biological:* Managers should limit fishing capacity and fishing pressure so that stocks remain economically and biologically viable (FAO, 1995). The most incipient threat to commercial sea cucumbers is the depletion of breeding populations (Conand, 2006a), so these must be maintained at productive levels. The "*natural factory*" that replenishes stocks after natural mortality and fishing is based on spawning of males and females that are in sufficient densities (Friedman *et al*., 2008a). It has been demonstrated that, for some species, successful [sexual] reproduction, in terms of overall population growth, can only happen in relatively dense populations (Bell, Purcell and Nash, 2008; Bell *et al*., 2008) (Section 2.1). An objective should be to ensure that enough dense breeding populations of each species are maintained in the fishery to allow for replenishment after losses through fishing. Measures should provide that depleted stocks are allowed to recover or, where appropriate, are rebuilt through restocking (FAO, 1995; Section 6.8).

   Examples of biological objectives in sea cucumber fisheries:
   - To reduce total caches by 20 percent within three years.
   - To ensure that there are some sites with breeding populations of at least XXX individuals per hectare (depending on the species) for each commercial species on at least one-quarter of reefs in the fishery.
   - To rebuild stocks in regions within the fishery where populations of commercial species have fallen below XX individuals per hectare (species dependent).
2. *Socio-economic:* Fishing of sea cucumbers is important to the cultures of coastal peoples; notably where they are used for subsistence (Kinch *et al*., 2008a; Eriksson, 2006). Management objectives should, therefore, state the need to safeguard the cultural and economic interests of fishers and subsistence users (FAO, 1995). A sensible objective is, therefore, to manage fishing impacts so that stocks are relatively stable over time and can deliver sustained incomes to fishers (Purcell, Gossuin and Agudo, 2009a). In the long term, this objective aligns with a key purpose of the ecosystem approach to fisheries (EAF); to ensure that future generations have access to the full benefit of today's fisheries (FAO, 2003). Managers should also set an objective to regulate fishing in order to prevent the need to close the fishery by moratoria (or "bans") because stocks have been overexploited. Other social interests should be addressed, such as those of tourist operators, naturalists, conservation groups and the general public.

An economic objective should be to maximize the money earned by fishers for each animal collected (see Section 6.7). This means preventing the capture of small animals, for two reasons: (1) larger animals are more valuable because they are heavier and prices are governed by weight, not numbers of individuals; and (2) larger beche-de-mer command much higher prices than smaller pieces per kilogram. For instance, a one kilogram animal may be worth ten times the value of an animal harvested at 250 g. Minimum legal size limits can be a strategy to help meet this objective (Section 5.1).

Examples of socio-economic objectives in sea cucumber fisheries:

- To ensure that fishing for subsistence uses can continue for current and future generations.
- To increase by 30 percent the income gained by fishers per individual sea cucumber harvested.

3. *Environmental:* Some of the objectives should seek to maintain biodiversity of sea cucumber populations and the ecosystems in which they live. Such objectives would require strategies to ensure that rare species, or those vulnerable to local extinction, are preserved (Section 6.3.2) and that ecosystems are protected from damage (FAO, 1995). The management plan should seek to avoid adverse environmental impacts on the resources and ecosystems through pollution, waste, catch of non-target species and destructive fishing gear (FAO, 1995). In sea cucumber fisheries, regulations on the size of trawl fishing gear or safe practices for disposing of the guts and waste water from processing could be set to achieve this objective.

Examples of environmental objectives in sea cucumber fisheries:

- To ensure that benthic habitats are not damaged by fishing activities.
- To increase the biodiversity of sea cucumber populations in each region by 10 percent.

In addition to these broad categories, managers may have other objectives. For example, political objectives could be set to avoid conflicts and social discord between interest groups (Hilborn, 2006). Most governments want to avoid legal battles and public conflicts in fisheries, e.g. aggressive protests by sea cucumber fishers in the Galápagos Islands (Shepherd *et al*., 2004).

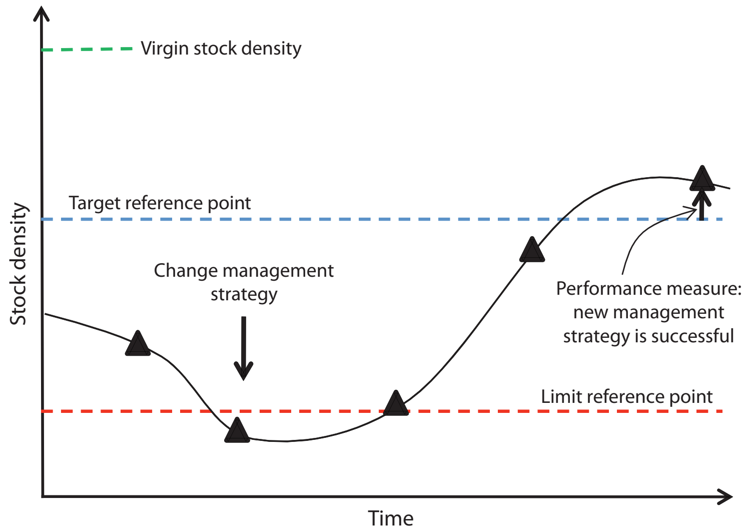
Broad objectives should be translated into "operational objectives" that have practical meaning in the context of the fishery and against which the performance of management strategies can be evaluated (FAO, 2003). For example, a broad objective could be to ensure that sufficient breeding populations are maintained in the fishery, and the operational objective could define the desired densities and frequency of breeding populations, as illustrated in the example above. In harmony with EAF, the setting operational objectives should be a process in participation with stakeholders. Issues within each objective should be discussed and prioritized, e.g. through a risk assessment (FAO, 2003).

Once managers establish a list of overarching objectives, strategies must be developed to achieve them (King, 2007). The strategies will include regulatory measures (Section 5) and actions by the managers (Section 6). For example, a network of marine reserves could be one of a few strategies to ensure that sufficient breeding populations of sea cucumbers are present to allow replenishment of stocks in fishing grounds.

The next step is to agree on indicators and reference points (FAO, 2003). Indicators describe in simple terms the state of fisheries resources and fishing activities and provide a measure of the extent to which the objectives are being achieved (FAO, 1999; King, 2007). Indicators should reflect parameters that can be measured or estimated with a good level of certainly from data that have, or could be, collected (FAO, 2003). Indicators should be chosen on the basis of a range of criteria, including cost, accuracy, practicality (FAO, 1999).

FIGURE 12

Example of stock density indicator and reference points to measure the performance of a management strategy (adapted from FAO, 1999). The black curve represents the average density of a species of sea cucumber in a fishery, over time, which is measured using fishery-independent surveys every few years (triangles). Data from field surveys showing that average stock densities fell below a limit reference point triggered a change in the management strategy, e.g. individual quotas were reduced by half or the number of licences was reduced. The densities then recovered in subsequent years to eventually attain the target reference point



Managers and stakeholders should then agree on reference points which define the subsequent success or failure of the management strategies. *Target reference points* state the desirable levels of indicators such as effort and production (King, 2007). *Limit* or *threshold reference points* define levels of indicators that are undesirable, and should not be exceeded (Hindson *et al*., 2005; King, 2007). For example, a target reference point for a particular species could be an average density of 300 adult sea cucumbers per hectare in fishing grounds, while the limit reference point could be 50 individuals per hectare (Figure 12). Monitoring data showing that limit reference points have been exceeded would trigger a change in management strategies because they were not meeting the objectives. The changes to management strategies should be pre-decided by "decision support rules" in the management plan (Hindson *et al*., 2005). A *precautionary reference point* could also be set between the target and limit reference pints, at which managers start to take actions to avoid the risk of falling below the limit reference point (Hindson *et al*., 2005). Reference points could relate to stock condition, yield, revenue and fishing pressure (FAO, 1999). Management performance is measured as the vertical distance between the indicator and the target reference point (FAO, 1999, 2003; King, 2007).

3.5 THE MANAGEMENT PROCESS

Most sea cucumber fisheries fall neatly within the class of "S-Fisheries": small-scale, spatially-structured, targeting sedentary stocks (Orensanz *et al*., 2005). These fisheries are radically different in nature from the industrial fisheries targeting highly mobile finfish, from which the classical theory of fishery management was developed. Data on which to base fishing harvest models are usually lacking, estimation of abundance is often technically or financially unachievable and fishery-dependent indicators like catch per unit effort (CPUE) are often useless (Orensanz *et al*., 2005). Stocks in S-fisheries are typically structured as "metapopulations", in which subpopulations (e.g. sea cucumbers on separate reefs within a fishery) are interconnected through the dispersal of larvae from spawning events. Also, the spatial structure of stocks tends to persist over a long time. S-fisheries are often artisanal, in the sense that technological development is modest, and therefore the cost of fishing is often low.

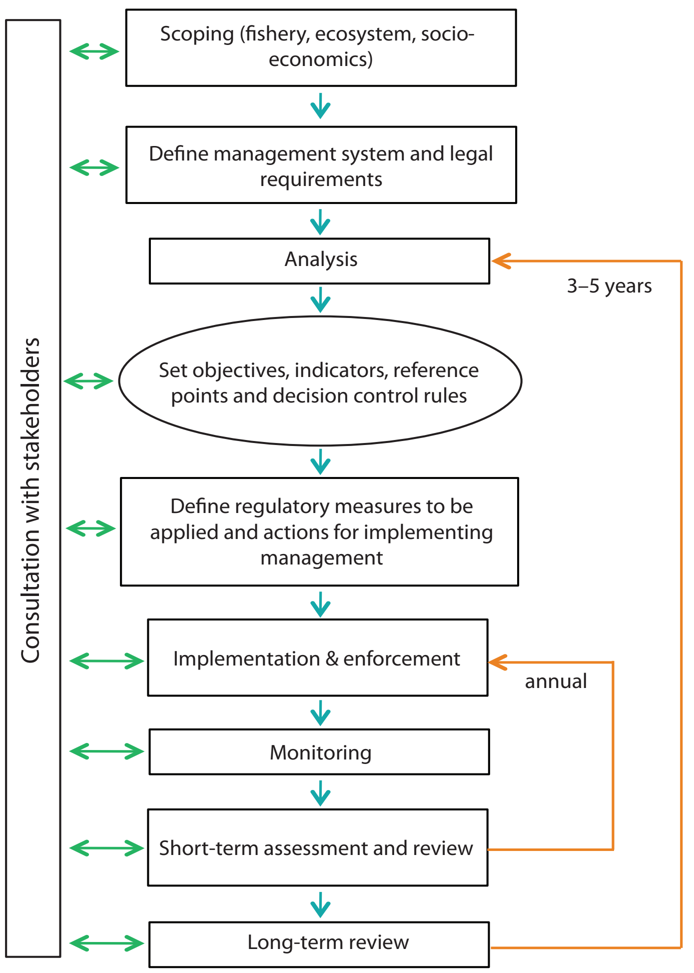
In open access fisheries, fishers have little incentive to leave juveniles and maintain breeding adults above a certain level because those animals they refrain from taking will most likely be collected by some other fisher. This ethos is the cause of the "tragedy of the commons" (Hardin, 1968) and a barrier to responsible harvesting strategies. Overfishing is a symptom, whereas the disease is the "race-for-fish" that arises from a lack of incentives for responsible stewardship of resources and from management institutions that exclude fishers from the management process (Parma, Hilborn and Oresanz, 2006).

The Code of Conduct for Responsible Fisheries (FAO, 1995) encourages appropriate institutional frameworks for fishers and fishing communities to govern access to marine resources (see Sections 6.2.1 and 6.2.2). Likewise, an EAF should involve the creation of incentives, in the form of resource-access rights (see Sections 5.3, 5.4 and 5.7.3).

The process of developing and modifying an EAF management plan requires a series of iterative steps (Figure 13; FAO, 2003). Important elements of the process are consultations with stakeholders, the setting of objectives, indicators and performance

FIGURE 13

Schematic representation of the process of developing, implementing, evaluating and modifying an EAF management plan. For the fifth step, refer to the roadmap in Section 4, which gives guidance on appropriate regulatory measures and actions for implementing management



Source: adapted from FAO, 2003.

measures (based on reference points), and a process of reviewing the management strategy at regular intervals and adapting it if needed. The process by which management decisions are made should be open and transparent and divorced from personal interests. Reference points should state measurable limits at which management actions will be taken and those actions should be specified (Parma, Hilborn and Oresanz, 2006).

A key lesson learned from successes and failures in global fisheries is that a range of tools are available and different tools may be appropriate for different situations (Parma, Hilborn and Oresanz, 2006). Marine protected areas (MPAs) have been the object of recent controversy as a tool for both fisheries management and conservation of marine resources (Lubchenco *et al*., 2003; Hilborn *et al*., 2004; Sale *et al*., 2005; Pauly, 2008). But it is fairly clear that MPAs alone will not be enough to repair, or sustain, fisheries; a suite of management tools and interventions are needed.

3.6 A DECISION-MAKING PROCESS FOR CHOOSING THE RIGHT TOOLS

Managers should start with a diagnosis of the current threats to the resource (Friedman *et al*., 2008a) and to the implementation of future management (Andrew *et al*., 2007). For instance, some fisheries may suffer from shortcomings in the institutional framework of management, while others suffer from habitat damage or conflicts over access to fishing grounds. Diagnosis after the scoping phase (Figure 13) involves gathering information on different opportunities, strengths and threats including those of ecological, social, economic nature and those of the external environment (Andrew *et al*., 2007). This is also a moment for managers to identify undesirable outcomes in their fishery and measures that will avoid them or correct them promptly (FAO, 1996). Within the scoping phase, managers should also gain a general understanding of the status of sea cucumber stocks (i.e. abundance and body size frequency; see Glossary), which can be shown, or inferred, from various simple indicators (Friedman *et al*., 2008a).

The basic information needed by managers in the scoping phase include the following:

- *Institutional set up* – Who are the decision-makers and who is involved in management planning, enforcement and monitoring? (Section 6.2.1)
- *Motivations and objectives to manage the fishery* – Are the underlying objectives of fishers similar to those of fishery managers and other stakeholders? (Sections 6.1.4 and 6.6)
- *Accountability* – Who is held accountable for mistakes or errors in the management of sea cucumber stocks? (Section 6.4)

FIGURE 14

Left: sea cucumbers being dried at a large processing station in Madagascar. Right: sea cucumbers being boiled and processed in small quantities by village fishers in Papua New Guinea

PHOTO: C. CONAND

PHOTO: J.P. KINCH

- *Legal framework including international agreements* – What are the current regulations, both locally and internationally, and how are new regulations set into legislation? (Sections 6.3.1 and 6.3.2)
- *Socio-economic situation* – Who are the fishers, processors and exporters, what are the drivers for fishing, gender issues and importance of sea cucumbers to their livelihoods? (Section 6.1.4)
- *Information about stocks and fishery* – What species are fished, from what habitats and locations are they fished, how fast do the sea cucumbers grow and reproduce, and how abundant are they in fishing grounds and reserves? (Sections 6.1.1 and 6.1.2)
- *Information on processing and trade* – How the sea cucumbers are sold by fishers and who does the processing and export (Figure 14), in what form and quality are sea cucumbers exported and what are the markets? (Sections 6.1.3 and 6.1.5)
- *Impact on ecosystem* – What role do sea cucumbers have in the ecosystems and what effects do fishing gears and practices have on the benthos? (Section 6.1.1)

Managers are encouraged to perform a "risk analysis" or "management strategy evaluation" (MSE) to try to predict the consequences of implementing different combinations of management tools (FAO, 2003; Grafton *et al*., 2007). This should be done around the time that objectives and performance measures are set. What are the trade-offs in acceptance or compliance and the biological performance of the resource? What are the risks of poor performance of various management scenarios in the light of uncertainty about compliance or biological parameters? An open discussion of the merits and consequences of different management strategies with the stakeholders will help in the agreement of performance indicators. A consultative process also allows for discussion of key uncertainties, logistic constraints and practicality of various management options.

Achievement in fisheries management seems to require a combination of management tools from the toolbox (Hilborn, Parrish and Litle, 2005; Parma, Hilborn and Oresanz, 2006; Pauly, 2008). Moreover, industrial and small-scale fishery problems have to be treated separately (Defeo and Castilla, 2005).

Friedman *et al*. (2008a) present a simple approach for managers to assess the health of sea cucumber fisheries and recommendations for management actions and regulations in cases where stocks are either depleted or still healthy. It is a quick "start-up" guide to decision-making and introduces the key concepts for implementing many of the common tools for managing sea cucumber fisheries.

This paper provides a more comprehensive appraisal of the full range of tools available in the manager's toolbox. It also suggests a logical approach, or "roadmap", for choosing the tools and actions that are needed in different types and states of fisheries.

4. Defining regulatory measures and actions – A roadmap

Various regulatory measures and actions, or "tools", could be adopted when managing a sea cucumber fishery. This section presents a "roadmap", in the form of a series of three questions and a table, for making decisions about which combinations of tools are advisable in a sea cucumber fishery, depending on the fishery type, stock status and management capacity. Each regulatory measure and action in Tables 1 and 2 is linked to specific parts of Sections 5 and 6 of this paper.

Firstly, the fishery manager needs to answer three basic questions to characterize the sea cucumber fishery being managed:

1. **What type of fishery is being managed?**
   - *Small-scale* – The fishers work from shore or use small boats in nearshore coastal waters. They would commonly involve modest technologies of fishing gears (e.g. simple breathing apparatuses and/or collection by hand).
   - *Industrial* – The fishers work in groups from larger boats, capable of accessing distant fishing grounds. Those fisheries considered "semi-industrial", i.e. sharing elements of small-scale and industrial types, could be placed in this category.
2. **What is the status of stock(s)?**
   - *Underexploited* – The fishery is new or the stocks of sea cucumbers are being exploited at low levels and believed to have a potential for expansion in annual production.
   - *Fully exploited* – The fishery is operating at or close to an optimal yield level and there is no room for the fishery to expand further.
   - *Depleted* – Catches are well below historical levels, irrespective of the fishing effort exerted, and sea cucumber populations are so sparse that the potential for stock abundance to recover through natural reproduction is limited.

   In some cases, there may be no recent data from fishery-independent surveys or managers may be unsure about the status of sea cucumber stocks in their fishery. The fishery manager should use simple indicators from looking at catches, export data, or by talking with fishermen (Box 1).
3. **What is the management capacity in the country?**
   - *Strong capacity* – Management institutions have technical skills to analyze fisheries data and skills and equipment for monitoring stocks and fishing effort, and fishing capacity can be effectively controlled; there are effective systems for surveillance and enforcement of fishery management measures; and there is adequate funding to establish a complex suite of regulations. Consider a suite of some or all of the **Recommended** regulatory measures and apply **Recommended** actions for implementing management.
   - *Modest capacity* – Management institutions lack the technical skills for complex fisheries analyses or modelling; expertise or equipment is lacking to monitor stocks; fishing effort and fishing capacity cannot be easily controlled; the systems for surveillance and enforcement of fishery regulations are insufficient; and there are insufficient funds to establish a complex suite of regulations. Use at least the **Minimum** regulatory measures and **Minimum** actions for implementing management.

BOX 1

Simple indicators to define stock status

The most useful tool in determining stock status is fishery-independent surveys; i.e. analyses of counts of animals underwater within replicated sampling units, e.g. transects (see Section 6.1.2). Underwater visual census of sea cucumber stocks should be conducted frequently, e.g. every 3–5 years. If data from fishery-independent surveys is old (i.e. >5 yrs) or unavailable, managers should endeavour to implement a stock assessment programme (using underwater visual censuses) and use simple indicators of stock status in the meantime while surveys are being conducted.

Friedman *et al.* (2008) propose six simple indicators of the status, or "health", of sea cucumber stocks. A combination of several, or all, of the following indicators would suggest that sea cucumber stocks were healthy (underexploited):

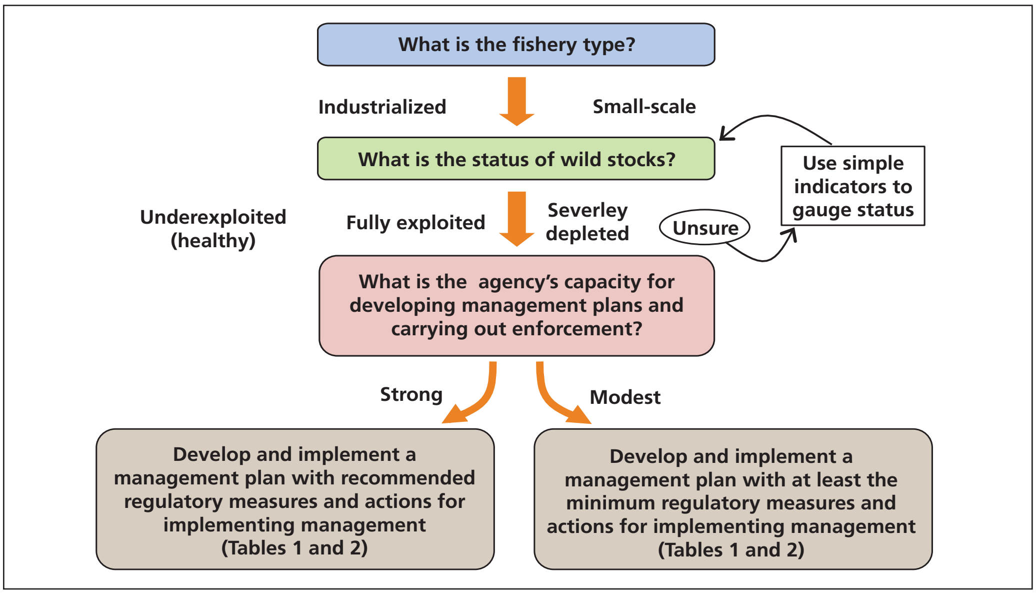
	Indicator	How to find out
1.	There are still areas where groups of adult sea cucumbers remain protected near the main fishing grounds	Underwater surveys and/or interviews with fishers
2.	Small-scale, traditional fishing methods are mostly used to harvest sea cucumbers	Observe the types of gear and boats used by fishers
3.	Abundances of sea cucumbers in the fishery are stable over long timescales	Records of exports and/or interviews with fishers
4.	High-value and medium-value species are still abundant in fishing grounds and well represented in catches	Records of exports and/or underwater visual census
5.	Large-sized sea cucumbers are still caught, and mostly "A" grade beche-de-mer is produced and exported	Records of exports and/or catch ("creel") surveys
6.	Economic benefits from the fishery flow mainly to fishing communities	Interviews and/or questionnaires to fishers and processors

Similarly, Froese (2004) proposed a set of just three simple indicators of stock status that can be obtained just by examining landings of fishers. These indicators apply to fisheries broadly, and could be adapted to gauge the status of sea cucumber stocks in the absence of underwater visual censuses:

1. Check the percentage of mature-sized sea cucumbers in catches. Any more than 5 percent of individuals under the size at first maturity would suggest that stocks are overexploited.
2. Check that the sea cucumbers in catches are mostly a size that would furnish A-grade beche-de-mer, or better. If fishers are collecting mainly small adults, stocks may be over-expoited.
3. Where upper size limits do not exist (e.g. there is only a minimum size limit), catches should comprise at least 30–40 percent "mega-spawners". These are defined as animals larger than the optimum trade length plus 10 percent – i.e. animals near the maximum size attained for each species, which have a high fecundity and contribute greatly to the population's reproductive output. Less than 20 percent of "mega-spawners" in catches would suggest gross overfishing and that stocks are moderately to fully exploited.

The three questions should lead to answers that characterize the fishery scenario (Table 1), which directs the fishery manager to a table of regulatory measures to impose and actions for implementing management in their situation (Table 2). These two tables were produced at the FAO-coordinated workshop in the Galápagos through working groups of the participant experts. The tables, therefore, represent a consensus of advice on minimum and recommended management measures from fishery managers, sociologists, ecologists and fisheries scientists.

The flowchart below illustrates the process. Each combination of answers to the three questions has a different set of recommended or minimum regulatory measures and actions for implementing management.



Below are two hypothetical examples of sea cucumber fisheries, with differing characteristics, to illustrate the decision-making process.

Example: Fishery 1 – A small number of fishers in groups of 6–8 persons use large boats of 15–20 m to access stocks of a single species of sea cucumber in deep waters using self contained underwater breathing apparatus (SCUBA) and hookah gear. The sea cucumbers have only been fished for a few years. Underwater surveys show that relatively dense populations exist, the animals are relatively abundant, and the annual catch of the fishery has been relatively stable. The management agency is relatively well funded with technicians and scientists, and there is a compliance department with fisheries officers to inspect catches and exports. Managers should treat this fishery as an **Industrialized** fishery, with **Healthy (Underexploited)** stocks. They should choose a suite of some of the **Recommended** regulatory measures and apply the **Recommended** actions for implementing management. The suite of regulatory measures could be: size limits (**1**), prohibit the use of nets and drags/dredges and authorize only the use of species-specific gear (**2**), limit the number of boats in the fishery (**3**), fishers are allocated an individual transferrable quota for each year (**4**), the fishers and processors pay for an annual licence and are required to record their catch and submit logbooks (**5**), a closed season during four months of the year when animals are less cryptic or during the spawning season(s) (**6**), no-take reserves (**8**), and plots of the fishing grounds could be allocated to fishing groups (**10**). Perhaps the seasonal closures are not needed and the manager decides not to allocate individual quotas, letting the fisher groups manage their harvest rates within their allocated plots (resulting in regulatory measures **1**, **2**, **3**, **5**, **8** and **10**). All of the **Recommended** actions for implementing management (**A, B, C, D, E, F, G, H, I, J, K, L)** should be employed. But perhaps in this example, fisher groups already process sea cucumbers to a very high and consistent standard, so there is no need to promote training in processing methods (i.e. action **L** is redundant).

Example: Fishery 2 – A large number of mostly small-scale fishers collect a range of sea cucumber species from the shore or in small boats of 4–6 m in length. Most fishers use free-diving (mask and snorkel) but some have started using hookah breathing gear. In this fishery, the sea cucumbers have been fished for decades, but catches have declined in recent years and few high-value species are now collected. Underwater surveys showed reasonable densities of most species, but high-value species were rarely recorded. Managers should treat this fishery as a **Small-scale** fishery, with both **Fully-exploited** and **Depleted** stocks. Owing to limited funding and a lack of skilled scientists and sociologists in the management agency, the manager should at least use the **Minimum** regulatory measures and apply the **Minimum** actions for implementing management. The regulatory measures should be: size limits (**1**), forbid the use of compressed air diving (SCUBA or hookah) and nets or drags/dredges (**2**), issue licences to fishers and processors who are also required to make records and submit logbooks (**5**), bans on fishing should be placed on species for which stocks are depleted (**7**), no-take reserves (**8**), and allocate fishing communities the exclusive rights to certain fishing grounds (**10**). All of the **Minimum** actions (**B**, **C**, **D**, **F**, **G**, **H**, **L**) should be employed by the fishery manager.

TABLE 1
Regulatory measures and actions for implementing management to be applied in different sea cucumber fishery scenarios

Fishery type	Health of stock	Regulatory measures		Implementing management	
		Recommended	Minimum	Recommended	Minimum
Industrialized	**Healthy** (underexploited)	1, 2, 3, 4, 5, 6[1], 8, 10	1, 5, 10	A, B, C, D, E, F, G, H, I, J, K, L	A, B, C, D, K, L
	Fully exploited	1, 2, 3, 4, 5, 6, 8, 9, 10	1, 2, 4, 5, 8, 10	B, C, D, E, F, G, H, I, J, K, L	B, C, D, F, G,H, L
	Depleted	5, 7	5, 7	B, D, G, I, K, L, M	B, D, K, L
Small-scale	**Healthy** (underexploited)	1, 2, 3, 4, 5, 6, 8, 9, 10	1[2], 5, 8, 10	A,B, C, D, E, F, G, H, I, J, K, L	A, B, C, D, K, L
	Fully exploited	1, 2, 3[3], 4, 5, 6, 8, 9, 10	1, 2, 5, 8, 10	B, C, D, E, F, G, H, I, J, K, L	B, C, D, F, G, H, L
	Depleted	5, 7	5, 7	B, D, G, I, K, L, M	B, D, K, L

[1] Particularly in temperate fisheries.
[2] Particularly in multispecies fisheries.
[3] In well developed small-scale fisheries the limitation of effort may be difficult.

TABLE 2
Regulatory measures and actions for implementing management, corresponding to number and letter designations in Table 1

Regulatory measures	Section	Implementing management	Section
1 – Size limits	5.1	**A** – Overview of the harvested species	6.1.1
2 – Gear limitation and development	5.2	**B** – Fishery-independent stock surveys	6.1.2
3 – Effort and capacity control	5.3	**C** – Fishery-dependent stock surveys	6.1.3
4 – Catch quotas	5.4	**D** – Socio-economic surveys	6.1.4
5 – Market chain licensing and reporting	5.5	**E** – Price monitoring	6.1.5
6 – Seasonal and short-term closures	5.6.1	**F** – Support institutional arrangements for local-scale management	6.2.1
7 – Bans or moratoria	5.6.2	**G** – Establish management advisory committees	6.2.2
8 – Marine protected areas and no-take reserves	5.7.1	**H** – Legislation of management regulations	6.3.1
9 – Rotational harvest closures	5.7.2	**I** – Assign accountability	6.4
10 – Territorial user rights in fisheries	5.7.3	**J** – Enforcement	6.5
		K – Education and communication with stakeholders	6.6
		L – Improve quality of processing through training	6.7
		M – Restocking	6.8

5. Regulatory measures

5.1 SIZE LIMITS

Definition

A minimum individual length or weight of sea cucumbers that can be legally fished or traded.

Size limits are species-specific and can pertain to fresh, live animals, or to animals in various stages of processing, e.g. minimum size limits for beche-de-mer.

Use

A principal use of size limits in sea cucumber fisheries is to protect juveniles and recently matured adults to allow individuals one or more seasons to spawn before they can be fished (Purcell, Gossuin and Agudo, 2009a). Minimum size limits must therefore have some biological basis corresponding to size at which individuals first become mature plus some additional buffer so they have time to contribute to spawning.

Fisheries managers may also want to set minimum size limits on (dried) beche-de-mer of different species, so that fishers and processors can maximise the export income for each individual removed from the stock. Large sea cucumbers are generally placed in a higher grade for export and fetch higher prices (Section 2.2).

Minimum legal size limits can be based on growth of animals in some fisheries but, in sea cucumber fisheries, are commonly based on the size at which individuals of a species first attain sexual maturity (i.e. have recognizable oocytes or spermatocytes in their gonads). Size limit varies with species because size-at-first-maturity differs from one species to another. Size limits can also vary from one country to another (Table 8 – Kinch *et al.*, 2008a) or vary between regions within a country, such as in Cuba (Toral-Granda, 2008a). Minimum legal sizes may differ because fisheries agencies have different management goals or because the size-at-first-maturity is higher at one country, or region, than another for the same species. Minimum legal size limits are imposed in about half of the fisheries of the Western Central Pacific (Kinch *et al.*, 2008a).

Limitations

It should be no surprise to those experienced with sea cucumber fisheries that determining and applying appropriate size limits is not as easy as it seems. One initial limitation is that they should reflect a size that the animals would be some years after animals first reach sexual maturity. Unfortunately, that information is available for only a relatively small number of species and such life-history traits vary from one region or country to another. Determining the size at reproductive maturity requires a significant amount of data (Bruckner, 2006b). Conand's (1989) seminal thesis[1] (recapitulated in English in Conand, 1990) provides these data for ten tropical species: *A. echinites*, *A. mauritiana*, *H. atra*, *H. fuscogilva*, *H. fuscopunctata*, *H. scabra*, *H. lessoni* (then *Holothuria scabra* var. *versicolor*), *H. whitmaei* (then *H. nobilis*), *S. herrmanni* (then *S. variegatus*) and *T. ananas*. Some other studies have provided size-at-first-maturity data for a handful of other species (Kohler, Gaudron and Conand, 2009). For other species and locations, determining size limits rests as educated guesswork but should

[1] Parts of the full thesis were also translated into English by the Secretariat of the Pacific Community (SPC) and are available by e-mailing: reeffishobs@spc.int

FIGURE 15
Fishery technicians measuring sea cucumbers in New Caledonia

PHOTOS: S.W. PURCELL

be based on closely related species and local knowledge of the biology of the species. More often, limited data are employed in other countries without local validation.

A second important limitation is that most commercial sea cucumbers contract when handled, so body length can differ greatly from the live size of undisturbed animals (Figure 15). This is an immediate concern of fishers when discussing size limits. Some species contract and expand markedly, so size limits based on weight, rather than length, would be more appropriate. This is particularly true for most *Actinopyga* species, *H. fuscogilva* and *H. whitmaei* (Purcell, Gossuin and Agudo, 2009a). As they contract, sea cucumbers gain in width and/or body height while their body weight remains unchanged. But implementing weight limits may cause compliance problems in many situations, as few fishers in developing countries have access to balances to weigh animals. Some other species, like *H. scabra, H. lessoni* and *S. herrmanni*, undergo minor contractions of the body length compared to other species (Purcell, Gossuin and Agudo, 2009a) and are thus less problematic to manage using length-based size limits. Fishers may still argue that it is difficult to abide by size limits but they will quickly know how the size of live sea cucumbers compares with the body lengths of the same animals once dead.

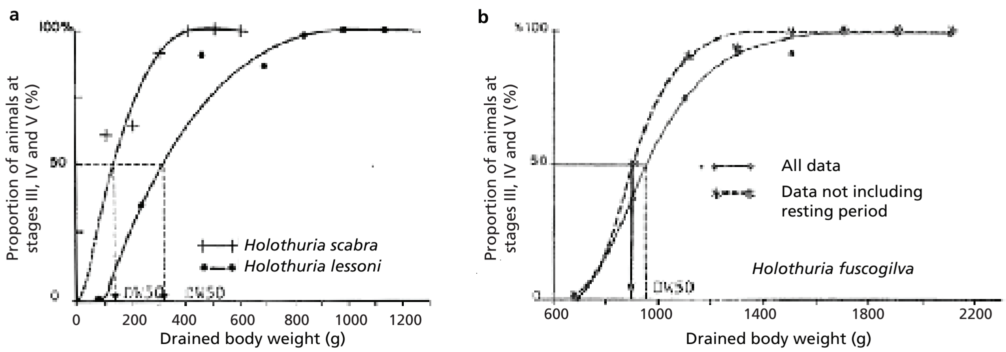
Variation in the shape of sea cucumbers of similar weight appears far less of a problem once the animals are boiled and dried into beche-de-mer, which tends to be uniform in dimensions and reflect the shape of dead animals. Although fishers will have to use sound judgement in collecting live sea cucumbers that are not under the legal minimum length once dead, there should be little difficulty for processors to know when a dead, unprocessed, sea cucumber will be undersized once cooked and dried. Thus, processors have little grounds to object to minimum size limits for (dried) beche-de-mer.

How to implement

Minimum size limits for sea cucumbers have been typically based on the size at first sexual maturity (Bruckner, 2006b). Some studies report size-at-first-maturity as L_{50} (the length at which 50 percent of the population is estimated to be mature) (Figure 16). However, using this length as the minimum size limit would mean that half of the population at that size is immature and could be fished legally. It would

FIGURE 16

Size-at-first-maturity curves for three tropical species: (a) *Holothuria scabra* and *H. lessoni*; (b) *H. fuscogilva*. The reproductive stages II, IV and V indicate that animals are mature. Body weight was used as the metric for size, and this could also be done for body length. Body weight at a chosen proportion of the mature population can be converted to body length using established mathematical relationships (Conand, 1989)



Source: Conand (1990), with modification.

be more conservative to set size limits that allow animals to reach maturity *and* have one or two seasons to spawn with the rest of the population before being fished. This could be done by taking a larger size along the size-at-maturity curve, such as the L_{90}, and add some centimetres to this to allow for a season or two of spawning (Purcell, Gossuin and Agudo, 2009a). Although observations of dissected animals can show the size at which individuals first develop a gonad, i.e. the onset of sexual differentiation, such individuals are not necessarily mature. The oocytes of females may not be fully developed or they may not yet actively participate in spawning. This is a further reason to add some centimetres to the estimated size-at-first-maturity and to use a conservative metric of the length at first maturity (e.g. the L_{90}). More scientifically, true size at sexual maturity can be determined from the first occurrence of mature (vitellogenic) oocytes and mature spermatozoa in the newly-developed gonad.

Where possible, managers should use biological parameters based on data collected in the fishery or region, or adopt examples from similar fisheries. However, in the absence of locally-representative studies, fishery managers should support at least some basic biological studies to compare with published findings from other regions and apply conservative size limits (FAO, 1996; Section 3.2). Ideally, the studies should assess size at sexual maturity in males and females and establish size-at-maturity relationships for commercial species.

Meet with fishers and processors and educate them on the biological reasons for size limits (Figure 17). Find out from fishers and processors what sort of measuring tools they could use to aid in verifying sizes of animals in the field and once processed. These could be as simple as rulers, sliding callipers, or stickers with graduated marks to place on boats. Fishery managers should be pro-active in developing and commissioning such measuring tools.

The process of deciding appropriate size limits in sea cucumber fisheries should involve fishers, processors, biologists and enforcement personnel. Fishery managers can expect to reduce their inspection costs and have a better compliance of minimum legal size limits by inspecting sea cucumbers (either dead or fully processed) of processors and traders more so than fishers. They will be often less numerous than fishers and at know locations, thus making the inspections easier to conduct. Improved compliance will arise when all processors and traders begin to refuse to buy undersized sea cucumbers from fishers. In this case, many fishers are forced by the buyers to comply with the minimum legal size limits rather than by the fisheries authority.

FIGURE 17
Left: children on a sandflat in Papua New Guinea with a catch of mostly undersize sandfish, *Holothuria scabra*. Right: juvenile sea cucumbers in a catch in Madagascar

PHOTO: M. KRONEN, SPC PROCFISH/C

PHOTO: IHSM/WIOMSA

EXAMPLES AND LESSONS LEARNED

Galápagos Islands, Ecuador

Since its re-opening in 1999, the fishery for *Isostichopus fuscus* in the Galápagos has been regulated by a minimum size limit for both fresh and processed sea cucumbers (among other regulatory measures). The size limits are not regarded as a useful tool by the fishers because they believe that sea cucumbers change length too easily to be effectively measured. Nonetheless, local fishers mostly agree, in principal, to have minimum legal size limits rather than none at all. Both management authorities and scientific bodies concur that this regulation is not as effective as others.
Source: V. Toral-Granda.

New Caledonia, France

At present, only the Northern Province has established minimum legal size limits for fishing sea cucumbers; there are no size limits in the other two provinces. A minimum legal length (in cm) is given for the fresh (live or unprocessed) animals and a corresponding one for the dried form. However, these were provided only for about half of the 15, or so, tropical species that are commonly collected by fishers. The size limits were based on analyses of the size-at-first-maturity of these species (or closely related species) plus a small percentage, and corresponding conversion factors of the change in length during processing, presented by Conand (1989) for these sea cucumbers in New Caledonia. While fishers did say that it is difficult to enforce legal size limits on fresh animals, because most species can contract and expand their body lengths considerably, fishers were in general agreement that the size limits should also pertain to the fresh animals (Purcell, Gossuin and Agudo, 2009a). At a national participatory forum in 2007, some processors objected that the corresponding minimum legal lengths of dried animals were inappropriate, leading to adaptive modifications to the legal size limits via a further participatory meeting. The process of consultation and discussion about the size limits seems to have improved the acceptance by fishers and processors.
Source: S.W. Purcell.

Yap, Federal States of Micronesia

Yap has recently developed a fisheries management plan based on regulating weight rather than size. Commercial species groups included in the management plan are described as either “premium” or “standard”. The plan establishes that a quota should be set for “standard” species groups individually, while more comprehensive quality control should be implemented for “premium” species groups. For export controls of “premium” species groups, shipments will be made and checked in 10 kilogram packages of beche-de-mer. Each package must only include beche-de-mer from a single “species group” and be labelled so as to be easily identified for inspections by the checking authority (for weight and counts). All “premium” species 10 kilogram packages need to include a maximum rate of dry sea cucumbers set out in the management plan; for instance:

Species group	*Wet (live) weight (g)*	*Dry weight of beche-de-mer (g)*	*Max. number per 10 kg package*
Black teatfish	2 400	168.0	60
Sandfish	750	37.5	280
Golden sandfish	1 400	70.0	150

The 10 kilogram packages allow agents to include product with a small weight variation around the specifications for individual dried sea cucumbers, as long as the 10 kilogram package as a whole complies with the maximum number of sea cucumbers allowed. The 10 kilogram packaging system is well aligned to market conditions and industry standards and also allows the authorities some ease of checking, being well suited to a small country with limited enforcement capacity.
Source: Friedman, Ropeti and Tafileichig (2008).

On setting minimum legal size limits

Setting minimum legal size limits should best be based on size at first sexual maturity of sea cucumbers, rather than opinions by fishers and processors about what are “good sized animals” (Purcell, Gossuin and Agudo, 2009a). The onset of sexual maturity is often reported as the L_{50} length, which is the estimated length at which 50 percent of animals in the population are mature. Whereas the size at onset of sexual maturity has been suggested elsewhere for setting minimum size limits of sea cucumbers (Bruckner, 2006a), Purcell, Gossuin and Agudo (2009a) argued that minimum legal size limits should be large enough such that animals can have at least one year to spawn after reaching maturity. They recommended a conservative approach of adding some centimeters to the L_{90} (estimated body length at which 90 percent of the population is mature) from the size-at-maturity analysis curves (e.g. provided in Conand, 1990, 1993; Kohler, Gaudron and Conand, 2009) to set the minimum legal size limits for each species. The equivalent size of dried animals can be calculated using conversion equations in Skewes *et al*. (2004) and the conversion factors determined by Conand (1989, 1990) and Purcell, Gossuin and Agudo (2009b). Fishery managers can prepare simple plastic rulers, with graduations corresponding to size limits of species, to give to fishers to verify sizes of animals in the water. It may be more practical to group species that have similar estimated size limits, rather than having many different sizes for fishers and processors to remember; e.g. the 15 or so species commonly fished in New Caledonia could be allocated into 6 to 8 size-limit groups.
Source: S.W. Purcell.

5.2 GEAR LIMITATION AND DEVELOPMENT

Definition

A prohibition or limit on the use of certain types, sizes or number of equipment for collecting sea cucumbers.

Gear limitations could entail a general prohibition on gears, e.g. no hookah gear allowed, or a specific limitation on the size of specifications of gears, e.g. net mesh size for trawl fisheries or the number of hookah hoses permitted per boat in dive fisheries.

Use

A principal use of gear restrictions is to reduce the number and places where sea cucumbers can be harvested by prohibiting the use of efficient, or industrialized, fishing systems. Examples of gears are nets, self contained underwater breathing apparatus (SCUBA) or hookah equipment, "bombs" (lead weights with small sharpened points imbedded; Figure 18) or spears, trawls and torches or surface lights (for night fishing).

Gear controls, like prohibition of compressed-air diving or use of equipment to collect sea cucumbers in deep water, give some respite to the resource to either being fished too rapidly, or being fished in areas not accessible to free-divers. For example, in the Seychelles, deep habitats have protected deeper, high-value, species from severe depletion (Aumeeruddy *et al.*, 2005).

Gear restrictions are imposed in half of the sea cucumber fisheries in the Western Central Pacific (Kinch *et al.*, 2008a) and most temperate fisheries (Hamel and Mercier, 2008a) (Section 2.4). While the prohibition of compressed-air diving, i.e. using SCUBA and hookah gear, is the most common gear restriction of sea cucumber fisheries, this regulation does not protect species with shallow distribution (Bruckner, 2006b).

Gear limitations can also be set to avoid risks to the environment or the fishers themselves. The FAO Code of Conduct for Responsible Fisheries (1995) advises

FIGURE 18

Left: a weighted "bomb" used for collecting sea cucumbers in deep water by skindivers. Right: the bomb is weighted and has a barbed metal harpoon at the end, which is lowered by a rope or fishing line to harpoon sea cucumbers on the sea floor that are too deep to reach by free diving

PHOTOS: M. KRONEN, SPC PROCFISH/C

FIGURE 19

Dragnets are used in Japan to collect *Apostichopus japonicus* from the sea floor in the province Hokkaido. Left: the large drag frame lifts the sea cucumbers from the sea floor and has tassles (yellow) that prevent the net from being caught on rocks. Right: the net of the drag follows behind the frame to collect the harvested animals

PHOTOS: J. AKAMINE

managing agencies to ensure that fishers use selective and environmentally safe fishing gear and practices (see Sections 3.1 and 3.3). Certain regulations, such as prohibition of "drags", dredges or trawls, safeguard against unnecessary damage to benthic habitats. "Drags", dredges (see Figures 7 and 19; *Examples and lessons learned* below) and trawls can damage seagrass beds and other benthic organisms like sponges and sea pens. The fishery might allow such gears, with a regulation on the equipment design that minimises damage to the sea bed or damage to the sea cucumbers being harvested. In Maine, *Cucumaria frondosa* are collected using "urchin drags" that cannot be wider than 1.67 m (Hamel and Mercier, 2008a).

Limitations are sometimes placed on the use of SCUBA or hookah to minimise diving accidents in the fishery. This is mostly relevant for developing and low-income countries where diver training is less rigorous or difficult to obtain, and often lack the medical capability and facilities to deal with diver ailments such as the "bends".

In certain circumstances, gear restrictions could help to enforce, or aid the implementation of, size limits. For example, trawl nets could be allowed but the mesh size could be restricted to greater than 50 mm for collecting sea cucumbers.

Limitations

Surveillance of the use of some fishing gears will be difficult, and enforcement on the water will be needed to see what gears are being used. Such enforcement brings added cost to management agencies. For example, torches and surface lights are prohibited in Papua New Guinea but fishers in all provinces regularly use them for harvesting sea cucumbers because enforcement officers are few and rarely conduct inspections at night (Kinch *et al.*, 2008b).

In some cases, the onus may be on the management authority to assess the effectiveness and optimisation of new gears. For example, to conduct experiments to find an optimal mesh size of trawls that minimises destruction to the benthos and bycatch while selecting animals that correspond to a minimum size limit. Gear development of this nature is usually costly.

How to implement

A survey of fishers should be conducted to know which gears are currently used. A literature review of other project reports and studies may be necessary to understand the advantages/disadvantages of other gear. For example, managers should have some information on how new gears would be likely to change catch rates and affect the environment. Also determine what gear restrictions could provide a refuge for some sea cucumbers.

The manager should then assess what human and financial resources are available to enforce gear restrictions. Also, how compatible will the restrictions be with other management measures in place, or what other companion management measures are needed (see Section 8.3)? Fishers should also be consulted to make sure they understand the reasons for gear restrictions and are prepared to respect them.

EXAMPLES AND LESSONS LEARNED

United States of America and Canada

Beginning around 1988, the "drag" or bottom trawl fishery for *Cucumaria frondosa* in Maine, United States of America, raised concerns about bycatch that led to conflicts with other local fishers over the gear employed in the fishery. Henceforth, a dragnet for sea urchins was modified for collecting *C. frondosa* and resulted in an acceptable reduction in bycatch.

PHOTO: L. BARRETT

Above: a "sea cucumber drag" used for fishing *Cucumaria frondosa* in Canada. It is towed behind a fishing or research vessel to collect the sea cucumbers in Newfoundland and Labrador, Canada. The sea cucumbers are too deep for collecting by divers.

In Newfoundland and Labrador, Canada, the exploratory sea cucumber fishery was initiated in 2001. Permission was granted by Fisheries and Oceans Canada (DFO) to use the drag gear developed for scallop (known as the Labrador scallop bucket) as the fishing method. In the following year, the gear used in Maine was modified and approved by DFO, who later gave permission to test the gear. Catch rates and bycatch were compared with two other vessels fishing commercially, one using Labrador scallop buckets and the other

using Digby scallop buckets. Results of the study were positive and DFO approved the new "Newfoundland sea cucumber drag" design. Underwater video observations confirmed the efficiency of the gear, which is now used as both a commercial fishing gear and a scientific survey instrument for the estimation of population abundance and distribution. This example shows that fishing gears can be developed and regulated in cooperation with the fishery management agency and used in population studies.
Source: A. Mercier and J.-F. Hamel.

New Caledonia, France
There are three sea cucumber fisheries in New Caledonia, managed by the fisheries services of the country's three provincial governments. In the Northern and Southern Provinces, the use of compressed-air devices (SCUBA or hookah) is prohibited, so fishers only collect the animals by free diving or wading in the intertidal waters. Torches and night fishing is also prohibited to allow some respite for sea cucumbers that feed more actively at night and would be exposed to divers more during that time. Despite this regulation, some direct accounts from fishers shows that some night fishing using torches does occur. It is difficult for authorities to enforce this regulation without conducting inspections at sea during night-time. There are no prohibitions yet on other gear, such as drags, dredges or trawl nets, although these are not yet in use. A recent study recommended the prohibition of gears like trawls, which could otherwise be developed and used in the fisheries (Purcell, Gossuin and Agudo, 2009a). A lesson is that some gear restrictions, like the use of torches at night, are difficult to enforce but some inspections by compliance officers at inconvenient times or locations are needed to ensure that fishers comply with regulations on fishing gear.
Source: S.W. Purcell.

Western Indian Ocean
Two contrasting examples of sea cucumber fisheries occur in the Western Indian Ocean. In the Seychelles the harvesting of sea cucumber is an industrial activity involving SCUBA divers. In Madagascar it is mostly a small-scale activity by villagers (Conand and Muthiga, 2007; Conand, 2008; Aumeeruddy and Conand, 2008). The use of SCUBA was prohibited in Kenya in 2003, but the lack of enforcement and communication with fishers has led to poor compliance of the ban (Muthiga, Ochiewo and Kawaka, 2007). While in the Seychelles there are specific regulations on the use of SCUBA, e.g. fishers need to be trained in SCUBA diving, in Madagascar the use of SCUBA is now legally prohibited, but still used and causing diving accidents. Enforcement, communication and, in some cases, training, are needed to ensure that fishery comply with gear restrictions, like the use of SCUBA.
Source: C. Conand.

5.3 EFFORT AND CAPACITY CONTROL

Definition

Capacity controls seek to restrict the total size of the fleet, while *effort controls* seek to restrict the fishing activity (FAO, 2003).

Both types of input controls are discussed here, and both types will group more specific regulatory measures. For example, capacity controls could pertain to the maximum allowable size of boats or the maximum number of them permitted in the fishery.

Use

These management measures aim to regulate the effort and/or capacity to levels that are biologically and economically sustainable for the demographics of the resource.

FIGURE 20

Large mother boats in Philippines are used to take groups of skin divers to more distant reefs in search of sea cucumbers. Left: boat with smaller "tender" canoes on bow, used by individual fishers at the fishing sites. Right: an outrigger boat equipped with salting bins and large pots for boiling sea cucumbers at sea. These boats carry 10–15 crew on trips of 2–3 weeks in the Spratly Islands

PHOTOS: J. AKAMINE

Effort and capacity controls serve to avoid overfishing of stocks by limiting the rate of exploitation. Excess capacity and fishing effort in fisheries are common conduits for overfishing, so States should prevent excess fishing capacity and ensure that fishing effort is in harmony with the productive capacity of the resources (FAO, 1995; Sections 3.1 and 3.2).

A common effort control is to place a limit on the number of fishers allowed to collect sea cucumbers. More specifically, they could place limits on the number of fishers allowed per boat or the number of fishers licensed to fish in a given area. In the Seychelles, sea cucumber fishing operated with open access until 2001 when capacity was limited to 25 licensed boats, each permitted to have a maximum of four registered divers to collect sea cucumbers (Aumeeruddy and Conand, 2008). Effort controls could also restrict fishers to collecting sea cucumbers only at certain times of the day or days of the year.

On the other hand, a capacity control could be to prohibit the use of boats above a certain length (e.g. Figure 20). This measure is useful for protecting sea cucumber populations on remote reefs, accessible only by large boats, thereby safeguarding some breeding stocks and refuges for biodiversity. Limiting boat size and other gears can also help to prevent fishers from continuing to harvest even when resource becomes depleted because they have loans for capital investments to repay.

These measures are a means of manipulating catch through control of fishing pressure (i.e. input controls). Effort controls can be adapted relatively easily to respond to changes in socio-economic variables or availability of stock but, as noted below, are difficult to enforce and are often considered ineffective as a management measure.

Limitations

It can be quite difficult to control behaviour of fishers despite being able to manipulate their numbers. For instance, it is hard to regulate fishing to just certain hours of the day. Most small-scale sea cucumber fisheries are open access and therefore managers have no control over the number of fishers.

In cases where the number of boats is limited, conflicts can arise with other fishers that have been excluded from obtaining a licence. For example, there is a waiting list of fishers in the Seychelles who would like a licence and they complain that licences should be revoked for those in the fishery who are not fishing actively for several months (Aumeeruddy and Conand, 2008).

Many fishers in small-scale fisheries collect other marine animals alongside sea cucumbers. It is therefore impractical to limit fishing of sea cucumbers to certain times or days, if fishers are then allowed to collect other resources. Enforcement of effort limitations becomes quite problematic in these situations.

How to implement

Managers need to know the number of fishers and vessels in the fishery. It is also complementary to know the number of households reliant on the fishery (Sections 3.6 and 6.1.4). The socio-economic impacts of regulating or reducing the number of fishers or amount of time they can spend fishing should be considered.

Managers should also establish or understand the legal framework for implementing effort or capacity controls. Is it possible to limit boats or fishers, and what legal body defines these? There should be a means of licensing fishers, and this can be accompanied by a mandate for fishers to complete and submit logbooks as a condition of licence renewal (Section 5.5). Naturally, this demands that managers establish a system to periodically evaluate the outputs of logbooks.

Enforcing controls on the number of fishers per boat or hours permissible to fish will require inspections of boats and fishers at sea (Section 6.5). Managers should also establish a system for managing data on licences, infringements and the response of the resource over time. This data can then inform advisory committees and decision-makers on the merits of this measure and whether it should be adapted over time.

EXAMPLES AND LESSONS LEARNED

Galápagos Islands, Ecuador

According to the Galápagos Special Law enacted in 1998, only small-scale fishers may take part on fishing activities within the Galápagos Marine Reserve (GMR). All fishing vessels have a set of regulations that should be met by owners and the maximum beam length for mother boats is restricted to 18 m. The restriction on boat size is a form of capacity control, which may be called a "technical control". The number of fishers has been regulated by means of a moratorium (effective as of 31 March 2003) which allows only sons and daughters of active fishers to become new registered fishers of the GMR. However, both, the fishing cooperatives and the Galápagos National Park Service (GNPS) are in the process of eliminating from the fishery non active fishers, hence leaving only fishers that depend on the activity as their primary source of income.
Source: V. Toral-Granda.

Pacific, Melanesia

Customary marine tenure practices vary across Melanesia. Access to the shorelines and lagoon reefs is often controlled by individual communities or family groups that consider these areas and their associated commercial resources as being exclusive property, not dissimilar to property on land.

In a recent cross-Pacific study (SPC PROCFish, 2002–2009), Vanuatu's customary fishing controls stood out as being one of the most intact local management systems, especially on Islands distant from the capital on Efate Island. On Malekula Island, communities on the Maskelynes group of islands still practice a complex system of fishing controls, especially for resources like *Trochus* and sea cucumbers. Aggregations of *Trochus*, by individual reef, came under the control of family groups, and high value sea cucumbers such as sandfish, *Holothuria scabra* were protected by harvesting tabu's, even close to the village forefront that was accessed by the whole community. In this case *H. scabra* had a mean density of 2131±662.4SE individuals/ha from forty-two, 40 m^2 transects close to the foreshore

(PROCFish data, Secretariat of the Pacific Community). This stock was protected from fishing as the local community leaders were waiting for the fishery to recover before commercialising their resource.

In addition, there are controls of effort over small "garden" areas and tabu reserves. "Garden" areas in front of family houses are commonly stocked with important species and protected from fishing in parts of Melanesia. This practise of concentrating resources (generally giant clams, but also other species) in "gardens" has been long documented in northern Papua New Guinea (Mitchell, 1972), and is seen across much of Melanesia. Greater areas under total protection from fishing were also found in Maskelynes. For example, in front of Pellonk village on Uliveo Island in the Maskelyne, the Ringi Te Suh Marine Conservation Reserve limits effort from a one kilometre square reserve. Ringi Te Suh has two meanings; to leave something to multiply and to leave something alone. This fits well with the aim of this reserve, where clam and sea cucumber species are found at higher stock densities, to facilitate successful reproduction, and thereby recruitment to surrounding reefs.

Source: K. Friedman.

5.4 CATCH QUOTAS

Definition

A catch limit set for a particular sea cucumber fishery, generally for a year or a fishing season. Quotas, also called "total allowable catch" (TAC), are usually expressed in tonnes of live-weight equivalent, but are sometimes set in terms of numbers of individual animals.

An overall quota, or TAC, can pertain to the whole fishery or be assigned on an individual basis to fishers or fishing vessels, e.g. individual transferable quotas (ITQs). Individual quotas (a form or access rights) can be transferrable, or not.

Use

Catch quotas are appropriate when fishing is spread over large areas (e.g. regions) and/or when fishers do not necessarily have an intimate (i.e. traditional or cultural) geographic association with the resource (Hilborn, Parrish and Litle, 2005). A primary goal of catch quotas is to control the quantity of animals removed by fishing each year, aligned with the fishery objectives (Section 3.4). A second goal of individual catch quotas is to remove the "race for fish" that can prevail if relatively low quotas are set for a whole fishery. They may be used as a companion management measure alongside other regulations like size limits (see Section 8.3).

Catch quotas can pertain to the entire fishery (a "global" quota for fishers collectively), in which case all fishers are allowed to collect sea cucumbers until the annual limit is reached. This mode, however, does not stop the "race for sea cucumbers". Alternatively, they can be allocated separately to various regions in the fishery and licensed to fishers as individual quotas (which can be transferrable [ITQs] or not [IQs]) or fishing vessels (IVQs). ITQs can provide a relatively secure use right, creating incentives to maximise value and husband resources (Parma, Hilborn and Orensanz, 2006).

Individual quotas, allocated to each fisher or licensed fishing group, can provide a way to equitably distribute potential earnings from the resource among fishers. In some invertebrate fisheries, quotas have been given to communities, which sub-allocated them to families (Defeo and Castilla, 2005). By providing fishers with secured access to a given proportion of the stock, individual quotas can help to maximise the value of the overall catch. For example, fishers then collect only large or valuable sea cucumbers because there is an incentive to be choosy and fill their quota with high-grade animals. Individual quotas relax the timeframe for fishing, thereby improving safety because the choice of when to fish is not determined by short-term competition (Hilborn, Parrish and Litle, 2005). In some fisheries with individual quotas, fishers are happier to see some of the fishery revenue spent on research and science, become more involved in the management of the resources, and work cooperatively (Parma, Hilborn and Orensanz, 2006).

Limitations

In as much as quotas are an effective tool, they suffer from being inequitable and difficult to monitor in small-scale fisheries. They demand technical competence and resources for monitoring, often beyond the limits of fisheries agencies in low-income countries.

Quotas, in general, can lead to monopolization of the fishery in the hands of few fishers. Where a single ("global") quota is set for an entire fishery, those with aggressive fishing strategies will gain the "lion's share" of the quota and leave little to the small-scale fisher collecting just enough each week to meet household needs. Fishers can overcapitalise, e.g. buy larger boats, to gain a competitive edge to secure a large personal catch before the quota is reached (King, 2007). Conflicts then arise when the quota is reached early in the year and the small-scale fisher, who was harvesting modestly, is forced to stop fishing for the remainder of the year. Likewise, ITQs can be bought out by fishing companies to later deprive resource owners of traditional income streams. However, it is worth noting that marine resources generally remain a public good (Hilborn, Parrish and Litle, 2005) and as such, the public can be compensated for its use.

An early dilemma is the allocation of individual quotas among fishers. Fishers reliant on sea cucumbers will argue they deserve larger quotas, while occasional fishers with alternative income streams will argue that it is inequitable to give them smaller quotas.

There are a number of approaches to setting a catch quota. The common process for setting quotas involves three steps:

1) Set the target reference point (in accordance with management objectives; see Section 3.4).
2) Determe the current stock status (see Section 4).
3) Set the quota to achieve the target reference point within a certain timeframe.

Estimating how many (or the weight of) animals that can be removed to obtain the target reference point can be a complex task. Such estimates arise through mathematical models, e.g. of maximum sustainable yield (MSY) (see Hilborn and Walters 1992; King, 2007). Stock assessment of this nature is more often tackled by teams of fisheries scientists in high-income countries with large fisheries, but is intangible for fishery managers with limited technical support.

The use of MSY models as a basis for assigning quotas in sea cucumber fisheries is further problematic. One difficulty with models to calculate MSY is the need to estimate (1) the annual rate of natural mortality (M) or the intrinsic rate of population growth and (2) the "virgin" (i.e. original, unfished) biomass of sea cucumber populations. These biological parameters are lacking for most sea cucumber species at most locations (Conand 2006a; c.f. Conand, 1990). For stocks of species that are long-lived or with very low productivity, as seems to be the case for many sea cucumbers (Section 2.1), the sustainable yield may be only a few percent of the virgin biomass (King, 2007). Additionally, the very premises of using MSY or "surplus yield" models are not well supported by field studies on sea cucumbers. For example, MSY theory assumes that the proportion of animals removed by fishing in one year can be reliably renewed by recruitment in the following year – but annual recruitment in some sea cucumber species appears to be quite irregular (Uthicke, 2004; Uthicke, Welch and Benzie, 2004; Section 2.1). Therefore, MSY theory is not appropriate for many (most?) sea cucumber species, and removing more than a very small fraction (e.g. 2–4%) of the virgin biomass each year may soon deplete breeding stocks such that replenishment of population losses from fishing becomes increasingly unlikely.

Simpler approaches for setting catch quotas can be based on knowledge of historical catches and whether annual catches were sustainable, or through adaptive harvest strategies (see below). However, catch quotas based on subjective criteria can be flawed if they can be based on political pressure rather than scientific information (Toral-Granda, 2008b). Regardless of the method, the implementation and compliance of catch quotas will be quite difficult for most tropical fisheries because, more often, fishers are numerous, catches are difficult to monitor closely, and multiple species are collected (Section 2.3).

Firstly, the fishery manager will normally need to update referenced points for catch quotas in subsequent years, based on fishery-dependent data or new modeling (Grafton *et al.*, 2007). Secondly, individual quotas should be set for each species in multispecies fisheries that predominate the tropics (Section 2.3); otherwise, the relatively uncommon high-value species will be vulnerable to being fished to depletion within the overall fishery quota. Thirdly, managers must monitor catches regularly to know exactly when the quota is reached and have an effective communication programme to alert fishers. In fisheries of most developing countries, data from fishers on a monthly basis is difficult to obtain. The periodicity of collating data from logbooks is thus a limiting factor to implementation. Where fishing grounds are remote, difficulty in contacting fishers once the quota has been reached can allow the quota to be exceeded – as occurred in the Galápagos Islands (Toral-Granda, 2008b).

For restoring depleted stocks, TACs alone tend to be inappropriate unless combined with other regulations (Caddy and Agnew, 2005). For example, spatial closures and limited entry (reducing the number of licenced fishers) may also be required. In such cases, the uncertainties in estimating and implementing sustainable catch quotas are high, so there is risk of causing irreversible impacts on stocks.

Quotas, if not allocated to limited areas, will not help avoid serial depletion of stocks. For example, the annual quota could be reached from depleting a few inshore fishing grounds, while leaving stocks in other grounds temporarily intact.

How to implement

Implement TACs through cooperatives and advisory committees; they will be instrumental in passing on the regulations to fishers in local dialects and marshalling the support of stakeholders. Seek their agreement of the goals of the quotas (i.e. to maintain or rebuild current stocks) and predefine the management actions if quotas are exceeded or if follow-up surveys indicate that stocks are not supporting the harvest rates.

The information requirements for setting TACs may be demanding on a fishery agency. To base TACs on an assessment of MSY, managers must have reliable and precise estimates of stock distribution and abundance to sensibly define them in the first instance. These can only come from underwater field surveys, which are costly and time-consuming to conduct over large areas. Additionally, the calculation of abundance will normally require technical competence with geographical information systems (GIS) and field ground-truthing. Based on the estimated standing biomass of each species, TACs can be proposed for those species in sufficient abundance only (Figure 21).

In place of using classical (e.g. MSY-based) stock assessment to determine quotas, an alternative approach is the use of adaptive harvest strategies (Hilborn and Walters, 1992; King, 2007). These approaches will be most useful for fisheries that lack the biological

FIGURE 21
Left: a catch of large sea cucumbers, mainly *Thelenota anax*, at Nabaina Beach, Milne Bay, Papua New Guinea. Fishers may start to target one particular species in a multispecies fishery, so species-specific TACs should be used. Right: fishers setting off on a sea cucumber fishing trip off Enivala Island, Papua New Guinea, using outboard driven dinghies

PHOTOS: J.P. KINCH

parameters of sea cucumber species for classical MSY models or for fishery agencies that lack the technical capacity to conduct statistical modelling (see Section 2.3). In new and developing fisheries, managers could set a conservative TAC for several years and monitor whether catch per unit of effort (CPUE) and densities of sea cucumbers are maintained at a target reference point (Figure 12; Section 3.4). Subject to operational objectives being met, the TAC could then be increased a little and the response of catch rates and sea cucumber populations monitored and re-evaluated. In an existing fishery, TACs may already be too generous, so the manager may downsize the following year's TAC if catch rates or population densities decline. However, both approaches rely on having the sustainable catch level exceeded to know the biological limits of the system (King, 2007), whereas the precautionary approach (FAO, 1995; Section 3.2) urges managers to control effort and capacity to within these limits. Another adaptive harvest strategy involves the use of different management measures in different regions of the fishery and comparing the response of the stock to the different strategies. In either the classical (modelling) approach or adaptive management approach, time-series data on the abundances of stocks after imposing TACs will be required to show whether the harvest rates are sustainable.

Managers need to review published studies and seek the advice of fishery scientists with expertise in sea cucumbers to obtain information on the population dynamics and sustainable harvest rates (e.g. MSY) of the commercial species. This information is generally lacking for sea cucumbers. It can be gained from biological studies on growth, size-at-maturity, rates of natural mortality and recruitment (see Section 2.1). The adopted harvest rates should be in harmony with the productivity of species and the role of the species in the ecosystem. When faced with uncertainties, TACs should be set conservatively. With our present understanding, a sustainable harvest rate would probably be between 2 and 5 percent of the virgin adult biomass per year.

The manager will also need updated information on captures to be able to close fishing once the TAC has been reached. This would need fishery officers to receive and collate log sheets from fishers, and preferably separate captures for each species. Managers may stipulate that if the TAC is exceeded, the surplus amount will be deducted from the following year's TAC, as has been practiced in Papua New Guinea (Kinch *et al.*, 2008b).

Catch quotas should be implemented through an adaptive management process, by which field monitoring and fishery-dependent data (e.g. landing surveys, logbook records or export statistics) are used to lower the quotas for species when stocks show signs of depletion. Zero quotas (i.e. no collection permitted) should be set for species that appear to be becoming sparse. These measures could be set as agreed actions in the management plan if an indicator of stock density depasses a specified limit reference point (Figure 12; Section 3.4).

EXAMPLES AND LESSONS LEARNED

Japan

Global catch quotas exist in some prefectures. For example, the Semposhi Fishery Cooperative Association set an annual quota of 50 tonnes, divided into seasonal quotas of 30 tonnes in spring and 20 tonnes in summer. Fishing is prohibited for the rest of the open season as soon as the annual quota of 50 tonnes is reached by all fishers.
Source: J. Akamine.

British Columbia, Canada

Fishing in British Columbia (BC) was initially permitted along the south coast areas only. The north coast was opened in 1986 with a quota of 500 tonnes. Landings of sea cucumbers have since been recorded from all management areas. The central and north coast currently supports about 80 percent of the fishery. The total allowable catch has augmented incrementally since 1998.

Canada restricts the permits to a single species for two reasons. First, it is much easier to manage and control the catches/quotas (both on board and upon landing). Second, it prevents fishers from opportunisticly starting to target other species for which management plans are not yet developed. With a single species quota and license, the fishers must return any bycatch to the sea and keep only the authorized target species.

Although sea cucumbers have been harvested for more than 20 years, little biological information exists to base quotas and harvest practices. The fishery was therefore incorporated into the "phased approach" described in the Pacific Region Policy for New and Developing Fisheries. Based on existing biological and fishery data in British Columbia and elsewhere, a framework was designed for an experimental fishery to provide data on stock abundance and on the response of the populations to different levels of exploitation.

The existing arbitrary quota of 233 tonnes of *Parastichopus californicus* is maintained in an area comprising about 25 percent of the British Columbia coastline. Another 25 percent of the coast is dedicated to experimental fishing, and the remaining half is closed until the biology of the species is well understood. The quota was justified over this proportion of the coast by extrapolating:

1) an estimated "density" of 2.5 sea cucumbers per meter of shoreline,
2) an annual exploitation rate of 4.2 percent, and
3) a mean individual weight ranging from 263–327 g, depending on the area.

Landings at designated ports are monitored by an independent industry–funded firm, funded through license fees (Bruckner, 2006c). The global quota is considered the most conservative of estimates used in sea cucumber fisheries in the states of Alaska and Washington (United States of America). The management plan allows for abundance surveys to be undertaken in the open areas to defend potential quota increases.
Source: A. Mercier and J.-F. Hamel.

Australia

In addition to other regulations, the sea cucumber fishery on the Great Barrier Reef (GBR) also has a total ("global") TAC and in some instances regulates a TAC for individual species. For instance, in 2004 the total TAC was 380 tonnes, consisting of 127 tonnes of white teatfish, zero catches of black teatfish and 253 tonnes for all other species.

In addition, the fishers in the industry agreed on species-specific limit reference points (Figure 12; Section 3.4), sometimes called "trigger values", for the annual catch. If these

are exceeded, in any given year, a stock assessment must be undertaken to establish "biologically-based sustainable yield estimates". Examples of limit reference points in the GBR fishery have been: sandfish, 15 tonnes; golden sandfish, 10 tonnes; prickly redfish, 40 tonnes; surf redfish, 25 tonnes; and deep water redfish, 25 tonnes.
Source: S. Uthicke.

5.5 MARKET CHAIN LICENSING AND REPORTING

Definitions

Requirements imposed on fishers, processors and traders to declare and report on their activities within the fishery.

These can be divided into actions for various stakeholder groups:

1. *Records on catches*: data on the quantity (number and/or weight) of sea cucumbers collected by fishers for each species, collected and reported by fishers and buyers.
2. *Records and statistics on trade*: volumes (weights), processed state and sale grades of sea cucumbers exported and imported for each country, collected by trade departments of government.
3. *Monitoring of catch and trade data*: an assessment of changes in catches and trade through comparison of data averages or totals over time, conducted by resource managers.

Uses

Monitoring of the catches and exports of fishers within a country can provide a means of revealing changes in the rates of exploitation (e.g. per year, not per unit of fishing time) of the resource or in the types or locations of species collected. For example, fisheries agencies that collect and closely monitor data from fishers' logbooks can see whether the annual catches of certain species are increasing or decreasing. States (i.e. fishery agencies) are urged, through the Code of Conduct for Responsible Fisheries (FAO, 1995), to maintain statistical data on fishing operations and update them at regular intervals. The data can be used as a proxy for monitoring the "condition" of the fishery in the absence of rigorous data from underwater population surveys (see Sections 3 and 4). The data can reveal the amounts of sea cucumbers removed, where fishing took place, how the animals were processed and the prices paid.

Licensing can be used to limit the number of buyers/exporters in the fishery to a manageable number. In doing so, collection of trade statistics by the resource manager is simplified. It improves the accountability of trading sea cucumbers since the exporting agents are recognized and have vested interests in abiding by the fishery regulations. Likewise, licences for buying or exporting sea cucumbers can act to limit the illegal and unreported trade by stipulating licence renewal conditions. Illegal buying and transport can be a key problem in fragmented small-scale fisheries (Kinch *et al*., 2007; Kinch *et al*., 2008b). The market for fishers to sell their catch is improved if licences are issued to separate companies that will act in competition to buy sea cucumbers.

Licensing of exporters can also be a way to initiate trade labelling to improve the reputation and prices for beche-de-mer. Similarly, the labelling can distinguish beche-de-mer arising from responsible fishing practices; e.g. "eco-trepang". Ecolabelling can involve the public in preferentially purchasing fish from sustainable fisheries (Pauly, 2008), although the benefits of these marketing tactics have yet to be demonstrated for beche-de-mer sold in Asia.

Limitations

A principal limitation is that the data collation and analysis of captures and trade require human resources and some technical capacity. This may be limiting in some countries for the detail needed to properly manage multispecies sea cucumber fisheries (see Section 2.3). Customs officers and fishery officers need to be able to identify sea cucumbers to species level, both in the unprocessed and processed (e.g. dried) forms. Although some guides are available to help them with this task (see Section 6.1.1), customs officers are commonly unfamiliar with identifying sea cucumbers, and so need appropriate training (see Section 6.5).

One obstacle in comparing trade statistics among countries is the harmonisation of trade names. Sea cucumbers are sometimes coded or grouped, which only hampers the ability to compare levels of trade across countries.

While exporters can be licensed, there are usually informal "middlemen" that buy from fishers and sell to other buyers or exporters. When the market chain is divided into multiple links in this way, licensing becomes problematic and difficult to regulate.

Exporters may be secretive about their sales and unwilling to provide data on prices and grades of exported beche-de-mer. In the Seychelles, logsheets required fishers and processors to state prices of sea cucumbers sold but compliance was difficult because they were reluctant to give that information, so the logsheet was revised to only include quantities sold (Aumeeruddy and Conand, 2008). In Madagascar, it has proven difficult to obtain accurate data on exports because exporters under-report their trade to avoid paying the corresponding taxes (Rasolofonirina, 2007).

A further underlying difficulty in obtaining accurate catch and trade data is the presence of illegal, unreported and unregulated (IUU) fishing. It is relatively easy to export beche-de-mer illegally in many countries, or it can be transhipped and re-exported from other countries, making the inferences about captures less reliable.

How to implement

Resource managers should gain an understanding of the market chain (including shipment routes to markets or harbours). To whom do the fishers sell sea cucumbers; who processes them; are there middlemen; and who exports the final product? These questions can be answered from sociological studies and discussion with fishers and buyers (Sections 6.1.4 and 6.1.5).

It is also important to understand how the grading of beche-de-mer works and the factors that affect sale price (Section 6.1.4). Obtain relevant conversion factors to harmonise the trade data to a common unit of measure (e.g. whole-animal weights) – most of these are published for the common commercial species (see *Examples and lessons learned*, Section 6.1.3).

Managers should find out the legal framework under which licensing requirements can be established for buyers and exporters. In some cases, legislation may afford some rights to the exporters or fishers to keep their transactions confidential. Managers should also find out if there are over-arching regulations from governments and international agencies on the trade of sea cucumbers (e.g. CITES).

Supply custom agents with the information needed to identify different species and grades of sea cucumbers. If possible, seek to harmonise the data format with other countries in the region and participate in some form of regional monitoring and trade controls.

Prepare or adopt logbooks with blank data sheets and examples to be completed by fishers, buyers and exporters. The logbooks should oblige them to record the weights and grade of sea cucumbers sold or exported for each species separately and include the product form (i.e. whole, fresh gutted, salted, dried). Recording the product form will allow data on the weights of each species to be converted to a standardised unit, e.g. fresh (whole) animal weight or dried weight. Rejected and discarded animals should also be recorded (e.g. Appendix 3). Kinch *et al*. (2007) proposed that carbon-copy receipt books should be used for transactions; the seller, buyer and fisheries authority should each receive copies.

Fishery managers should arrange or define the mechanisms for data collection from fishers and exporters – do they submit logbooks or are these collected routinely by a fisheries officer? For example, landing logsheets are required to be filled by fishers and submitted after each landing to the management authority in Newfoundland and Labrador, Canada (Appendix 3). Compliance with this reporting is a condition of renewal for their fishing licences. In the Seychelles, licensed fishers are required to submit logsheets of their catches on a monthly basis (Aumeeruddy and Conand, 2008). Managers should establish a chain of custody to follow shipments from different areas, for example by coding shipments by fisher licence number, site and date and have this information passed on to buyers along the market chain. Government agencies responsible for trade should collate and summarise the data in a way that can easily reveal changes in the data over time.

Establish an industry "code of conduct" whereby licences are renewed on a condition of compliance with the fishery regulations. Incentives could be given to fishers and exporters for reporting completely and on time.

The critical stages should be regulated in the market chain – i.e. stages that are easy to identify and where important information can be collected and verified with available resources. For example, managers should develop and implement a strategy for active monitoring of the main harbours (i.e. export hubs).

EXAMPLES AND LESSON LEARNED

Galápagos Islands, Ecuador

The Galápagos Marine Reserve (GMR) has a Fishery Monitoring Programme (FMP), in which information is collected on fishing sites, fishing effort, total catch and fishing methods, etc. Presently, the FMP is carried out by the Galápagos National Park Service (GNPS). Information is collected throughout the chain of custody. The chain starts in the GMR fishing site and ends with the exporter in mainland Ecuador. By the Special Law of Galápagos, fishers are obliged to provide all the required info to the FMP. The chain of custody involves the following steps:

1. Upon arrival of the fishing boat to one of the ports: (1) GNP personnel will record catch information, fishing sites, biological information; and (2) GNPS verifies compliance to fishery regulations; any catch not complying with these is impounded. A Fishing Monitoring Certificate (FMC) is issued to the owner of the catch. This certificate verifies the amount of *I. fuscus* harvested and state of the produce (i.e. fresh, in brine, dry).
2. 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).
3. Once the sea cucumber merchant has gathered enough products 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 (*I. fuscus* was included in Appendix III of CITES on 15 August 2003).
4. The sea cucumber merchant must present all TADs and CITES official export permits in the airport or cargo pier in the Galápagos 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.
   Source: V. Toral-Granda.

Cuba

The fishery for sea cucumbers is not a traditional activity in Cuba; hence there is little local interest in fishing them unless there is a known legal market. All fishing activities for *Isostichopus badionotus* are controlled, with monitoring of the landings, follow-ups and a strict comparison between what is caught, the sales to the exporters and the actual export figures. There is one exporting company authorized in Cuba (NENEKA C.A.) which ships "Class A" product to China, Hong Kong Special Administrative Region, and "Class B" product to China or the Republic of Korea. Additionally, there is a Sanitary Registration that must be issued to the export product which will be checked by customs upon departure. All paperwork must match precisely in order to leave the country. Up to date, there has not been any illegal shipment detected.

Source: I. Alfonso.

New Caledonia

In both the Northern and Southern Provinces of New Caledonia, fishers are registered through a licensing system. They are required to present themselves at the fishery service and renew their licence each year, for a nominal fee. In the Northern Province, the fishers must also apply for a special "Concession" to harvest sea cucumbers. The licensing system allows the fishery services of the Provinces to monitor the number of fishers, and provides an opportunity to update them on any new regulations. At the time of licence renewal, each fisher is given a booklet, the "Carnet de pêche" that contains the fishery regulations and log sheets (blank forms) to record their catch, in terms of numbers and weights of sea cucumbers collected on each fishing trip. One limitation is that the log sheets are submitted once per year (Purcell, Gossuin and Agudo, 2009a), so the fishery service cannot regularly monitor catches, e.g. as would be required if a TAC limit was in place.

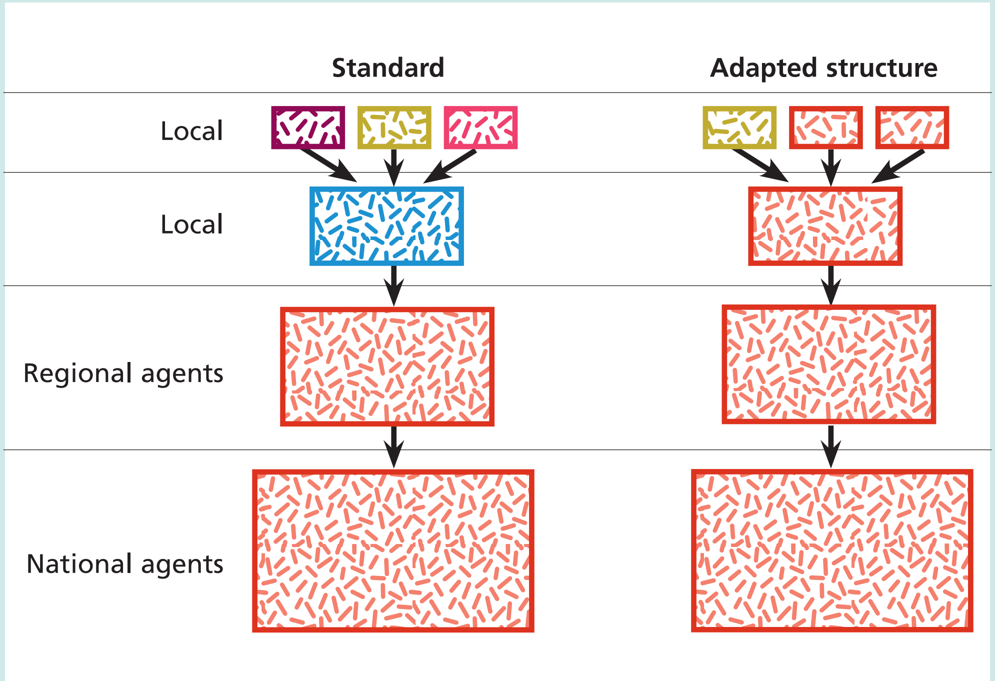
Source: S.W. Purcell.

Fiji

Fiji, a large island group of 332 islands in the mid-Pacific, provides a relevant example of a market chain between sea cucumbers in the lagoon and a dried beche-de-mer consignment ready for shipping to international markets. If we take the northern Island of Vanua Levu and the eastern Lau group of islands as examples we can see that a number of variations exist in the type of market chain present. These scenarios reflect changes in market chain structures across the Pacific.

Usually there are at least four stages along the route from lagoon to export warehouse, although in some cases there may be more (see Figure below). The fisher or community of fishers collects and sells product to local/island middleman who passes it to regional agents and eventually national agent/capital warehouses. In the more traditional structure, fishers in the western lagoon of Vanua Levu and the Lau Group catch sea cucumbers and process the catch into dried product (beche-de-mer) before marketing to local buyers or saving it up until they have enough to take to buyers in larger regional centres. This market chain has changed somewhat in recent years, with a tendency for fishers to be employed on wages and be working for managers employed by the larger export license holders. These fishers, recruited from local villages, dive at numerous areas where they have access, collecting sea cucumbers which are transported directly to the regional centres for processing. In addition, some marine agents prefer to buy wet product from independent fishers and process it themselves to the strict levels of quality requested by the market. Due to the increasing value of the product and the lack of post-harvest skills of some fishers, there is also a tendency for agents to re-process the product they buy, to enhance its appearance and value.

Source: K. Friedman.



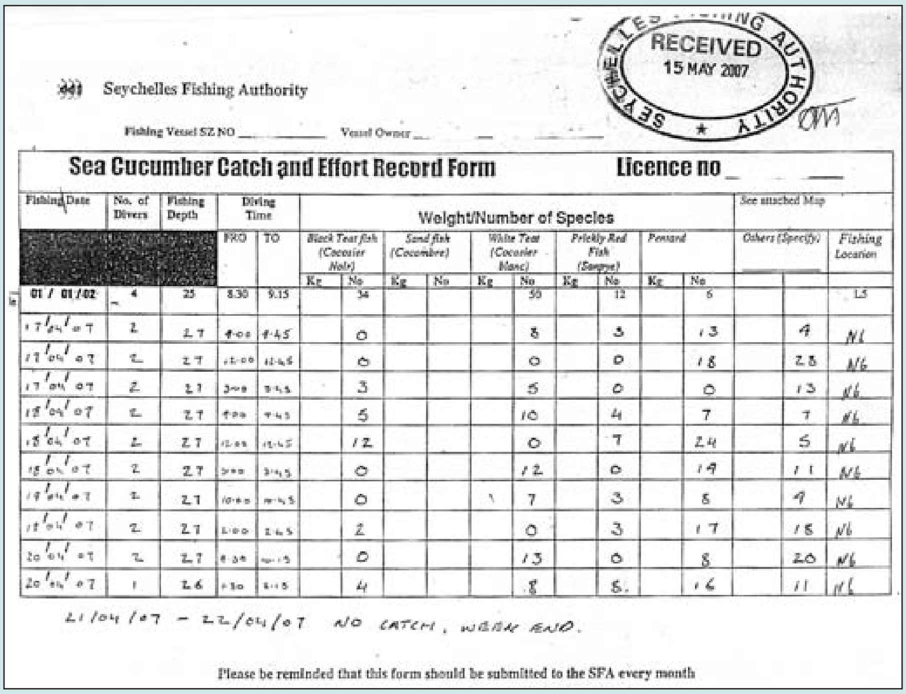
Above: More traditional market chain (left) and variations currently seen (right). Each box texture represents a different stakeholder (i.e. person or company) along the market chain. In the adapted structure, the exporting company employs regional agents, local agents, processors and fishers, thereby controlling or taking away traditional employment of middlemen and local fishers.

Western Indian Ocean

The Seychelles and Madagascar could again be taken as examples of two contrasting fisheries, one with effort and capacity controls (Seychelles) and the other under an open access regime without controls (Madagascar) (Conand and Muthiga 2007; Conand 2008; Aumeeruddy and Conand 2008).

In the Seychelles, fishers, processors and exporters are licensed and monitored by the fishing authority. A management plan came into effect in 2008, with the adoption of the plan by the Cabinet of Ministers; it is the public statement and legal basis for management of Seychelles's sea cucumber three sectors of activity: harvesting, processing and export. The sea cucumber fishery is controlled through a limit of 25 fishing licences to Seychelles citizens. Licences are issued to individuals and registered companies possessing a valid local fishing licensed vessel, to prevent monopoly on fishing licences. The licence fee varies according to fishing vessel type. A maximum of four divers with life insurance are authorized to fish under a sea cucumber fishing licence. The fishing season has been set for nine months starting from 1 October to the 30 June. Licence holders are provided with sea cucumber catch and effort forms, along with a grid map of the Mahe Plateau, which guides them in reporting their fishing locations.

Real-time monitoring is undertaken at designated landing sites. Monitoring of the activities of the processors is constantly done to ensure that illegally caught sea cucumbers are not traded. The processors are required to keep detailed records of their purchases and stocks in a logbook which is then reported back to the Seychelles Fishing Authority (SFA). Most of the sea cucumbers harvested are processed to a dried state and exported by air cargo to main Asian markets. At export the consignment is jointly certified and sealed by the SFA and Custom Officers. A small management fee charged for each kilogram of sea cucumber is paid in Seychelles Fishing Authority's account to better manage the resource.



SEYCHELLES FISHING AUTHORITY
RECEIVED
15 MAY 2007

Seychelles Fishing Authority

Fishing Vessel SZ NO ________ Vessel Owner ________

Sea Cucumber Catch and Effort Record Form **Licence no** ________

Fishing Date	No. of Divers	Fishing Depth	Diving Time		Weight/Number of Species										See attached Map		
[redacted]			FRO	TO	Black Teat fish (Cocosier Noir)		Sand fish (Cocombre)		White Teat (Cocosier Blanc)		Prickly Red Fish (Sampye)		Pentard		Others (Specify)		Fishing Location
					Kg	No	Kg	No	Kg	No	Kg	No	Kg	No			
01 / 01 /02	4	25	8.30	9.15		34				50		12		6			L5
17/04/07	2	27	9:00	9:45		0				8		3		13		4	N1
17/04/07	2	27	12:00	12:45		0				0		0		18		28	N6
17/04/07	2	27	3:00	3:45		3				5		0		0		13	N6
18/04/07	2	27	9:00	9:45		5				10		4		7		7	N6
18/04/07	2	27	12:00	12:45		12				0		7		24		5	N6
18/04/07	2	27	3:00	3:45		0				12		0		19		11	N6
19/04/07	2	27	10:00	10:45		0				7		3		8		9	N6
19/04/07	2	27	1:00	1:45		2				0		3		17		18	N6
20/04/07	2	27	9:30	10:15		0				13		0		8		20	N6
20/04/07	1	26	1:30	2:15		4				8		5		16		11	N6

21/04/07 – 22/04/07 NO CATCH, WEEK END.

Please be reminded that this form should be submitted to the SFA every month

Above: a stamped sheet from a fisher's logbook showing the fishing dates, number of divers, depth, fishing times, number of individual sea cucumbers captured and the fishing location.

The lesson from the successful monitoring of catch and trade in Seychelles' sea cucumbers is that licensing and monitoring must be conducted at the 3 levels: harvesting, processing and export. The data collected on the catch and effort allows the evaluation of the state of the resource.

In Madagascar, on the other hand, monitoring and controls have been difficult to implement. In the last decades, the fishery has partly shifted from a low tide gleaning by family groups including women and children, to a semi-industrial activity with motorised boats and diving equipment, although SCUBA diving for sea cucumbers is illegal (Rasolofonirina, 2007). The traditional exploitation is very active in remote villages.
Source: C. Conand.

5.6 TEMPORAL CLOSURES

5.6.1 Seasonal and short-term closures

Definition

A cessation or prohibition of fishing for a short specified time period, generally for less than a year and often over the breeding season.

Temporal closures could be a seasonal or cyclical closure, or just a one-off closure for a short period.

Use

Seasonal closures have been used in some sea cucumber fisheries (Bruckner, 2006b; Toral-Granda, Lovatelli and Vasconcellos, 2008). Two principal uses of seasonal closures are: (1) to prevent fishing of sea cucumbers in a period when they are more easily collected, because they are forming groups or less cryptic, such as when they are breeding; and (2) to limit the number of days in a year that fishers have to collect the animals. However, Purcell, Gossuin and Agudo (2009a) argue that the biological precept of the first use is not valid for the majority of sea cucumber species. In the uncommon cases where the behaviour of the species makes them more vulnerable to fishing (more easily collected), seasonal closures have a biological basis.

Only two fisheries in the Western Central Pacific have seasonal fishing closures (Kinch *et al*., 2008). A large benefit of temporary closures lies in the reduction of annual fishing effort. They can limit annual effort by reducing the total number of days per year that animals can be harvested. For example, the fishing season in some parts of Japan is closed for 10 months of each year (Choo, 2008a). Evidence from field population assessments indicates that this measure, in addition with other companion regulations, has increased the densities of wild stocks (Choo, 2008a). On the other hand, while fishing in the Galápagos Islands is restricted to two months between March and August, in addition to other regulatory measures, stocks have continued to decline (Toral-Granda, 2008b). Likewise, a 5-month temporal closure in the sea cucumber fishery in Eritrea apparently did not prevent depletion of stocks (Conand, 2008).

Temporal closures could be viewed as measure to protect sea cucumbers at certain critical times of the year, such as during spawning (Bruckner, 2006b). In this way, fishing does not disturb them in a biologically vulnerable period, but this idea is unfounded if the seasonal closure causes heavier fishing pressure. That is, seasonal closures may backfire as a management measure if heavy fishing prior to the spawning season lowers the densities of spawning animals to levels lower than if there was no seasonal closure in the first instance (see Figure 22).

Temporal or seasonal closures can have some benefit for export marketing of the beche-de-mer. For instance, fishing may be closed when the animals would be of poorer quality for processing, e.g. during aestivation. For example, a long annual temporal closure in British Columbia, Canada, allows fishing for only three weeks, at a time of the year when the muscle weight is greatest and the animals have reabsorbed their internal organs (Hamel and Mercier, 2008a).

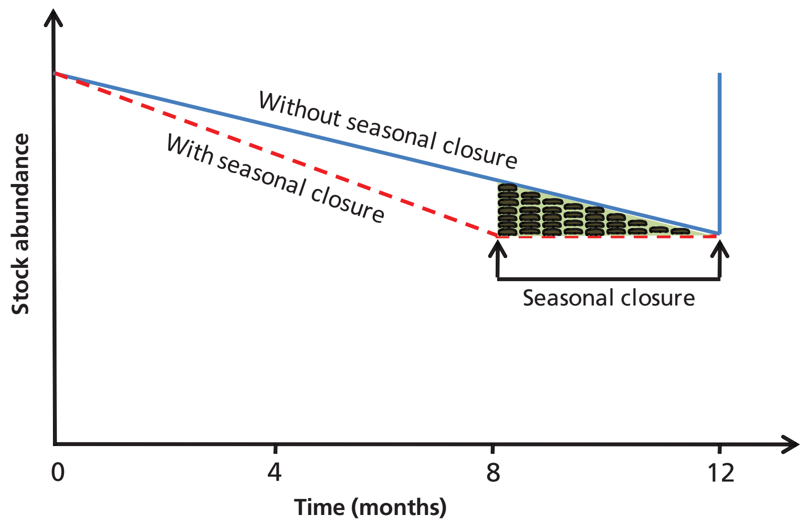
Limitations

There are clear reasons why seasonal closures can reduce the likelihood of overfishing if their purpose is simply to reduce effort. This assumes that fishers do not then fish more intensely during the open season, and that annual harvests are lowered because there is less time for fishers to collect sea cucumbers. In this case, seasonal closures could be placed at any time of the year. In other fisheries, closures are commonly set during the spawning season of the animals to prevent exploitation of spawning aggregations or to avoid disturbance to spawning behaviour. That would only hold true if animals were more vulnerable to being caught during the spawning season or if spawning behaviour was somehow deterred (e.g. by chemical cues of released by distressed animals when captured) by the collection of some animals – which are probably not the case for the majority of commercial sea cucumbers. Most species do not form aggregations for spawning and there is no evidence that they are much more visible to fishers during the spawning seasons. Therefore, there is no behavioural basis to close fishing when animals spawn or during breeding seasons because sea cucumbers do not appear to be more vulnerable to being collected during these periods. In addition, closures based on spawning seasons will be problematic in multispecies fisheries (see Section 2.3) if species spawn in different months.

Shorter fishing seasons can prompt stronger fishing pressure in the open season, thus taking adults out of the population even before they spawn. A seasonal closure can therefore decrease the number of breeders in the spawning season if fishers try to catch an equivalent number of sea cucumbers in the fishing season as they would have without a seasonal closure (Figure 22). Seasonal closures should be used with some form of output control, e.g. a reduced TAC (Section 5.4), if this may be the case (see Section 8.3). Managers may therefore need to monitor catches following the implementation of temporal closure to ensure that rates of fishing do not increase in the open season.

FIGURE 22

A simplified representation of declines in stock biomass through the fishing season with an equivalent annual catch, with and without a seasonal closure. The solid line (blue) shows a gradual decline in stock biomass though the whole 12 months, from a constant fishing rate, followed by recruitment of new animals the following year. The dashed line (red) shows a faster decline in the stock in the first 8 months (before a 4-month seasonal closure) because fishers collect at a faster rate to obtain the same annual catch in 8 months. The seasonal closure in this case coincides with the spawning season. The number of adults harvested annually is the same in both scenarios. The shaded area shows the deficit in spawning biomass at various times during the spawning season with a seasonal closure compared to a fishery without a seasonal closure



Conflicts can arise due to a clash between the timing of temporal closures and the economic needs of fishers or environmental factors. For example, the closures could be set during months when fishers need cash for certain expenses or when sea conditions are conducive to fishing. For example, fishers in Oman usually collect sea cucumbers for six months each year (Conand, 2008) and may object to closures during months of economic need or convenient weather.

How to implement

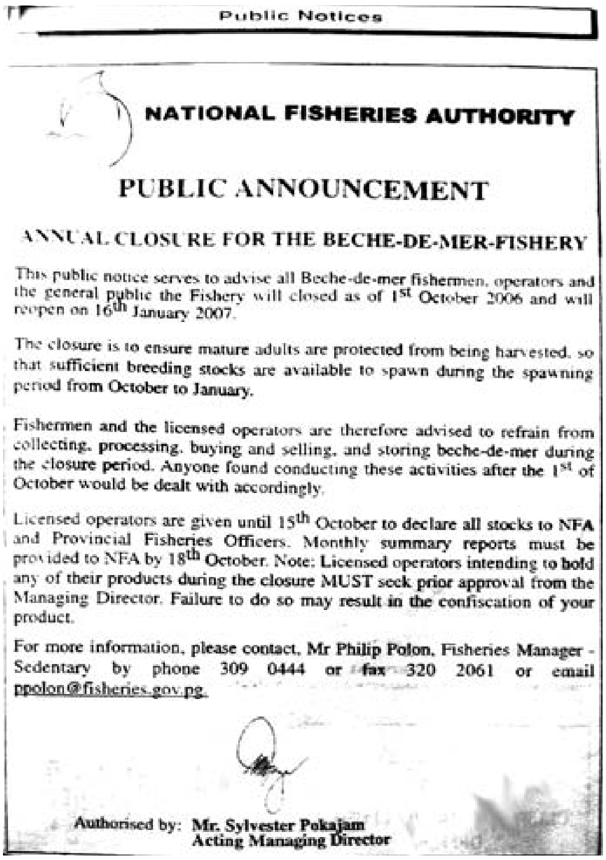
Managers should determine if there are good reasons for imposing temporal closures and consider the potential shortcomings of basing these on spawning seasons. The reproductive cycle of the commercial species should be known. How many months are needed for the gametes in sea cucumbers to become mature and what is the spawning periodicity?

Managers should find out if the season or periods of closure will accommodate fishers' cultural and economic needs (Section 6.1.4). Will the temporal closure prevent fishing in months of favourable seas or at a time when monetary needs are greatest? In addition, find out if there is a demand from exporters or from the market in certain seasons. Are there limitations on processing in certain months? Will temporal closures cause a disruption to relationships with exports, if they expect regular delivery of beche-de-mer? Seasonal closures should be notified to fishers, through meetings, newsletters or news media (Figure 23).

Care should be taken to monitor and ensure that fishing does not intensify in the open season. Temporal closures should be used only in combination with other management measures, such as minimum size limits (Section 8.3).

FIGURE 23

A notice in a newspaper in Papua New Guinea, notifying fishers of the upcoming seasonal closure. It tells why the closure is put in place, that fishers and traders cannot collect, process, buy or sell sea cucumbers in the period and that traders must declare their inventory of sea cucumbers by a specified date



Public Notices

NATIONAL FISHERIES AUTHORITY

PUBLIC ANNOUNCEMENT

ANNUAL CLOSURE FOR THE BECHE-DE-MER-FISHERY

This public notice serves to advise all Beche-de-mer fishermen, operators and the general public the Fishery will closed as of 1st October 2006 and will reopen on 16th January 2007.

The closure is to ensure mature adults are protected from being harvested, so that sufficient breeding stocks are available to spawn during the spawning period from October to January.

Fishermen and the licensed operators are therefore advised to refrain from collecting, processing, buying and selling, and storing beche-de-mer during the closure period. Anyone found conducting these activities after the 1st of October would be dealt with accordingly.

Licensed operators are given until 15th October to declare all stocks to NFA and Provincial Fisheries Officers. Monthly summary reports must be provided to NFA by 18th October. Note: Licensed operators intending to hold any of their products during the closure MUST seek prior approval from the Managing Director. Failure to do so may result in the confiscation of your product.

For more information, please contact, Mr Philip Polon, Fisheries Manager - Sedentary by phone 309 0444 or fax 320 2061 or email ppolon@fisheries.gov.pg.

Authorised by: Mr. Sylvester Pokajam
Acting Managing Director

PHOTO: M. KRONEN, SPC PROCFISHIC

EXAMPLES AND LESSONS LEARNED

Japan

Each prefecture in Japan manages its own fishery. Harvesting of sea cucumbers in most fisheries is allowed during winter and there is a closed season for several months, starting in April. This is because spring is thought to be a spawning season in most of the Japanese archipelago. However, prefectures in Hokkaido, in northern Japan, are an exception. Each fishery cooperative association set down their fishery regulations and regulate their fishing activities on a voluntary basis. For example, Semposhi Fishery Cooperative Association self-regulates their fishery season: from March 1 to April 30 and June 16 to July 20. In another prefecture the fishery is closed from May 1 to June 15.
Source: J. Akamine.

British Columbia, Canada

In British Columbia, the annual *Parastichopus californicus* fishery lasts for about three weeks in October. The open season is set at this time because muscle weight is greatest and the animals have reabsorbed their internal organs (DFO, 2002).
Source: A. Mercier and J.-F. Hamel.

5.6.2 Bans or moratoria

Definition

A long-term cessation or prohibition of fishing, i.e. for periods >1 year.

In contrast with other permanent closures like MPAs or No-take zones, bans or moratoria are temporal closures and cover a large part, or all, of a fishery.

Use

A "ban" or "moratorium", allows sea cucumber populations to recover to levels at which breeding stocks can be dense enough to allow positive per-capita population growth. They are generally set in place where the resource is overexploited to the extent that other management measures would not be enough to allow populations to recover within a satisfactory time frame. Here, a complete ban on further fishing is a necessary admission that the previous management regulations were insufficient.

Moratoria can also be placed at the onset of a developing fishery or where the status of the resource (i.e. abundance and body size frequency) is uncertain. These measures allow the manager some time to develop management plans or to evaluate the current status of stocks. In this case, moratoria are the most precautionary regulation in the interim period of developing other management plans.

Limitations

An immediate consequence of imposing bans can be conflicts with fishers who depend on the resource or have a traditional or historical attachment to fishing sea cucumbers. Social acceptance is low where fishers have limited options to shift to other means of gaining income for their livelihoods. Where there is strong attachment to the resource, a ban can lead to a black market in illegal capture of sea cucumbers (Conand, 2008), resulting in poor processing and wastage because animals are not sold to experienced processors.

A secondary effect of moratoria is increased fishing pressure on other resources. Fishers who collected sea cucumbers may shift to harvesting other marine animals like sharks for the shark fins (Kinch *et al*., 2008b).

How to implement

Sensibly, bans should be imposed as soon as possible after recognizing that stocks are depleted, before critical damage to sea cucumber populations occurs (see Section 2.4). There is a hard trade-off that managers must make between giving fishers ample notice of a forthcoming ban and minimising the cost in recovery time of the resource when fishers exploit stocks at a maximal rate prior to a ban.

Regular communication with fishers will help managers understand how they will cope with a moratorium. If this is yet clear, consult with fishers about the impact on their livelihoods. Implement an education program to ensure that all fishers are aware of the ban, through the media and signposting (Section 6.6).

Likewise, managers should also gather the support and commitment of decision-makers to maintain the ban in the face of public opposition and influence from buyers. Support will be best won if they are well informed about the basic biological need to conserve/restore adequate breeding populations and the costs of delaying the imposition of a ban.

Managers should meet with policy makers to decide the criteria by which a ban can be lifted in the future. This may logically be a certain average density of sea cucumbers in populations of certain species or species-groups on designated reefs to be monitored (Skewes *et al*., 2006). At the onset of the ban and periodically thereafter, stocks should be monitored to document recovery (Section 6.1.2). The data also gives a subjective ground for lifting the ban in years to come, if stocks have recovered to pre-determined levels.

There are two main fields of information needed by the fishery manager before deciding to impose a complete fishery ban; socio-economic impacts and status of stocks.

It would be best practice to determine the dependency that fishers and communities have for collecting sea cucumbers as an income source (Section 6.1.4). Which communities will be most impacted and what other income-generation activities do they have to fall back on if a moratorium is set? Managers may then need to work with other government sectors and NGOs to mitigate economic hardship on communities through development and training in other ways of meeting people's livelihood needs. Sea cucumbers are also important for provincial and/or national revenues through taxing exports, so the likely economic impacts of the ban on these broader economic needs should be gauged and weighed up against the ecological risks to the resource of continued fishing. The likely impacts on other resources should also be considered, as fishers shift their activities to other income streams.

In order to gain social acceptance of bans, managers should seek to obtain data on population densities or abundance over different areas of the fishery (Sections 6.1.2 and 6.1.3). Is a ban needed throughout the entire fishery, or is it really needed just in one sector? Fishers and processors may also argue that animals can still be found and that a complete ban is unnecessary. A simple analysis of data from underwater visual census or trends in CPUE or exports (separated by species) will support the need for such drastic measures. This sort of data also provides a baseline for further monitoring in years after a ban is imposed. It is also useful to consider the approximate densities at which breeding populations need to exist to reproduce successfully, although there is little scientific data available for sea cucumbers (Bell, Purcell and Nash, 2008). A critical question is: at what densities do sub-populations of the different commercial species need to reach to start spawning successfully and replenishing recruitment for the fishery? The answers to this question can be used to place target reference points on population recovery before the fishery is re-opened (Skewes *et al*., 2006; Section 3.4). Similarly, the manager should find out the current size-structure of the population and may want to place a management goal to re-open the fishery after animals measured in the field have attained a certain average size.

EXAMPLES AND LESSONS LEARNED

Australia

The Torres Strait sea cucumber fishery, between the north-eastern tip of continental Australia and Papua New Guinea, experienced declines in several high-value sea cucumber populations after years of commercial fishing. A ban was instigated in 1996–2000 for sandfish (*Holothuria scabra*), but no significant recovery of populations occurred. The ban was extended thereafter, based on follow-up underwater visual censuses. Likewise, fishing for surf redfish (*Actinopyga mauritiana*) and black teatfish (*Holothuria whitmaei*) was banned in the Torres Strait in 2003 after a survey showed that the stocks were overexploited (Skewes *et al*., 2006). There were several lessons from the moratoria in the Torres Strait:

1. Some populations of sea cucumber may take many years to recover, or may not recover at all, after imposing a moratorium. There can be many reasons for the lack of recovery of the populations:
   (1) densities of spawners may be fished too low prior to the moratorium to allow natural recovery of the population;
   (2) the population may rely heavily on larval supply from another population, which may also be depleted;
   (3) recruitment may be naturally infrequent in the target species due to intrinsic factors such as the frequency of spawning in adults, or to extrinsic factors such as certain particular environmental conditions required for successful development or transport of larvae (e.g. seawater temperature, a narrow range in current speed or

direction, or availability of particular microalgae in the water column on which the sea cucumber larvae feed during development in the water column).

2. Fishery managers should take steps to monitor stocks and implement conservative management so that moratoria are not needed, since these measures may not always allow stocks to recover within acceptable timeframes.
3. Placing a moratorium on fishing of one species can increase the fishing pressure on other species in the fishery. Therefore, the need for a moratorium due to overexploitation of one species suggests that fishing strategies are not sustainable, with regard to the resource stocks. Fishery managers should therefore consider setting stricter companion regulatory measures for other, fishable, species when imposing fishing moratoria on a subset of the species in the fishery.

In the sea cucumber fishery of the Great Barrier Reef, in the state of Queensland, *H. whitmaei* became overfished in the late 1990s. A fishery ban (zero TAC) has prohibited the collection of that species since 1998. At that stage, the densities of this species on reefs fished was 20–25 percent of that on reefs protected from fishing. Surveys after the closure showed no measurable recovery up to 4.5 years after fishery closure, suggesting that recruitment in this species is very low. The main lesson, again, is that a measurable, or significant, recovery of stocks after the start of a moratorium may take years or decades. Managers should not expect that all sea cucumber populations will recover quickly after ceasing fishing through a moratorium.

Source: S. Uthicke.

Solomon Islands

The importance of the beche-de-mer fishery to the people of Solomon Islands is revealed by the 1999 census. The village-level nature of the fishery directly impacts the sociological and economic well being of rural coastal communities. At the time of the census, almost 6 000 households had recently been involved in catching and selling sea cucumbers as beche-de-mer. The number of people fishing for sea cucumbers increased greatly during the subsequent years of ethnic tension, when the national systems for exporting copra and cocoa broke down and many rural communities had no other source of income. In the southern islands of Rennell and Belona, where cyclones have recently destroyed plantations, beche-de-mer remains the main source of cash. In the atoll of Ontong Java, beche-de-mer has been the main source of income for decades.

The heavy fishing pressure on sea cucumbers in the Solomon Islands has resulted in a downward shift in species composition of harvests and decreasing catch rates over the last decade. Levels of personal debt of sea cucumber fishers (among others), even in remote village communities, are quite high, mainly to local business entrepreneurs. The great surge in dependence on beche-de-mer by rural communities is reflected in the number of companies licensed to export beche-de-mer, which increased from 9 in 2000 to 23 in 2003.

In December 2005, the Solomon Islands Government declared a ban on the export of beche-de-mer in response to declines in the fishery (Nash and Ramofafia, 2006). The ban made it difficult (or impossible if alternative sources of income were not available) to service these debts (Nash and Ramofafia, 2006). Villages in Isabel Province where a survey was conducted were found to be heavily dependent on beche-de-mer for income, and this was lost when the ban came into effect. A serious consequence of this loss of income was that parents found it difficult to find school fees, particularly those whose children were studying at the secondary level. In the absence of school fees, students would be temporarily removed from schools until fees were paid. Another impact highlighted was the increased fishing pressure on other fisheries, particularly *Trochus* and shark fin. The potential of increased social problems due to lack of income was also raised (WorldFish Centre, 2006).

In April 2007, following an earthquake and tsunami that damaged stretches of coastline in the Western and Choiseul Provinces of Solomon Islands, the Ministry of Fisheries and Marine Resources lifted the ban (Ramofafia *et al.*, 2007). After one year, the cabinet in Solomon Islands had approved the closure of the fishery again (from 1 April 2008). The fishery will remain closed until the interim management plan is finalized and implemented.
Source: J.P. Kinch and K. Friedman.

Indian Ocean
Several countries that have experienced overexploitation of sea cucumbers decided to implement bans on the collection, processing and trade of commercial species. This has been the case, for example, of Egypt and India (Conand, 2008). Despite the official bans, there are often illegal captures. In several countries bans have been abandoned under the pressure of fishers and exporters.
Source: C. Conand.

5.7 AREA-BASED MEASURES

5.7.1 Marine protected areas, including no-take zones

Definition

A marine protected area (MPA) is a portion of the marine benthos and water, with its associated biota, reserved to protect part, or all, of the enclosed environment (Kelleher, 1999).

In the broad context, MPAs are areas managed to enhance conservation of marine resources and many MPA types allow fishing at regulated levels (Lubchenco *et al.*, 2003; Hilborn *et al.*, 2004). They include many sub-classes, defined mainly upon the level of protection and primary conservation goal; e.g. marine sanctuaries, no-take reserves, harvest refugia, multiuse MPAs, marine reserves, ecological reserves (Browman and Stergiou, 2004; Sale *et al.*, 2005). "No-take zones" (NTZs) or "fully-protected marine reserves" are a special class of MPA, which prohibit any extractive activities such as fishing. MPAs and No-take zones are one type of spatial closure.

Use

Although there are few well documented cases, marine reserves are believed to act as a management tool by supplementing fished stocks in surrounding areas (Sale *et al.*, 2005). They may achieve this in two ways:

1) through "spillover", as increasing abundance of juveniles and adults within the MPA will make some animals to move out to surrounding areas where they can be fished, and
2) through larval supply, as a build-up of breeding adults in the reserves allows for more active spawning and fertilisation of eggs, which are carried by currents to settle in fishing grounds.

Marine reserves may be particularly useful for sea cucumbers because effective spawning and fertilisation seems to require high densities of spawners, which may not occur in most of the "open" fishing grounds (Bell, Purcell and Nash, 2008). MPAs therefore aim to provide "insurance" of future fishery recruitment in a "meta-population" by promoting dense breeding populations that can spawn successfully. For sedentary species, like sea cucumbers, spatial management through marine reserves may achieve larger reproductive outputs than global controls for comparable harvest rates (Hilborn *et al.*, 2004).

In some cases, marine reserves may be designed or established to improve ecosystem conservation. Reserves that provide a sanctuary for large or rare sea cucumbers could also improve the attraction of sites for tourism, extending economic benefits beyond fisheries. They also present a useful tool for conserving stocks in multispecies fisheries, common to sea cucumbers (Section 2.3), where it is difficult to control catches of individual species through catch quotas or size limits (Hilborn *et al*., 2004). For example, there are thousands of fishers in various districts of the Philippines who exploit more than 30 species of sea cucumbers (Choo, 2008b). Quotas and rotational harvest strategies would be impossible to regulate, but there are more than 500 MPAs in the country, which should protect breeding populations of sea cucumbers in some locations.

For both science and management, NTZs provide a baseline reference of unexploited populations by which to compare fished populations. They are perhaps the best basis for understanding the broader impacts of fishing on ecological systems, through comparing trends in fish production, age, size and sex structure of the stock, and effects on habitats, with fished areas (Schroeter *et al*., 2001; Hilborn *et al*., 2004). Similarly, they provide important opportunities for research that may not exist in fished areas, e.g. easy access to high-value species and ability to work with dense populations.

Limitations

Implementation may be difficult where the marine reserves are relatively large and exclude users from traditional grounds. The implementation of marine reserves close to communities will probably force fishers to travel further to unfamiliar grounds or reduce the short-term gains of the fishers with limited mobility (Hilborn *et al*., 2004). The loss of short-term gains in fishing may be a main cause for low acceptance. Conflicts can arise among user groups, not necessarily just fishers (e.g. tourism operators, marine traffic and conservationists).

Carving out marine reserves from traditional fishing grounds will naturally cause fishers to collect sea cucumbers elsewhere, which could have undesirable consequences. Fishing effort or catch quotas may then need to be lowered, and this presents an economic loss to the fishery. Protecting 30 percent of available habitat area in marine reserves, for example, may require a reduction in effort of the same magnitude to avoid overfishing. The impact of effort re-allocation may, therefore, be substantial (Hilborn *et al*., 2004).

Active enforcement of reserves near the coast may require a cost to communities in paying surveillance officers or rostering "guardians". Small and numerous marine reserves away from the coast mount the difficulty in enforcement, since fishers can stray within the reserve boundaries beyond sight of guardians on shore. While there are hundreds of MPAs in the Philippines, only 10–15 percent are reported to be effectively managed and many may not serve their purpose to rebuild breeding populations of sea cucumbers because they are too small and illegal fishing is difficult to control (Choo, 2008b).

Another challenge of marine reserves lies in the need to judiciously decide on the areas to be protected. Few reserves have been established just for sea cucumbers – more likely they are designed and sited as refugia for other resources (e.g. predatory fish) or to benefit a suite of biota. The locations of existing MPAs may have been decided by socio-political factors more than bio-ecological factors (Browman and Stergiou, 2004). The locations may not be favourable for species that need them the most. Marine reserves, unless very large, will rarely satisfy the conservation objectives for all species in a multispecies fishery because the various habitats required by the various species cannot all be represented in one reserve (see Section 2.3). This will commonly be the case for tropical sea cucumber fisheries. Likewise, populations at some sites may contribute little to fishery recruitment for various reasons. A network of relatively small reserves has been advocated for sea cucumbers as a means of spreading risks of irregular reproduction or poor siting (Purcell and Kirby, 2006). Managers should seek data on the existing or historical densities of sea cucumbers at various locations and the potential migration of target species as fundamentals to deciding the site and size of reserves. Poor planning of marine reserves, or MPAs, can lead to unfulfilled expectations, the creation of disincentives and a loss of credibility about their role in resource management (Hilborn *et al*., 2004).

A further and most controversial limitation is the difficulty in confirming the effectiveness of marine reserves for improving fisheries (Hilborn *et al*., 2004; Sale *et al*., 2005). Increased abundance or size of animals in the reserve is all good and well for scientists and tourists, but affords no direct fishery benefit. It is the greatly enhanced reproductive potential of such populations (and, to a lesser extent, "spillover" of juveniles and adults) to surrounding fishing grounds that affords marine reserves a place as a fishery management tool, and it is this effect that is difficult to prove rigorously. In the absence of evidence to show their effectiveness for boosting sea cucumber fisheries, the use of marine reserves should be balanced with other management tools (Stefansson and Rosenberg, 2005; Section 8.3).

How to implement

Stakeholders should be part of the process of planning and implementation of marine reserves. A first step should be discussion with stakeholders and biologists on the value and implementation of marine reserves. Decide what class of MPA is best: a protected area that allows some fishing under certain conditions, a no-take zone prohibiting fishing only for sea cucumbers or a fully protected reserve. Some compromises may be needed to keep some sites open to fishing that can be practically accessed, particularly where women and children collect by wading from shore.

Managers should also gauge which areas will be easily monitored by compliance officers or community guardians and which areas will be prone to poaching. It should also be determined who will be in charge of doing the surveillance. The legal framework in which the MPA regulations are situated should be understood and the regulations and penalties should be made as simple as possible (Kelleher, 1999).

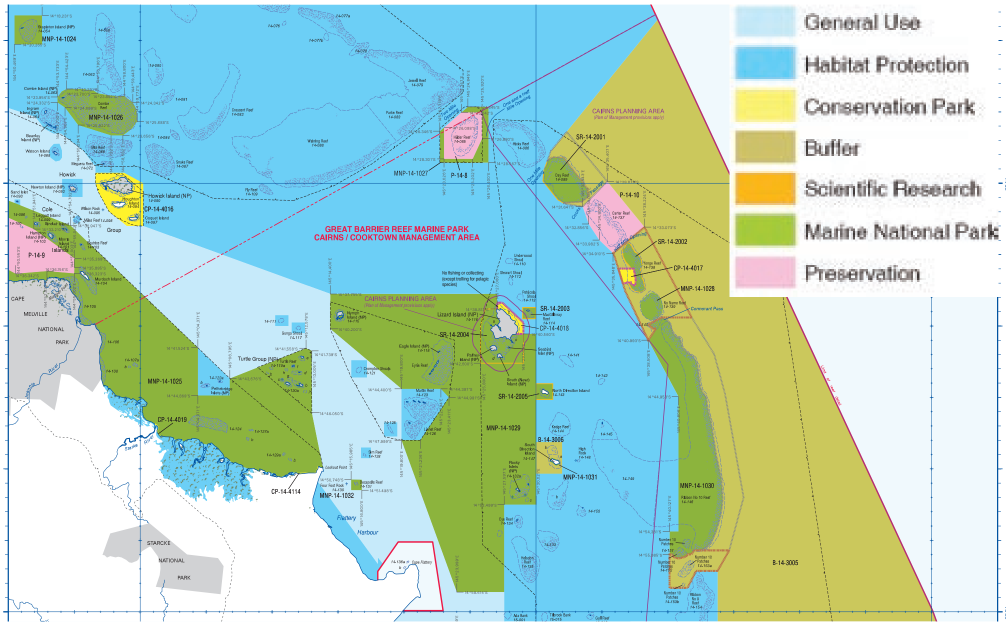
Decide on a minimum size for the reserves. For rebuilding nucleus breeding groups of sea cucumbers alone, these need not be very large (e.g. 50–300 ha) because most species do not appear to migrate long distances. Very small reserves (i.e. <10 ha) will be unlikely to deliver real fishery benefits since they will probably not contain enough adults nor allow for animals to move around without migrating beyond the boundaries where they can be legally fished. Some stocking of wild adults into reserves may boost reproductive output for stock rebuilding (Bell, Purcell and Nash, 2008). More likely, the reserves will be developed with an intention to also protect mobile animals like fishes, in which case they should be considerably larger (e.g. several hundred hectares). For biodiversity conservation of various marine species, larger reserves will be more effective (Sale *et al*., 2005).

Consider a network of multiple marine reserves within the fishery and protecting a significant proportion of the habitat. As an example, the Representative Areas Program (RAP) on Australia's Great Barrier Reef allocated one-third of the total marine park area as no-take reserves (Figure 24). A common target in fisheries management has been to place 20 percent of representative habitat in marine reserves, but recent studies suggest that more than 35 percent of available grounds should be fully protected to avoid recruitment overfishing (Sale *et al*., 2005).

Delineate a large enough area of suitable habitat for sea cucumbers and limit fishing by MPA or NTZ regulations; e.g. limit fishing effort or prohibit fishing. The boundaries should be described or marked clear enough for all stakeholders to identify the reserve borders when at sea. For example, the geographic waypoints of boundary limits can be listed in fishery handbooks and brochures and marked at the sites with buoys or markers. Also, compliance is less ambiguous when marine reserve boundaries are delimited by waypoints joined by straight lines rather than defined by a certain distance from shore.

FIGURE 24

A section of the Great Barrier Reef Marine Park (GBRMP) that is important to the sea cucumber fishery. Licensed fishers are allowed to collect sea cucumber by hand only in General Use and Habitat Protection Zones



Source: Great Barrier Reef Marine Park Authority, MPZ5 Cooktown Detailed Zoning map, with modification.

The key information needs arise from the questions of where to site the reserves, how big they need to be, how closely should they be spaced and how to ensure they will be respected by users. As mentioned, the establishment of the reserves will seldom be divorced from the conservation and fisheries objectives for other resources. Where a network of reserves is planned principally for sea cucumbers, managers need some information on four attributes of the populations to design the network structure:

1) how many separate populations are there in the metapopulation?
2) how are the populations distributed (close together or far apart)?
3) how abundant are the animals in each population? and
4) how variable are the population abundances over time (Browman and Stergiou, 2004)?

One key piece of information needed at the onset of designing a network of reserves is the extent of connectivity among local populations of the target species, a feature about which we know relatively little (Sale *et al.*, 2005). Thus, the fishery manager may need surrogate information to best-guess such processes.

Current patterns should be sought from hydrographic studies to judge the direction that larvae from marine reserves will disperse. Up-current sites will be best in terms of placement for improving recruitment to neighbouring unprotected sites via the reproduction of breeders in reserves. Some larvae may recruit back to the natal site, while others will disperse some distance to rebuild stocks elsewhere (e.g. on fished areas).

How far sea cucumber larvae disperse from natal sites is a question for which we have few confident answers (Section 2.1). Although some tank-based studies tell us about the longevity of larvae, less is know about how sea cucumber larvae act in the water column to mediate their dispersal (Conand, 2006a; Lovatelli *et al.*, 2004). They are far from *passive* particles and are unlikely to behave like the floating beacons used to determine surface currents. Studies assessing the population genetics of sea cucumbers across sites, can provide a surrogate for gauging the likely dispersal potential of larvae in the absence of studies of larvae in the wild (e.g. Uthicke and Benzie, 2000; Uthicke and Purcell, 2004). Such studies also help to understand the geographic boundaries of populations (i.e. stock delineation). Inevitably, management agencies will (in most cases) need to best-guess the dispersal potential of larvae from reserves to decide how close they should be spaced in a fishery to furnish recruits to all target fishing grounds. Conservatively, a network of reserves would include breeding populations spaced closer than the maximum distance that larvae can commonly disperse.

At the level of individual reserves, managers then need information to know what habitats they should include and how big they need to be. Ecological studies on commercial species should be reviewed. How far can they move in a lifetime and what habitat do they most seem to prefer? Multivariate analyses on the relationship between abundances of individuals and biotic and environmental variables will indicate the affinities of species to various habitats. Mark-recapture and short-term movement studies will be the basis for understanding the movement potential of the animals. Such information allows the manager to suitably site the reserves in good habitats and set them to be large enough such that most of the animals do not migrate beyond the boundaries where they can be legally removed by fishers – a phenomenon known as "spillover" (Purcell and Kirby, 2006). After all, it is the build up of sufficient densities of breeders inside the reserve that allows it to perform its function in fisheries management.

After the planning and declaration of marine reserves, managers and stakeholders will want to know whether breeding populations have built up to at sufficient densities to expect significant reproduction and larval export to neighbouring fishing grounds. In a depleted fishery, this may take many years. In this regard, it is useful to conduct some underwater field surveys to describe the species abundance, diversity and habitats within the reserve (see *Examples and lessons learned* below; Section 6.1.2). These data provide a baseline for future reference. Data exists for few species on the threshold densities or distance between sea cucumber adults at which reproduction becomes broadly successful (Babcock *et al*., 1992; Shepherd *et al*., 2004). The required densities of adults for effective reserves will naturally vary among species. Some scientists have postulated that, as a minimum for successful reproduction, tropical sea cucumber populations should be denser than 10–50 individuals ha^{-1} containing some groups of breeders <5–10 m apart (Bell, Purcell and Nash, 2008). These threshold densities currently remain as "best guesses", even by experienced ecologists, in the absence of empirical studies on fertilisation kinetics and mating behaviour of target species.

EXAMPLES AND LESSONS LEARNED

Malaysia

Malaysia has a number of marine reserves, which are not especially for sea cucumbers but for fish and invertebrates generally. There are five marine parks comprising a total of 40 islands in Peninsular Malaysia and Labuan Federal Territory in East Malaysia and three marine parks in Sabah in East Malaysia. In addition, there are three Fisheries Prohibited Areas (FPAs) in Sarawak in East Malaysia, two in Melaka and one in Negeri Sembilan located in the west coast of Peninsular Malaysia. The FPAs are under the administration of the Department of Fisheries (DoF) and fishing is prohibited in waters within two nautical miles from the outermost points of the islands.

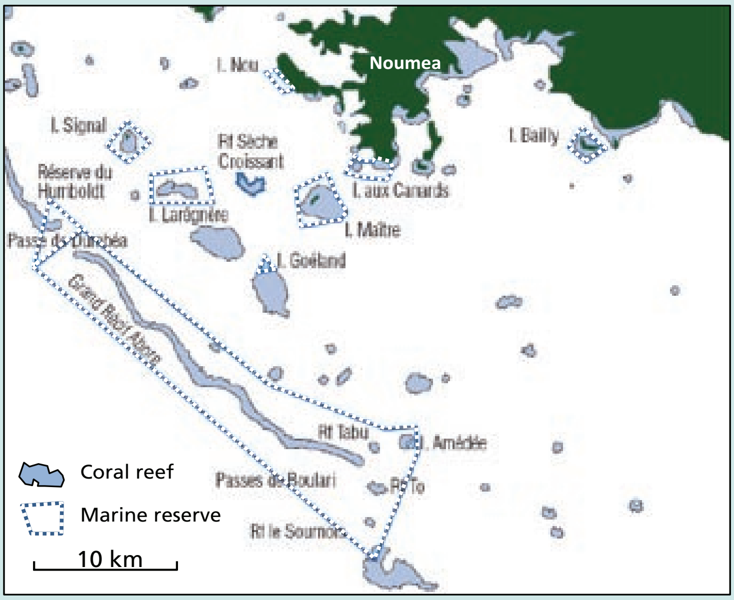
Generally, the marine parks in Peninsular Malaysia are well protected from illegal fishing and fishers tend to keep their distance for fear of being spotted by officers based in the parks. A survey conducted by Coral Cay Conservation (CCC) indicated little poaching of sea cucumbers in the Redang Island Marine Park, which contributed to the highest overall invertebrate abundance (Comley *et al.*, 2004). In Peninsular Malaysia, poor people are also not financially desperate enough to gather sea cucumbers either legally in the coastal areas or illegally in marine parks (Butcher, 2004). However, the marine parks in Sabah have a large population of illegal immigrants and poor fishers, and incidences of fishing with illegal methods (e.g. dynamite and cyanide) have been reported quite frequently and enforcement officers have stepped up efforts to prevent poaching.

The system of national marine parks and the fishery zoning regulations in Peninsular Malaysia have met with some successes and Malaysia's national coral reef management efforts are some of the most successful in Southeast Asia. Malaysia also has effective fisheries regulations, separating different user groups to different fishing zones thus helping to reduce conflicts and overfishing. Management of marine parks in Malaysia can be further enhanced by strengthening state capacity especially in East Malaysia, improving the integration of state and federal authorities to achieve sustainable coastal development and addressing destructive fishing in East Malaysia.

Source: P.Z. Choo.

New Caledonia, France

There are a number of marine reserves in New Caledonia for broad fishery and conservation purposes, but these represent a very small percentage of the available areas for fishing sea cucumbers. Some of them seem to be working effectively as spawning refugia for sea cucumbers because adult populations in the reserves are now relatively dense compared to populations in neighbouring fishing grounds. However, more reserves are probably needed (e.g. 20–30 percent of habitats) to give the best insurance against the potential loss of breeding capacity in fished areas. Most of the reserves cover several hundred to several thousand hectares and most are in the Southern Province, where the human population is greatest (see map below). In many cases, the reserve boundaries surround one entire reef, with a central small island, and bordering lagoon seabed. Most appear to be well respected by fishers.



Above: marine reserves in New Caledonia are most numerous in the vicinity of the capital city, Noumea. In this area, the no-take reserves form a network of sanctuaries for sea cucumbers and other biota, on nearshore, lagoonal and barrier reefs.

Source: ISEE, New Caledonia, with modification.

One, relatively long-established, reserve (Ilot Maître; see map) has an impressive abundance and diversity of sea cucumbers; over 9 000 ind. km^{-2} of species of high and medium value (across five habitats) and a total of 19 species recorded (Purcell, Gossuin and Agudo, 2009a). However, the proliferation of sea cucumbers on the reef flat at that site seems to have stunted the growth of many species.

The only marine reserve in the Northern Province is large and includes mostly coastal seagrass beds and mangrove habitats. Although the area was previously fished, probably for more than a century, densities of sandfish (*H. scabra*) in that reserve are now quite high (site density varying from 81 to 244 ind. ha^{-1}). This at least shows that populations of some species can build up in reserves to represent important breeding groups for supplying larvae to neighbouring fishing grounds. Unfortunately, there have been recent cases of poaching, which were brought to the national courts.

Importantly, although long-term reserves in New Caledonia tended to have greater sea cucumber populations than reserves established recently, they did not always lead to a huge build-up of sea cucumber breeding populations (Purcell, Gossuin and Agudo, 2009a). Some recently established reserves did not yet have dense populations of sea cucumbers. The lesson from these comparisons is that reserves may relieve fishing pressure so that dense breeding populations of sea cucumbers can build up, but the site characteristics will play a large role in this and it may take many years or decades for populations to become dense. Therefore, a network of many reserves is needed in a fishery to account for the fact that some sites may not be ideal for sea cucumbers.

The study also showed that species richness of the sea cucumber communities was significantly greater on mid-shelf reefs within the lagoon than on barrier reefs. The lesson in this example is that more marine reserves should be placed on lagoon reefs for conservation purposes. Some barrier reef reserves are also needed to protect some breeding populations of species not often found at lagoonal sites.

Source: S.W. Purcell.

Solomon Islands

Stock surveys of sea cucumbers at the Arnavon Island Marine Reserve (AIMR) in the Solomon Islands were completed three times before, and three surveys after the declaration of the Islands as a conservation area (AMCA): January–February, April–May and July–August 1995 (before); and September 1998, January–February 1999 and April 1999 (after) (Lincoln-Smith *et al*., 2000).

PHOTO: GOOGLE EARTH

PHOTO: M. LINCOLN-SMITH (CARDNO ECOLOGY LAB)

Left: Arnarvon Island in foreground. Right: a researcher on SCUBA conducts a belt-transect survey for sea cucumbers on a shallow reef in the Arnavon Islands.

After the islands had been protected by the 82 km^2 reserve, surveys at the AMCA revealed that the establishment of the conservation area had not caused a significant increase in the number of all holothurians, but it may well have prevented declines in abundance that was evident elsewhere in the region. This suggests that over this short time period, the AMCA maintained populations but was mostly ineffective at enhancing them. The lesson may be that it takes many years, perhaps decades, for some species of sea cucumbers to rebuild breeding populations inside marine reserves. Abundance data indicated that sea cucumber numbers declined on average by one-third outside the Arnavon group, but remained relatively similar in the protected area from before to 3+ years after the declaration.

An exception was the abundance of amberfish, *T. anax*, with more individuals within the AMCA relative to surveys of the surrounding areas, from before to after declaration. The ratios of observed proportional differences between AMCA and control areas from before to after declaration were generally quite small, suggesting a relatively small effect after 3 years of closure. The more notable response was that the abundances of white teatfish, *H. fuscogilva* increased in the AMCA relative to fished (control) areas, but this result was statistically non-significant.

One cannot exclude the possibility that the AMCA caused a redistribution of harvesting effort to surrounding areas, including the controls areas that were surveyed. Declaration of marine protected areas without any changes in the level of activity of fishers would result in increased activity in the fishery outside the reserve. In fact, if this was the case, then the declaration of areas of insufficient size as protected, could accelerate declines across the fishery, so overemphasizing the benefits of the reserves. Managers need to ensure there is sufficient spawning mass across the fishery, to ensure the sustainability of harvests.

The study at the AMCA shows that the time needed for a species to recover from harvesting might be longer than expected, and will depend on factors such as generation time, severity and extent of previous fishing, local oceanographic features, location and size of the reserve, infringement of the reserve and availability of nursery and adult habitat. This study suggests that it may take many years to restore each of the target species to preharvest levels, assuming the reserve is an effective mechanism for mediating fishing.

Source: K. Friedman and J.P. Kinch.

5.7.2 Rotational harvest closures

Definition

A periodic temporal and spatial shifting of fishing effort, in a systematic way among demarcated fishing grounds.

Use

The ethos of rotational harvest closures is to allow populations to recover in some fishing plots for a couple years, while fishing is shifted to other plots. For example, the fishing ground in front of a community is partitioned into four plots and fishers are only allowed to collect animals in one plot each year, which is then shifted to a different plot the following year, and so on. It is a concept with origins from rotational harvesting of agricultural crops.

An assumption is that the same areas will be fished again after some time or after reaching some certain state. Where populations can recover fairly quickly, then it is possible for rotating fishing effort over relatively short time intervals, e.g. two to three years. In this way, rotational closures allow the sizes and abundance of sea cucumbers in the closed plots to recover for a couple years before being fished again. Rotational closures can also be used to reduce costs of field surveys to estimate stock size because the fishable area for any given year are only a fraction of the whole fishery (see *Examples and lessons learned* below).

Rotational closures are a novel approach in sea cucumber fisheries and their success as a management tool is yet to be proved.

Limitations

Rotational closures have received support in some industrial-type sea cucumber fisheries with high technical capacity, like those in western Canada and north-west United States of America (Humble, Hand and de la Mare, 2007; Hamel and Mercier, 2008a), and on the Great Barrier Reef, Australia (Kinch *et al*., 2008a) (Section 2.3). This may be appropriate where user rights are well defined and respected, but the system will quickly breakdown elsewhere. In addition, the demography and growth of some species may render them unsuitable in some cases (see Purcell, Gossuin and Agudo, 2009a) (Section 2.1).

A principal assumption of rotational harvest closures is that population numbers and animal sizes will recover relatively quickly, e.g. over a couple years. As reviewed earlier (Section 2.1), some species appear to grow slowly and have relatively slow rates of recruitment. To have confidence in rotational closures, managers should verify that the commercial species in the fishery are likely to have fast growth rates and regular annual recruitment. This management tool may therefore be useful for species with fast rates of recovery after fishing but inappropriate for populations with slow turnover or in multispecies fisheries (see Sections 2.1 and 2.3).

The rate of exploiting stocks, per unit of fishing ground, can also rise sharply with rotational closures. This could occur where the fishing ground is divided into multiple units and fishers allowed to collect sea cucumbers only in some of them, instead of across all possible fishing grounds. Fishing impacts must be, therefore, well regulated through imposed, or *de facto*, quotas or effort limitation for each fishing ground (see *Examples and lessons learned* below). Related to this constraint, the different fishing plots will probably not have equivalent population sizes of animals – so the impact of a given fishing rate will be harsh on those with smaller population sizes. Managers should take steps to find out if population sizes vary greatly among plots so those with relatively sparse populations are not over fished. Some safeguards also need to be set so that populations in fished plots will not be depleted below critical levels. These types of provisions place a burden of research and monitoring on the fisheries agency or local management institution.

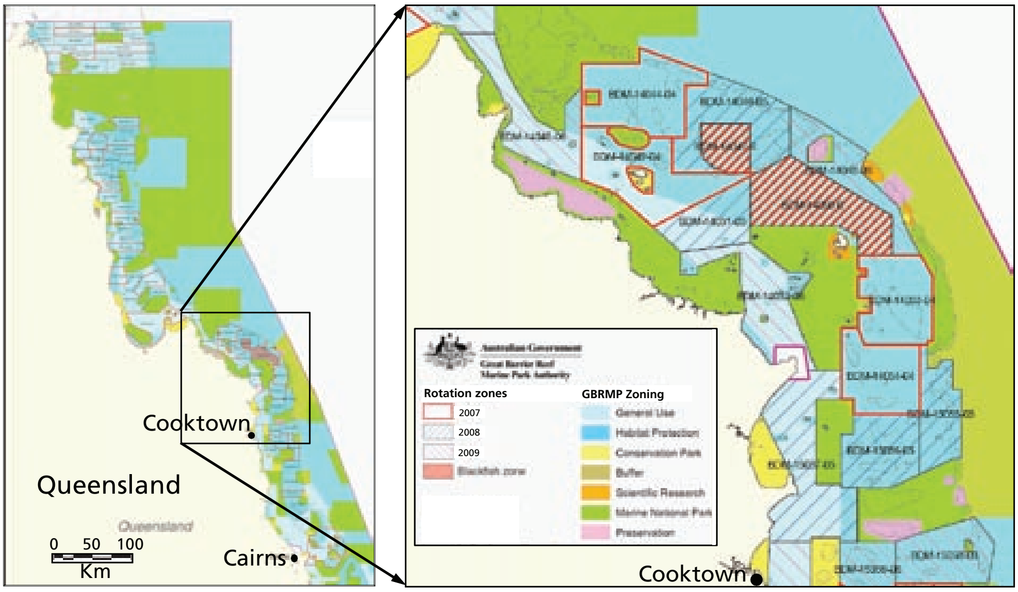
In small-scale fisheries, fishers with limited access to distant or deep fishing grounds may be disadvantaged by rotational closures in years when nearby or shallow fishing plots are closed. Many fishers in the Philippines, particularly women and children, glean for sea cucumbers on shallow reef flats and lack the gear to fish in deeper plots (Choo, 2008b). Fishers may traditionally have access to a small area in front of a village, so multiple plots would become unrealistically small. Compliance is a problem in these situations, as it is difficult to verify if sea cucumbers were collected from open plots or poached from closed plots, particularly if plots are close together.

How to implement

Rotational closures can only be implemented if sociological and biological conditions in the fishery allow it. An ecosystem approach to fisheries in this regard would include a review of stakeholder needs and constraints and the biological potential of the fished species to adapt to periodic fishing pulses (Section 3.3). Sociological studies or meetings with stakeholders should be conducted to appraise whether rotational harvesting of plots can be well understood and respected by fishers and other groups with vested interests in the resource (Section 6.6). Importantly, the current access rights of fishers and other stakeholders should be determined. The constraints fishers have to getting to sites or accessing the resource in different plots should also be understood (Section 6.1.4).

FIGURE 25.

Maps showing plots for a rotational harvest strategy in the sea cucumber fishery of the Great Barrier Reef, Queensland, Australia, for the years 2007–2009. Sea cucumbers in the demarcated plots (right) can be fished by licensed fishers in the designated year only and then the populations are excluded from fishing for 2 years. The blackfish (*Actinopyga spinea*, *A. miliaris* and *A. palauensis*) zones are controlled by quotas and are not part of the rotational zoning



Source: Great Barrier Reef Marine Park Authority, Zoned Sea Cucumber Fishery Waters – Northern GBR – Detailed Zoning map, with modification.

The fishing grounds for each fishery unit need to be divided into a logical number of plots. For example, for a 3–year rotational harvesting strategy the fishing grounds could be zoned into 3 plot types, of which plots of any one type are fished each year (Figure 25). The decision depends on the administrative resources, compliance issues and the needs of fishers. Although more plots increase the administrative work, there may be advantages to opening multiple smaller plots.

The size of plots does not need to be similar. It may be sensible to partition the fishing grounds based on population sizes of sea cucumbers in the resultant plots rather than on the surface area of suitable habitats. For example, larger plots are assigned where populations are at lower densities and vice versa.

The number of years for cycling the fishing in plots should be determined from biological data on recovery times for animals to grow to larger size and time needed for population densities to recover to levels well above those needed for successful spawning. The periodicity of the rotational opening of fishing plots will probably be in the order of 2–10 years. Resource managers should either ascertain or acquire estimates of how many years populations would take to recover from being fished down to a certain density. This requires some understanding of the regularity of recruitment and population turnover. Likewise managers should have information on the average growth rates of juvenile and small adults of the species being fished (see Section 2.1). Demographic and life-history estimates of this nature are generally pre-requisites for using rotational harvest strategies for sea cucumbers because they inform the manager of the appropriate time intervals to rotate fishing among plots.

Where managers have sufficient technical capacity and data on life-history and population dynamics of fished species, rotational harvest strategies can be determined through mathematical modelling (Humble, Hand and de la Mare, 2007). Most fisheries will lack the basic data to prescribe rotational closures with any scientific confidence. Alternative management measures should then be considered or managers should apply best guesses for biological parameters or proxy data from similar species to design the rotational strategies and adapt them as reliable data become available.

Some field surveys should be undertaken to estimate the abundance or densities of each commercial species to be fished in plots (Section 6.1.2). For example, dive surveys are conducted prior to the fishing season in rotational plots in southeast Alaska, United States of America (Hamel and Mercier, 2008a). These measures may also need to be monitored, possibly during fishing, and at least to verify recovery of populations in plots after fishing.

EXAMPLES AND LESSONS LEARNED

Alaska, United States of America

Current sea cucumber management measures in Alaska, using rotational harvest strategies, have provided sustainable harvests and consistent quality of *Parastichopus californicus*. Divers rotate their effort between 16 harvest areas, some of which are divided into more than 20 sub–areas in an effort to maintain sustainability throughout the fishing grounds (Ess, 2007).

In southeast Alaska, each fishing area operates on a three year rotation and is harvested (each three years) at a rate of 6 percent per year (Bo Meredith, Alaska Department of Fish and Game, personal communication). Thus, in years of harvest, approximately 18 percent of the surveyed biomass is removed, then the area is left unfished for the next two years. Before the sea cucumber fishing season opens on the first Monday of October, dive surveys are conducted in each of the harvest areas. Two other conservative measures are added into the development of the harvest rate managed by the Alaska Department of Fish and Game (Woodby, Smiley and Larson, 2000): 1) a 50 percent reduction to account for the possibility that the model assumption is incorrect; and 2) an approximate reduction of 30 percent to account for sampling error in the assessment survey. A third safety measure consists of counting only sea cucumbers occurring at depths above 15 m in the population size estimates.

Underwater surveys are conducted by Department divers prior to fishery openings in each management area. In this example, the 3-year rotation was put into place as a means of reducing management costs for surveys and management and not as a method to allow stock rebuilding between harvests. Additionally, a minimum biomass density threshold of 1 kg of sea cucumber per linear meter of shoreline is set for the fishery. The plan also identifies 20 sub-areas closed to commercial sea cucumber fishing to provide for subsistence harvests and research sites.

Source: A. Mercier and J.-F. Hamel.

Sagay, The Philippines

The 32 000-hectare Sagay Marine Reserve in northern Negros Occidental, is a marine protected area (MPA) managed by the Sagay Marine Reserve-Protected Area Management Board (SMR-PAMB), a multisectoral body co-chaired by the City Mayor and the Regional Technical Director of the Department of Environment and Natural Resources.

While there are about 10 commercial species of sea cucumbers found within the MPA, the fishery regulation is specific to *Phyllophorus proteus* (locally called *bola-bola* meaning ball-shaped) which is the most abundant. Rotational closures of harvesting *P. proteus* started in 2004, were then suspended in 2005, and resumed the following year up to the present. The implementation of this measure consists of the following:

(1) the SMR-PAMB determines the harvest season, plots (areas) and fishing time; the maximum number of boats per season; the minimum size limit of the sea cucumbers; and, the maximum number of *N. proteus* per season;
(2) only boat owners who are local residents with duly registered boats can bid for the harvest; the highest bidders get the permit to harvest the sea cucumber for one season;
(3) the Licensing and Permit Section and the Coastal Law Enforcers (Bantay Dagat Team) monitor the catch per boat at a duly designated weighing station within the Reserve; and
(4) a price "floor" is established and shared among the City (80 percent), Barangay (smallest political unit) (10 percent) and the Sagay Marine Reserve (10 percent). The profit of boat owners and fishers comes from the difference between the market price and the price floor.

Some measures of social success are:
(a) increased stewardship of the resource as a result of making local residents the watchers and guards of the Reserve, requiring them to register their boats, to obtain permits and then giving them the preference to bid;
(b) better governance brought about by the multisectoral monitoring group and the full implementation of the regulations of the reserve led by the SMR-PAMB with support from the city officials;
(c) sense of economic equity in the practice of sharing profit based on consensual agreement and the premium for resource use; and
(d) increased awareness of the community about sustainable fishing of the resource by practicing rotational closure and harvest.

Despite the temporal and spatial respite offered by the rotation of the harvest, data on the first 3-year catch showed a declining harvest. The SMR was quick to acknowledge that their management plan and some of their technical decisions have to be reviewed based on sound data. Nonetheless, the SMR was the first runner up for the 2007 Best Managed Reef in the country given by the MPA Support Network.

Source: T. Dacles and R. Gamboa.

Great Barrier Reef, Australia

In the state of Queensland, the sea cucumber fishery on the Great Barrier Reef is broken up into 154 fishing sectors, each averaging 548 km^{-2} in area (roughly 160 square nautical miles each). These sectors are divided into three fishing years for any 3-year cycle (see Figure 25). The rotational sectors occur only in open fishing areas, exclusive of the existing marine reserves in the Marine Park.

During the permitted year of fishing in the 3-year cycle, each sector can only be fished for 15 days per year. This management measure is implemented by the fishing industry and agreed to in a Memorandum of Understanding with the management agency, The Great Barrier Reef Marine Park Authority. Also, no more than four divers are permitted to be in the water at any time from a fishing vessel. The plots are allocated to the fishing licence holders (of which there are just two in this fishery), who are then allowed to trade them for convenience of location. The agreed trades are then conveyed to the management agency. Thus, each fishing business has exclusive rights over any particular rotational sector, providing an incentive to harvest for long-term productivity.

Surveillance and enforcement of such a management scheme can be difficult. In the GBR this is possible; however, since all fishing vessels are equipped with vessel monitoring systems (VMS). This system relays precise information about boat locations to management agencies to show where the vessels are located, which is matched against logbook records of fishing days at each rotational sector.

It should be noted that rotational harvest strategies are a relatively new idea in sea cucumber fisheries and there are no data available to show whether this approach is sustainable, or not. At present, it seems to be working relatively smoothly on the Great Barrier Reef, owing to three factors: 1) the VMS system, which allows monitoring of fishing locations and durations for each licensed boat; 2) there are few fishing businesses in that fishery (only two businesses hold all the licences), so the process of allocating plots and reaching agreement among fishers is simplified; and 3) the rotational sectors are relatively large, such that fishers cannot easily deplete the resource within each sector during the year of rotation. A final lesson is that the rotational scheme can operate without needing to be set in legislation – in this case, a simple Memorandum of Understanding between the fishers and the management agency sets the conditions for the scheme.
Source: S. Uthicke and S.W. Purcell.

5.7.3 Territorial user rights in fisheries

Definition

The provision to certain users, e.g. fishers or sea ranching proponents, of exclusive privilege to exploit certain resources and/or access certain areas of sea bed.

Use

In the words of R.E. Johannes (1981) on secured access to fishers: "Where such tenure of marine fishing grounds exists it is in the best interest of those who control it not to overfish […]. In contrast, where such resources are public property, […] it is in the best interest of the fisherman to catch all he can. Because he cannot control the fishery, the fish he refrains from catching will most likely be caught by someone else."

Although leading fisheries scientists have proposed differing solutions for turning the tide of depleting stocks, there is solidarity over the need for managers or institutions to afford fishers with predictable and exclusive access to the resources, whether in the form of rights to specified proportions of the allowed catch (i.e. ITQs, Section 5.4) or to tracts of fishing grounds (Hilborn, 2004; Pauly, 2008). Place-based, or "spatially-explicit", tenure systems have been used especially for sessile, sedentary or benthic organisms (Hilborn, Oresanz and Parma, 2005; Hilborn, Parrish and Litle, 2005; Defeo and Castilla, 2005). Sea cucumbers fit squarely into this category. Territorial user right in fisheries (TURFs) are one form of exclusive access to defined portions of sea bed for harvesting sedentary or sessile animals, which may be granted to fishers or fishing cooperatives (Hilborn, Orensanz and Parma, 2005). TURFs can provide a potent incentive to the sustainable management of sea cucumber populations in many cases. The rights over areas could be at the local, national, regional or international level. At a local level, Customary Marine Tenure in Melanesian countries is a traditional system giving exclusivity to certain tribal or family groups or families (Kinch *et al*., 2008a).

Another benefit of TURFs is that resources can be best allocated to those people who need it or those complying with management regulations. Resource access privileges, or "rights", allow fishers or fishing groups/firms to plan their operations (Pauly, 2008). They bestow more accountability and ownership over stocks and their sustainability than open access scenarios because the changes in population abundances over time can be accredited to the rights holders. In this way, place-based access rights minimise the problem of fishers racing to collect all animals in an area or taking small animals because "if they don't someone else will"; the so called "tragedy of the commons" (Hardin, 1968). Enforcement of fishery regulations also becomes easier because the users of each fishing ground are well known.

Limitations

With all of the benefits of TURFs or other place-based access rights, it is a shame that a place-based access right is not an appropriate tool in all situations. When territorial rights are established in open access fisheries, conflicts can naturally erupt. In some cases, it is very difficult for people to respect the access rights. Users can become angry over the way in which rights were given, or because the areas of exclusive access are overstepped or ambiguous. Modern governments, changes in lifestyles and imposing religious doctrines, have in cases reduced the access rights and lead to free-for-all access (e.g. throughout most of the Philippines). Poaching can occur in areas allocated to other people-groups through dislocation or jealousy.

TURFs seem most easily implemented and maintained in fisheries with relatively few fishers or fisher groups. The demarcation of fishing grounds and administrative work to define them coherently and survey infringements can be arduous (Orensanz *et al*., 2005). This may be a significant limitation in cases where institutions lack technical and/or human resources. Human population size and fishing pressure are so high in some places that it is very difficult, or unfeasible, to partition fishing areas into a large number of small plots (e.g. in Indonesia or the Philippines) (Figure 26; Section 2.3).

In some cases, giving territorial access rights to users may not lead to greater sustainability of the resource. An assumption is that access rights like TURFs will create incentives to reduce fishing effort. Management authorities should, therefore, appraise whether the provision of access rights to fishers is likely to lead to reduced effort. That is, the provision of access rights must lead to better ownership and stewardship of resources by the fishers for this measure to be successful.

How to implement

The immediate questions in assessing the utility of TURFs concern the choice of who gets access and who is left out, and whether plots of fishing grounds can be sensibly partitioned among the users and demarcated. Managers should also know or seek information on the human populations, their behaviour and whether access rights are culturally compatible (Section 6.1.4).

The decision of who gets territorial access rights and who does not is often predicated on knowing who the current fishers are and who most deserve them. Traditional or cultural links attachments to the fishing grounds or resources are important considerations. The decision process should ensure that current users, with valid needs for harvesting the resource, are not marginalised through the access rights. Decisions can also be based on historical behaviors; e.g. which of the fishers have

FIGURE 26

Left: fishers gleaning sea cucumbers and other invertebrates on a sandflat in the Philippines. The sheer number of resource users makes access rights for individuals a difficult proposition. Right: a day's gleaning catch (2–3 hours) off a small coastal village in southern Philippines

PHOTO: R. GAMBOA

PHOTO: R. GAMBOA

respected management measures in the past? The management agency must also decide if the user groups pay for the access rights and how much. Commonly, there is an initial or annual license that bestows and defines the fishing rights.

Governments themselves will normally incur a cost in administering and establishing the spatial boundaries or resource-specific privileges in allocating TURFs. The planning phase in allocating TURFs should examine, or collect, data on the abundance and distribution of the resource (Section 6.1.2). Once granted, government or local management agencies will need to invest time and resources in enforcement at sea to ensure that users are not breaching boundaries set by the TURFs (Section 6.6).

To implement territorial use rights, the socio-economic and legal structure of the fishery should firstly be known (Sections 6.1.4 and 6.2.1). This step may reveal that authority to give access rights to users is best devolved at a local level through community-based management or organised alongside communities through co-management. As noted above, the managing body should consider traditional user rights, equity and enforcement issues. In industrial fisheries, a randomised allocation of fishing areas to fishers is an alternative to formal planning and may avoid conflicts with users about the fairness of the rights allocation process.

Assigning TURFs to fishers, fisher cooperatives, or fishing communities can be a rather elaborate process (Orensanz *et al*., 2005). The available fishing grounds within the jurisdiction of the management institution may need to be mapped to define habitat types and to estimate the abundance of target sea cucumber species. Consultant ecologists, NGOs or regional development agencies may be able to assist in this process. There will likely be certain fishing grounds to which fishers have existing (sentimental, traditional, or cultural) attachment and other grounds that are less desired. The fishery manager, or an assigned impartial body, will need to mediate the decisions about who gets what, in a transparent and equitable way. In some other fisheries, rights to certain fishing grounds are allocated to fishers through an auction process (Hilborn, Parrish and Litle, 2005). In comparable invertebrate fisheries in Chile, TURFs are assigned for a short number of years and renewable upon compliance with the regulations (Orensanz *et al*., 2005). Within Australia's Great Barrier Reef Marine Park, TURFs for sea cucumber fishers are also broken into rotational harvesting zones (Kinch *et al*., 2008a).

EXAMPLES AND LESSONS LEARNED

Japan

Japanese holothurian fisheries are doubly regulated in the existing fisheries law (practiced since 1949) by the "fishery rights" and the "fishery permit" systems. The "fishery rights" system was established to maintain order and adjust fishery operations in public waters. The system applies to *common fisheries* like those for sedentary animals such as holothurians. Only local fishery cooperative associations are eligible for the right. Thus, no one except the fishery cooperative association members can collect sea cucumbers for any purposes.

However, if a member of a fishery cooperative association wants to employ a heavy gear, such as dragnet, in the capture of sea cucumbers he needs to apply also for a "fishery permit". This is because the dragnet fishery for holothurians is regulated under the Governor Permitted Fishery (GPF). The permit is valid for ten years and to renew it fishers are required to discuss with the prefectural government the fishing-ground plan. For conservation reasons, it is more difficult to apply for new permits than to renew old permits.

Source: J. Akamine.

Australia

In the state of Queensland, the sea cucumber fishery on the Great Barrier Reef is divided into 154 fishing zones of approximately 100 to 150 nautical square miles. Access to commercial fishing in this fishery is limited to just 18 licences. However, these licences are in the hands of two companies.

The Torres Strait fishery, between the northern tip of Queensland and Papua New Guinea, also has a restriction on the number of commercial fishers. Licences are issued only to Traditional Inhabitants of the Torres Strait.

Source: S. Uthicke.

The Philippines

An experimental sea ranching project is underway in the Philippines, coordinated by scientists from national universities, the Bureau of Fisheries and Aquatic Resources (BFAR) and the WorldFish Center, through funding from the Australian government. Its objective is to test the feasibility of village-based sea ranching of sandfish (*Holothuria scabra*) by producing thousands of juveniles in hatcheries and releasing them into sub-tidal seagrass beds allocated exclusively to communities who harvest the sea cucumbers once they reach market size.

Fishing communities at several of the project's sites generally have de-facto rights over the adjacent shallow seabeds. But poaching and the temptation to harvest small sea cucumbers are potential problems that need to be resolved by formal access rights. The communities apply for permits from the local municipal government and village council to have exclusive access to inshore plots (5–10 ha) for the sea ranching. The granting of access rights requires public consultations on proposed sea ranching, implementation mechanisms and arrangements including sharing of costs (e.g. labour, guarding of area) and benefits (i.e. harvest and access rights). Enforcement of the size limits and access to the managed areas is at the local level – the Municipal governments deputise fisheries wardens from communities to do the enforcement.

Source: S.W. Purcell.

Pacific, Polynesia

In Tonga, a large island group in the Polynesian Pacific, problems of overfishing have been exacerbated by a lack of local ownership of reef resources, enabling commercial collectors to harvest even close to local communities.

In 1875 Tonga's first constitution removed chiefly privileges, placing control in the hands of the Crown/State and opening access to all Tongans. At this time economic pressures were such that communal and extended family activity was commonplace, but was not a major issue, and even as late as the 1920s, marine area ownership was still reportedly strong. In Tonga today, open access has replaced traditional ownership arrangements, and some commentators believe the Crown/State may be less able than local communities to regulate the use of marine resources (Malm, 2001). Urbanization, development of the cash economy and increases in commercialisation of marine resources, coupled with changes in life styles have exposed flaws in today's open access system of marine resource management.

One example of the direct consequences of Tongan law was recounted from an island in the Ha'apai group, where fishermen knew that increasingly intense commercial exploitation of invertebrates was too taxing on the lagoon resources to be sustainable, but felt that there would be no point in reducing the intensity of exploitation because the resources could be exploited by fishermen from other islands in the district. This example of the effects of open access on common property under today's economic environment may not have had the same outcome under the social conditions faced 50+ years ago.

State ownership in Polynesia has not always resulted in a breakdown of local controls. In American Samoa for example, where the American military governor declared all submerged lands and reefs to be a part of the public domain, American Samoans continued to claim exclusive fishing rights to their adjacent reefs (Hill, 1978). Similarly, in neighbouring Samoa (formerly Western Samoa), the reef and lagoon areas are owned by the State, but customary ownership by the village of local fishing rights is recognized and remains firmly entrenched (Fairbairn, 1992). One must also note that despite these controls, overfishing has also occurred in Samoa, especially in urban and populated areas, even with customary ownership in place.

Whether local reef ownership across the ages was due to a "conservation ethic" or just inter-groups rivalry, it has generally been recognized as having some limiting effect on the rate of exploitation. In the last 5–10 years, the state fisheries agency in Tonga has been re-developing local area management networks, to rekindle some of the original strengths of local tenure arrangements. All this is happening in the face of increasing external pressures to commercialise marine resources, pressures that are beyond the production capacity of most coral reef inshore systems.

Source: K. Friedman.

Madagascar

The fishery is mostly located in villages on the west coast (Rasolofonirina, 2007). The traditional fishery has expanded in the last decades, often bringing overexploitation of the high valued species. Fishers now go from one area to another, depleting stocks in succession. For instance, with the depletion of resources in the north of Madagascar (Nosy Bé Island) in the 1990s, fishers started to operate along the west coast to the Mahajunga region. Recently, migrating fishers were observed in temporary villages organized in the Radama islands. This situation, which occurs due to the lack of well defined access rights, often raises conflicts with local communities and leads to heavy depletion of the wild stocks.

Source: C. Conand.

6. Implementing management

6.1 INFORMATION FOR MANAGEMENT

6.1.1 Overview of the harvested species

Definition

Simple surveys and literature searches to understand the ecology of sea cucumbers in the fishery and the past and current exploitation by fishers.

The information should give the resource manager an understanding of the range of species harvested, their basic biology (e.g. size-at-maturity, behaviours and preferred habitats), their value and distribution in the fishery (Figure 13; Section 3.1).

Uses

Basic surveys and reviews of the literature will allow the manager to interpret and apply results from stock surveys and to gauge the ability of various species to respond to management measures. A simple inventory of species and exports will reveal whether the fishery is multispecies and whether there is a mixture of species of high, medium and low value.

Information on the distribution of species within the fishery allows the manager to correctly assign size limits and to understand fishing activity. The manager should understand how local names correspond to various species (see Annex 10.1). Although individual species can be grouped, generally each species must be treated separately.

Limitations

Fishers may not have as many names for species as scientists describe them. In this case, local names might combine several similar species or incorrectly describe species.

The range of species collected by fishers will not generally reflect the full range of species available, so an initial overview of this nature will not thoroughly describe the available resource. Also, the economic value of each species from local sale price may poorly reflect the true international values (see Section 6.1.5).

How to implement

Managers should be confident they understand what species can be found in the fishery. Information should be gathered on the distribution of each species to know if these are endemic and whether their distributions are locally restricted. The preferred habitat of each commercial species should be understood.

The basic drivers for fishing effort should be understood. Are some species sought after more than others, and why? Information should also be collected to describe the main constraints of fishers and exporters.

Field guides published by reputable agencies will give an overview of the identification of species and the habitats in which they generally occur (see *Examples and lessons learned* below). Published reviews should be consulted in addition to local reports and studies.

The manager should prepare a ranked list of export species by value. Experienced ecologists or taxonomists should be contacted to verify the species names and that fisheries agencies are assigning the correct scientific name to the sea cucumbers in their fishery.

It is also desirable to obtain a general preliminary indication of the stock abundance of species in the fishery through the use of simple indicators (Friedman *et al*., 2008a).

These indicators could be gathered from evaluating the general state of sea cucumber populations using rapid underwater census, sociological surveys and export data. Indicators could be, for example, a recent change in the species composition of sea cucumbers exported or reports from fishers that certain species are harder to find.

EXAMPLES AND LESSONS LEARNED

Identification guides and other information resources

PACIFIC REGION

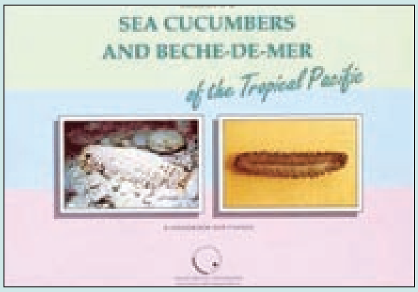
The Secretariat of the Pacific Community (SPC), a regional inter-governmental agency, publishes descriptive posters and informative books, booklets and reports to inform stakeholders about issues relevant to sea cucumber ecology, the fishery and post-harvest processing.

Beche-de-mer information bulletin

A periodical that has been running regular editions since 1990 and generally includes a diverse range of articles on all sea cucumber issues. All articles and abstracts published in the SPC Beche-de-mer Information Bulletin can be consulted at: www.spc.int:coastfish/news/search_bdm.asp

Pacific Island sea cucumbers and beche-de-mer identification cards

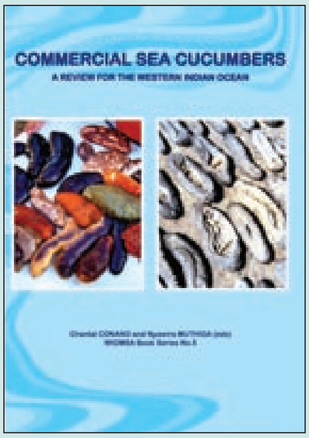
A pocket-sized waterproof identification guide presenting 21 important sea cucumber species from the Pacific Islands region. A card for each species gives a colour underwater photograph of the live animal on one side and photographs (ventral and dorsal views) of the dried animal (beche-de-mer) on the other side. It also contains some basic information on the species (preferred habitat and depth, average sizes) and a short description of the dried product. Additional information on beche-de-mer processing and sea cucumber biology is given at the end of the publication. The guide is available at: www.spc.int/coastfish/fishing/bdm-id/bdm-idcards.htm



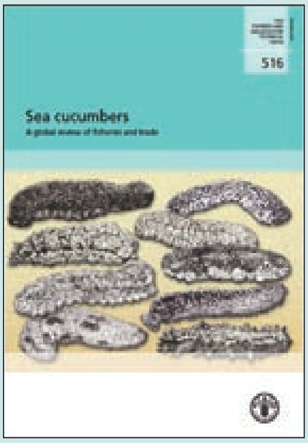
Sea cucumbers and beche-de-mer of the Tropical Pacific: A handbook for fishers

In this third edition of the handbook, 15 of the most common commercial species of tropical sea cucumbers are described and the methods used for their processing, grading and marketing are detailed. It is interesting to note that many species that belonged to the "medium" or "low value" categories in 1994 would be placed in "higher value" categories today, which is a sign of the increased demand and high level of exploitation of commercial sea cucumbers worldwide. The handbook is available at: www.spc.int/coastfish/fishing/bdm_hdbook18/hdbook18e.htm

Commercial holothurians of the tropical Pacific
This poster illustrates 28 species of commercial holothurians in tropical waters of the Pacific Ocean. For each species the known geographical distribution is indicated along with a number of key identification features and commercial value. The poster is available at:
www.spc.int/coastfish/fishing/posters/images_posters/holothurians.jpg
K. Friedman.



INDIAN OCEAN REGION
The Western Indian Ocean Marine Science Association (WIOMSA) has recently published a book on the fisheries, the state of knowledge and the needs for managing sea cucumber fisheries in the main countries in the region. The book is available from:
secretariat@wiomsa.org
C. Conand.



GLOBAL
The Food and Agriculture Organization (FAO) has recently released a review document on the population status, fishery and trade of sea cucumbers worldwide through the collation and analysis of the available information from five regions, covering known sea cucumber fishing grounds: temperate areas of the Northern Hemisphere; Latin America and the Caribbean; Africa and Indian Ocean; Asia; and Western Central Pacific. The publication is available from:
www.fao.org/docrep/011/i0375e/i0375e00.htm

6.1.2 Fishery-independent stock surveys

Definition

A process of collecting and analyzing data on the sea cucumber populations through surveys that are divorced from fishers or the animals they have collected.

Most often, fishery-independent surveys comprise underwater visual census (UVC) of sea cucumber densities (e.g. via counts of animals in replicate randomly allocated transects) and later analysis of abundance, diversity and distribution.

Uses

The collection and analysis of data on the densities, distribution and sizes of sea cucumber species in the fishery will form a basis for understanding the relative "health" of the stocks (i.e. whether animals are abundant or not; or "stock status"). The estimates of densities of commercial species over broad areas (i.e. tens to hundreds of hectares) will be principal in evaluating whether stocks in some sites or regions are depleted (Uthicke, Welch and Benzie, 2004; Skewes *et al*., 2006; Friedman *et al*., 2008b; Purcell, Gossuin and Agudo, 2009a). At a finer level, underwater survey data will indicate which species are rare or critically stressed by fishing. The field data may also be used to calculate the total number (Kaly *et al*., 2007) or biomass (Skewes *et al*., 2002; Aumeeruddy *et al*., 2005) of sea cucumbers in a region or fishery. Such measures could be used for periodically evaluate the management strategy in relation to target reference points (see Section 3.4). While the ability to monitor abundance reliably does not guarantee sustainable outcomes, it certainly makes them more likely (Hilborn, Orensanz and Parma, 2005). More broadly, the surveys allow for comparisons to stocks in other fisheries (Friedman *et al*., 2008b; Kinch *et al*., 2008a).

In cases where long-term marine reserves are evaluated, the surveys furnish benchmarks of virgin stock densities. These estimates can be used to calculate virgin biomass of the fishery, which may be used for defining TACs (e.g. Skewes *et al*., 2002; Aumeeruddy *et al*., 2005). The benchmarks of virgin densities can also be used to indicate depletion of stocks on fished areas in the absence of comparative historical data (Kaly *et al*., 2007; Purcell, Gossuin and Agudo, 2009a).

The community composition of sea cucumber species can be described (Aumeeruddy *et al*., 2005; Purcell, Gossuin and Agudo, 2009a). Direct comparison of this information with the landings from fishers will show the level of selectivity by fishers, which cannot be easily gained otherwise. The range of species and their prevalence in the field are used to calculate diversity indices for the communities, which are important for conservation management and choice of sites for marine reserves.

Population surveys can be conducted at the same sites repeatedly to monitor the response of stocks to a certain fishery pressure or management measures (Schroeter *et al*., 2001; Skewes *et al*., 2006). The surveys provide a direct method for determining changes in the status of the resource over time. Assessments to understand population status through regular ongoing monitoring are referred to as "stock monitoring".

Limitations

Foremost, population surveys by underwater visual census are relatively costly and time-consuming. They most often require two experienced divers trained in sampling and species identification, a boat driver and a suitable boat. Personnel time is probably the greatest cost, and this is increased by boat costs, fuel and the equipment for diving and safety. Many months may be needed for a team to adequately assess stocks in a fishery – roughly 30–50 transects can be surveyed by a team of three in a day, which may correspond to just one site of 100–200 hectares (see Purcell, Gossuin and Agudo, 2009a).

Fishery officers/technicians are often not appropriately trained in sampling design to be able to conduct surveys scientifically or to identify all species in the field. There may be as many as 30 or 40 species in the sea cucumber communities. Grouping species may be seen as one solution, but it can backfire on fisheries managers when depleted or rare species are determined to be abundant because other species are included in the counts. Misidentification of species may likewise confound the correct distribution of species in the fishery. Likewise, a lack of synchronisation and training of survey teams can create irreparable errors in data sets that prevent certain analyses (Kaly *et al*., 2007).

While the data from population surveys can be averaged to provide estimates of density of each species in different habitats, this does not reveal abundances over broad areas. Estimates of abundance will mostly be calculated through integration of the data with Geographical Information Systems (GIS), which requires a high level of technical competence. The satellite or aerial imagery for enabling the GIS packages to calculate surface area of habitats in which sea cucumbers were counted can be costly or not accessible.

Estimations of population densities or abundance derived from population surveys do not always allow the determination of a TAC. For instance, it may still be unclear what virgin biomass would be if the stocks were not fished. However, TACs can be set through knowledge of the abundance of sea cucumber populations in the fishery, or "stock status" (see Section 5.4), which can be estimated using fishery-independent surveys.

How to implement

The information needed for fishery-independent stock surveys of sea cucumbers relates mainly to population surveys in the field and analyses of data. A list of species that can be found in the country should be well established and verified by taxonomists or experienced ecologists. Likewise, the manager will need to define the habitats and depths in which sea cucumbers are fished and in which the commercial species may occur. This information can be obtained from fishers and field guidebooks and published reports. In many cases, it may be best get advice from, or hire, specialists who have experience in designing and coordinating underwater population surveys.

Before starting field surveys, managers must choose what precision they want from the study and what questions they hope to answer. The spatial limits of the fishery should be defined and may include remote reefs visited infrequently by fishers. Other preliminary questions include:

- Do surveys need only indicate stock health in broad terms or will they be used to estimate biomass and density of each species over the whole fishery?
- How many sites will be surveyed?
- Will the sites be re-censused over time?
- Will marine reserves be surveyed?
- What is the annual budget to cover costs of field surveys?

The answers to these questions will structure the design for the field surveys. Data collection should be on the spatial scale appropriate to the biology of the target animals (i.e. the sea cucumbers being fished) and the structure of the fishing communities (Hilborn, 2004). Where possible, the costs of surveys should be recovered from revenue of the fishery (FAO, 1995). "Power analyses" can help to show how many sampling units (e.g. transects) are needed per habitat strata, or per site (Skewes *et al*., 2002; Aumeeruddy *et al*., 2005; Kaly *et al*., 2007). In some cases, it may be sufficient for fishers or other community members to do simple counts and measurements of sea cucumbers in a structured way to monitor stocks.

Survey design will also depend on whether the purpose is periodic monitoring or a "once-off" estimation of densities or abundance. For monitoring purposes, perhaps fewer surveys (e.g. belt transects) are needed. For periodic monitoring of stock abundance/density, fixed transect (or "station") sampling may be preferred to random sampling designs. In this case, the replicate transects/stations should be physically marked so that the same tracts of sea floor can be surveyed again in the future.

The design of underwater field surveys should correspond to the resolution of population estimates required for developing the management plan. Several different approaches have been used in fishery-independent stock surveys:

- *Estimation of total stock abundance*: Surveys can be broadly-spaced within the whole fishery in order to estimate stock size and biomass, which can be used in the calculation of MSY (Skewes *et al*., 2002; Aumeeruddy *et al*., 2005). The fishing area is defined and survey stations are allocated randomly in predefined habitat strata. Representative areas across the entire fishery need to be surveyed and each area should have an equal chance of being sampled. This approach can provide a good estimation of the abundance of commercial holothurians (as a group) across the fishery. However, it does not provide estimates of mean density at any particular site and may require a lage number of surveys.

- *Estimation of stock abundance at particular sites*: Surveys may be grouped at sites of interest to the fishery managers, such as in marine reserves or reefs frequented by fishers (Purcell, Gossuin and Agudo, 2009a). The sites are chosen then the underwater surveys are positioned randomly within predefined habitat zones once at the site. This approach gives relatively good estimates of sea cucumbers at the species level, provides precise estimates of abundance of whole reefs or parts of reefs and can be used for monitoring. However, it cannot be used to accurately estimate the abundance of holothurians in an entire fishery.
- *Estimation of comparative abundance:* Surveys may be conducted over broad areas in habitats most utilized by fishers, to gain a measure of abundance in comparison with other localities (Friedman *et al.*, 2008b – broad-scale surveys). Long (~300 m) transects are surveyed to cover a large area of fishing grounds in certain reef habitats. This approach is time-efficient and indicates the broad status of sea cucumber populations. However, "the haphazard measures taken in main fishing grounds are indicative of stock health in these locations only and should not be extrapolated across all habitats within a study site to gain population estimates" (Friedman *et al.*, 2008b).
- *Estimation of densities of sea cucumber aggregations:* Surveys can show the densities of sea cucumbers in aggregations in particular areas within sites (e.g. Friedman *et al.*, 2008b – fine-scale surveys). Sites are nominated by fishers or by finding dense aggregations of sea cucumbers. Short (40 m) transects are then placed close together within the aggregation. These estimates cannot be extrapolated beyond those aggregations to describe abundances at whole sites (e.g. reefs) or within a whole fishery (Friedman *et al.*, 2008b).

Field scientists or technicians should decide on the boundaries of each site and how large of an area is to be surveyed (Skewes *et al*., 2002; Aumeeruddy *et al*., 2005). There is a logical trade-off in the size of sites; they need to be small enough to reliably estimate populations but large enough to draw some generalities over reasonable spatial scales. The different habitats in which the sea cucumbers occur should be defined and preferably sampled in a stratified way in the field (Skewes *et al*., 2002; Aumeeruddy *et al*., 2005; Purcell, Gossuin and Agudo, 2009a).

Multiple, randomly-placed sampling units will be required for estimating population abundance at sites. The following sampling methods can be used to census sea cucumbers:

- Circular sampling units, when densities of individuals are relatively high (e.g. Hearn *et al*., 2005).
- Belt transects, overlaying a band of the sea floor, are more commonly used for surveys. They may range from 50 to 200 m or more in length. Transect width is usually between 1 and 5 m, depending on habitat complexity and confidence in sighting animals (see Skewes *et al*., 2002).
- The manta-tow method for transect surveys (Figure 27) is efficient at covering a large amount of the benthos with least effort. Tow speeds should be slow enough (e.g. 2–3 km h^{-1}) to allow the observer (generally free-diving) to confidently count all animals.
- SCUBA divers may simply swim along transects in habitats that are too complex, too deep, too turbid or too exposed for manta-tow (Purcell, Gossuin and Agudo, 2009a) (Figure 28). In such cases, a "hip-chain" (or "chainman") device can be used to measure transect length, which improves sampling efficiency of the field team (Leeworthy and Skewes, 2007).

- Remote video equipment can be used for surveying sea cucumbers in very deep habitats (Aumeeruddy *et al*., 2005).

To estimate abundance (number of animals over large areas) the average density of each species in each habitat is multiplied by the surface area of each habitat. The latter of these measures is estimated by GIS technology using imagery from satellites or aerial photographs (see Purcell, Gossuin and Agudo, 2009a). Since some species may occur in multiple habitats, the abundance estimates (and errors) from each habitat in a site need to be pooled to give an overall estimate of abundance.

Although individual species can be grouped in survey records, generally each species should be counted separately in field surveys. It is an advantage to measure some representative individuals of each species at each site, as these data can indicate fishing pressure through comparison with unfished sites or baseline data. The size measurements provide for size-frequency analysis, from which the regularity of recruitment can be inferred (Skewes *et al*., 2006). Other variables about the habitats and substrata can also be collected at the same time, which can provide for informative analyses or comparisons (Skewes *et al*., 2006; Kaly *et al*., 2007; Purcell, Gossuin and Agudo, 2009a).

FIGURE 27
A skin diver counts sea cucumbers within a 2 m wide belt transect on a shallow tropical reef flat. The manta board he holds has a data sheet and collection bag and is towed behind a boat at slow speed

PHOTO: S.W. PURCELL

FIGURE 28
Two SCUBA divers surveying sea cucumbers on soft sediments in deep water. One diver reels out a measuring tape to standardize transect lengths

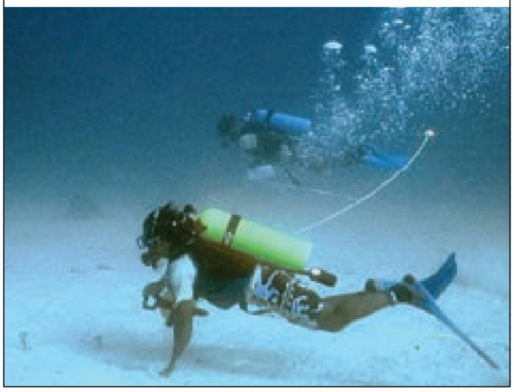


PHOTO: M. LINCOLN-SMITH (CARDNO ECOLOGY LAB)

The technical competencies of the fisheries staff need to meet the demands of both underwater population surveys and the archiving and analysis of data. For example, stratified sampling is a concept that may be difficult for field teams to fully understand (Kaly *et al*., 2007). Are the technicians well educated and trained to design the surveys, collect the data, construct or manage a database and analyse data? Managers should seek templates from other studies on what data to collect and should consider help from development and non-government agencies with appropriate expertise.

EXAMPLES AND LESSONS LEARNED

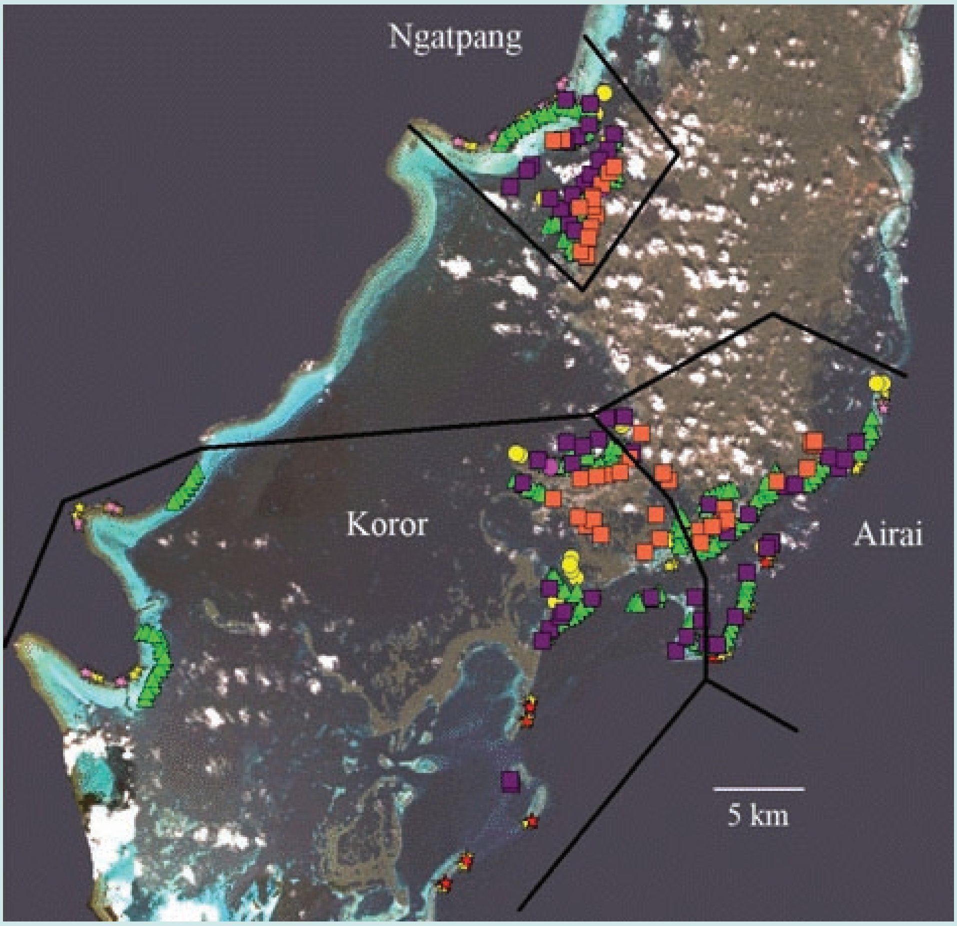
Galápagos Islands, Ecuador

Since the reopening of the sea cucumber fishing seasons in 1999, fishery-independent surveys have been carried out before and after each season. These surveys include fished and non-fished sites in the six islands where the activity takes place (Española, Fernandina, Floreana, Isabela, Santa Cruz and San Cristobal). The surveying team generally includes members of the fishing sector, Galápagos National Park Service, Charles Darwin Foundation and

naturalist guides. The fishery was closed for 22 months during 2005 to 2007 on the basis of the survey results that showed a general population decline. The surveys were instrumental in showing a major recruitment event in 1999, but poor recruitment in other years.
Source: V. Toral-Granda.

Pacific-wide PROCFish surveys

The PROCFish program of the Secretariat of the Pacific Community (SPC) has conducted standardized surveys of most commercial invertebrate species, including sea cucumbers, in 17 countries and territories of the Pacific (e.g. Friedman *et al.*, 2008b). Ten different methods are used, including time-period assessment on snorkel or SCUBA, manta-tow and belt transect surveys. For sea cucumber surveys, the surface area of each replicate census varies from 40 to about 754 m². The assessed surface area of each study site was roughly 10 ha, depending on the size of the site and the number of habitats being assessed.



Above: example of coverage of PROCFish/C surveys – Map of the southern part of Palau showing survey stations at three of the sites. Colour codes denote different survey methods used.

In each site, broad scale surveys, using the manta-tow technique, were used to give a broad indication of species' distributions. Twelve manta-tow stations (6 replicates of 300 × 2 m per station at an average towing speed of 2–3 km/h) are made on the reef top and along reef edges of fringing reefs, lagoonal patch reefs and back reefs and the observers recorded all species (identity, number, size estimates) and habitat descriptors. In the general area assessed with manta stations, small-scale surveys are used and comprise a number of adjacent short belt transects to make more precise measurements of size and numbers of sea cucumbers in areas where they were found at high density. Twenty-four benthos belt-transect stations (6 parallel belt transects of 40 × 1 m per stations), were spread over the site, firstly targeting the best aggregations of sea cucumbers and/or habitats (both coral reef areas and sediment areas) recorded during the manta tow stations. In environments where manta tow is usually not possible, such as the surf zone or on the deeper area such as the passages, outer slope or deep lagoon areas, dedicated time-period assessment are used (6 replicates of 5 minutes per stations). Four stations were made on snorkel in the surf zone (1 to 5 m) and 4 stations are made walking on the barrier reef at low tide for the shallow water species such as the medium value *Actinopyga mauritiana*. Four stations are made on SCUBA (15 to 45 m) for the deep water species, such as the high-valued *Holothuria fuscogilva* and *Thelenota ananas.* During these time-period assessments, species of interest and habitat data are recorded, but to keep a good area coverage, little time is spend on measuring individuals. Only small samples of the individuals were measured, the rest were simply counted. Each station is geo-referenced using Global Positioning System (GPS) and count/density maps are produced using GIS software. The typical sea cucumber PROCFish survey is not designed for stock estimates, but inform on the status of resources (e.g. if the stock seems healthy, moderately healthy or depleted), and able comparison across sites, countries and regions.

The regional approach has been useful to understand what was the range of density from unimpacted sites to heavily impacted sites. It allows managers and researchers alike to figure out what potential densities a resource can reach, which in most case is very low and how far from this potential density the resource is.

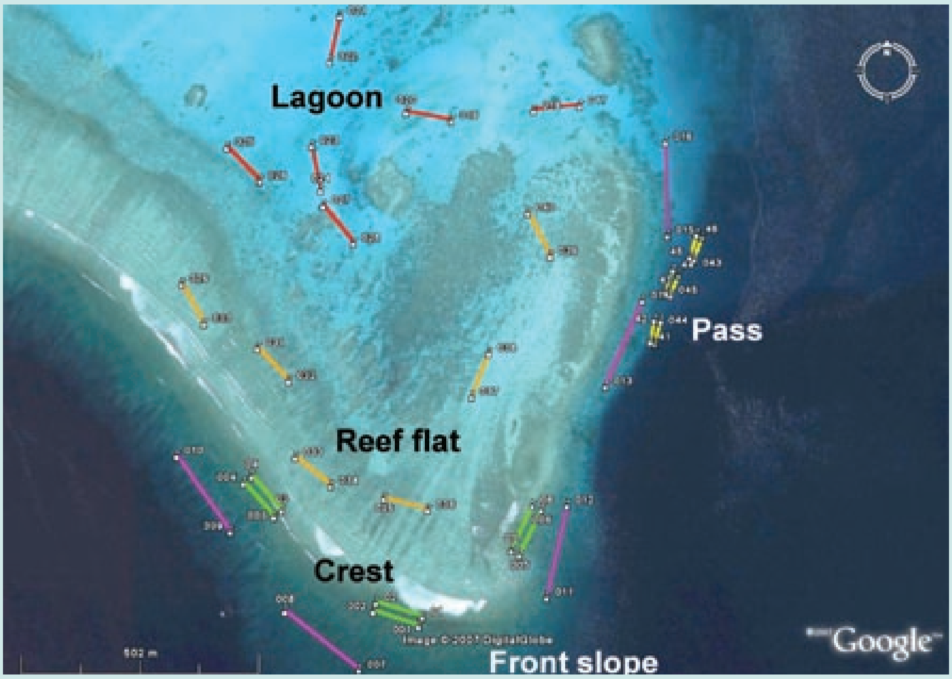
Source: E. Tardy.

New Caledonia, France

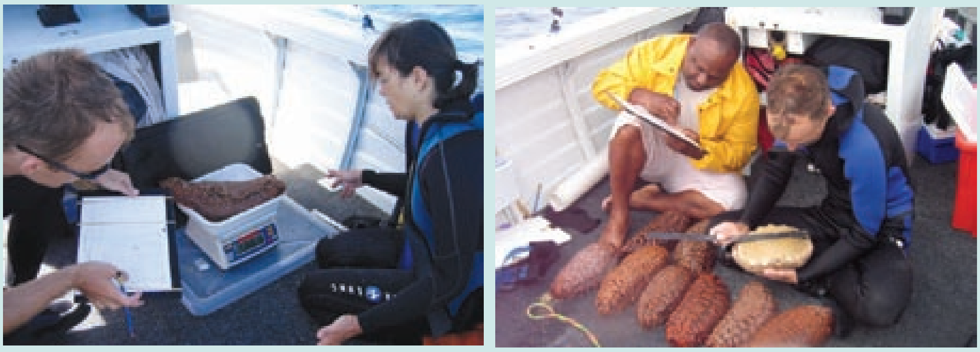
A recent study by the WorldFish Center described the status of the sea cucumber fishery of the main island of La Grande Terre, New Caledonia (Purcell, Gossuin and Agudo, 2009a). Underwater visual censuses (UVCs) estimated the abundances and sizes of sea cucumber communities on a total of 50 lagoon and barrier reef sites, mostly 60–160 ha in area. The populations were surveyed using stratified, replicate, belt transects that were geo-referenced using Global Positioning System (GPS) technology. At each site, approximately 25–30 belt transects were stratified among five habitat types. Transects were 2 m wide, whereas length varied from 50–200 m depending on the habitat. Likewise, equipment and methodologies were adapted to suit the constraints imposed by the habitats: reef crests were surveyed by skindivers in tandem, using handheld GPS to measure transect length (100 m); deep habitats were surveyed by SCUBA divers in tandem using the hip-chain method to measure transect length (50 m); the manta-tow method using onboard GPS to measure transect length (100–200 m) was used with skindivers for other habitats.

The first six individuals of medium- and high-value species encountered along each transect were collected – these were measured (length and width) and weighed on the boat. Animals are left for one minute on the deck of the boat to evacuate seawater before being weighed.

GIS software (MapInfo®) was used to calculate the surface area of sites and of each of the five habitats within each site. The total abundance of each species per site could then be calculated by summing estimates of abundance from all of the habitats. Estimates of densities in the habitat in which each species was found most, for each site, were also calculated. The measurements of representative individuals allowed the calculation of average weights and size-frequency distributions. In this study, both fished and unfished (marine reserve) sites were surveyed, but the abundance estimates were not extrapolated to estimate the global abundances of sea cucumber in the entire fishery.



Above: aerial photo of one of the barrier reef study sites (southeast end of Récif Tetembia, Province Sud), showing the actual position of transects in the five habitats. Pink (long) transects (200 m) – Front slope. Green transects (100 m) – crest. Orange transects (100 m) – reef flat. Red transects (100 m) – lagoon. Yellow transects (50 m) – deep water in the barrier reef pass.
Source: Purcell, Gossuin and Agudo (2009a).



PHOTOS: S.W. PURCELL

Above: weighing (left) and measuring (right) representative individual sea cucumbers collected on transects of the population surveys.
Source: S.W. Purcell.

6.1.3 Fishery-dependent stock surveys

Definition

A process of collecting and analysing data on fishing activities and catches of sea cucumbers in the fishery.

Fishery-dependent surveys collect information on what, when, where and how animals have been caught in the wild, so are therefore inseparably dependent on fishing. Most often, these surveys are based on data submitted by fishers (e.g. via logbooks) or data collected by fishery officers by observing or inspecting the sizes and types of sea cucumbers caught, processed or traded.

Uses

Data on fishing effort and catches will reveal a great deal about fishing activities as well as providing a surrogate measure of abundance of sea cucumbers in the wild. Managers are called upon to monitor fishing activities regularly and use fishery-dependent data to evaluate the performance of management measures (see Sections 3.1 and 3.4). When the fishing locations are stated, data from fishers or landing surveys can be used to compare the density of stocks among different fishing grounds. These data are used as surrogates of data from field population surveys (e.g. underwater visual censuses) to indicate stock composition and abundance because the data are much easier and cheaper to collect (see Section 4). Of course, one must be careful and cautious, about how fishery-dependent data are interpreted (see below).

Data on catches can be used to characterize the species composition of individual fisheries, to assess the level of utilization and fishing mortality of the different species, to calculate catch per unit of effort (see below) and to monitor quotas. Monitoring of catches over time can show historical trends in the fishery and indicate the abundance of the stock. Data on catches are extremely important in fisheries where quotas are used, because these allow managers to determine whether the quotas have been met, are being underutilized or have been exceeded.

The catch structure in the fishery can also be examined with catch data and compared over time or among locations. Catch structure refers to the size of individuals and species composition of each species in the catch. Shifts in the catch structure are strong signals of overfishing or potential non-sustainability in the fishery. Shifts in catch structure may reflect, for instance, a serial depletion process by which excessive fishing pressure is exerted on individual stocks (e.g. of high-value species) leading to a shift of fishing pressure to less-preferred species or size classes. Comparison of catch structure and sizes of sea cucumbers in catches with corresponding data from fishery-independent surveys (e.g. underwater visual census) over the same areas can reveal selectivity by fishers. These comparisons show fishery managers which species the fishers prefer to catch, compared to what is present in the wild and whether they are leaving small individuals or simply collecting all sizes available (Purcell, Gossuin and Agudo, 2009a).

Data on catch and fishing duration can be used to calculate catch-per-unit-effort (CPUE) (Hilborn and Walters, 1992; FAO, 1999). This ratio can be examined over time to reveal any trends in the efficiency of fishers to obtain their catch. Catch can be expressed as the number or weight of the entire catch, a selected subset of the catch, or a particular species in the catch. Effort usually refers to the time a fishing gear is deployed in the water, but on a coarser scale can also refer to the number of active fishing units in the fishery (e.g. number of vessels or fishers). Many aspects of the fishery can be monitored utilizing CPUE analysis, including trends in overall fishery catch rates, catch rates of target species, catch rates in specific geographic areas and seasons and catch rates of size classes. CPUE is a much more powerful tool than catch data alone.

Limitations

Data collected by researchers or catches at landing sites, processing stations or fishers' homes is easily obtained and the researcher can often control the accuracy of the measurements. However, data obtained from the logsheets or logbooks of fishers may be incomplete or incorrect. They may, for example, not declare all animals caught or not identify or separate some species correctly or may receive or buy sea cucumbers from children or other fishers and declare that it was caught by them over their fishing periods. These inaccuracies may lead to a false understanding of total catches in the fishery or CPUE.

Fishery-dependent data will often give a biased indication of the composition, sizes and abundance of wild stocks. Therefore, data must be interpreted with caution.

The reason is that fishers or fishing gear is probably selective towards certain species and sizes of individuals. It is therefore useful to compare catch data with fishery-independent data to better understand biases in the data.

A decline in CPUE over a time period is usually a good indication that stocks are declining. However, the degree of confidence in CPUE as an index of abundance will vary according to the type of behavioral interactions between fish and fishers. For instance, Hilborn and Walters (1992) have categorized three possible relationships between CPUE and abundance:

1) *hyperstability*, where CPUE stays high as abundance declines. This can occur in fisheries where search for the target species is highly efficient, effort concentrates in areas of high abundance and the species remains concentrated as abundance declines;
2) *proportional*, where CPUE is roughly proportional to abundance. This occurs in situations where the species is homogeneously distributed in the fishing grounds and the process of searching is random; and
3) *hyperdepletion*, where CPUE drops faster than abundance declines. This condition is expected, for instance, when there are marked differences in the vulnerability of portions of the stock, such that there is a smaller but more vulnerable potion of the stock which is depleted and a less vulnerable but more abundant subset of the stock that remains underexploited (e.g. a large part of sea cucumber population in deeper waters not accessible to fishers).

Also, advancements in fishing gear, improvements in fishing abilities of fishers and captains, weather patterns, etc., can all influence CPUE trends. Interpretation of CPUE data, therefore, must be undertaken with knowledge of such potentially contributing factors.

How to implement

Data on catches and catch structure can be gathered in the following ways:

a) landing surveys conducted by researchers at boat ramps, ports or fishers' homes;
b) surveys conducted by researchers at processing stations;
c) logbooks or logsheets given to fishers, who record the data themselves and submit the forms on a regular basis; and
d) fishery observers/researchers who travel with fishers as observers on their boats.

Landing surveys and surveys of processed sea cucumbers will be the most reliable, since the researcher can correctly identify the species caught and accurately measure and weigh the animals (Figure 29). It can be difficult to arrange meetings with fishers in remote locations but this may be facilitated by researchers travelling with buyers to collect sea cucumbers from fishers (Purcell, Gossuin and Agudo, 2009a). The landing forms should include the locations fished (even a general region), time spent fishing, time spent travelling to the fishing sites, number of fishers, number and weights of each species caught (Appendices 1 and 2). The forms may include the prices paid or received (Appendix 1).

FIGURE 29
Researchers measuring and weighing dried sea cucumbers at an exporter's facility in Alotau, Milne Bay, Papua New Guinea. These fishery-dependent data are later used to help monitor the sizes and species caught in the fishery

PHOTO: J.P. KINCH

Logsheets or logbooks given to fishers should be supported by taxonomic identification tools to verify species identities (e.g. waterproof identification cards, Section 6.1.1). Fishers should be expected to record their catch within a short time, e.g. 12 h, after returning to shore. It may be a clause of their fishing permit that they submit the forms on a regular basis, e.g. after each landing or every three months. In recording their catches, it is important that the forms also ask fishers to account for any sea cucumbers or bycatch species discarded (see Appendix 3) or retained for personal consumption.

In trawl or dragnet fisheries, like the growing fishery for *Cucumaria frondosa* in Newfoundland and Labrador, Canada (Section 2.4), fishers may also be expected to record the geographic positions of the start and end points of each tow (see Appendix 3). In dive fisheries, as in the Seychelles, the fishing logsheets can include data fields for dive depth and fishing region (see *Examples and lessons learned*, Section 5.5). These types of data can then be used by the fishery manager to monitor where sea cucumbers have been collected and see if fishing depths or locations change over time.

When calculating CPUE, the units of effort to use will depend on the type of fishery and fishing gear. Effort can be expressed, for example, as the numbers of hours spent fishing, number of fishers, number of vessels, vessel-days or number of trawl-hours. For sea cucumber fisheries conducted by diving, the most useful effort unit would be the actual amount of dive time spent in the water, i.e. total person-hours diving.

Some measures should be put in place to validate the accuracy of data submitted by fishers. For example, fishery officers could make impromptu visits to fishers and weigh and check the species in their catch to see if these records correspond with the records in the fishers' logbooks. A collation of data on catches from logbooks could also be compared with data on exports for a given period.

EXAMPLES AND LESSONS LEARNED

New Caledonia, France

Landing surveys were conducted to examine the composition, body sizes, catch volume and fishing effort of fishing campaigns in New Caledonia (Purcell, Gossuin and Agudo, 2009a). Fishers or processors were visited in six study regions and measurements were taken on batches of harvested sea cucumbers. A data form was filled in by researchers, not the fishers (Appendix 2). The exact weight or estimated proportion of the catch made up of various species was recorded along with individual measurements of body lengths and weights of 20 random individuals of each species. The fishers were asked about the fishing locality, number of fishers, total time fishing, time spent fishing and travelling to sites. The weights of gutted, salted or dried sea cucumbers were later converted to estimates of whole body weight using conversion factors (Conand, 1989, 1990; Skewes *et al.*, 2004; Purcell, Gossuin and Agudo, 2009b).

An early lesson was that landing surveys at processing stations were easier to organize than at fishers' homes or at boat ramps. At best, fishers told of the fishing region rather than specific sites. A total of 17 species were recorded from 54 landings, representing 453 fisher-days of collecting sea cucumbers.

The size frequencies of sea cucumbers in the landings were compared directly with corresponding size frequency data from underwater visual censuses. This approach revealed selectivity towards larger individuals in some regions. The data from landings were also used to calculate CPUE of fishers in each study region, which was compared to CPUE data from sociological questionnaires. Purcell, Gossuin and Agudo (2009a) highlighted a few important lessons for fishery-dependent surveys:

1. Whole body weights converted from dried animals will be less biased if the animals are fully dried.
2. Size selectivity by fishers can be best seen by comparing landed sizes to measurements of animals taken by divers during field surveys. Therefore, both sets of data are recommended.

3. Estimates of CPUE based on sociological interviews may be inaccurate. Landing surveys are a better estimator of CPUE, since data on fishing times and catch can be recorded more accurately, but good replication of landing surveys is required.
4. Unless all landings are well documented, landing surveys cannot be a sole reference for judging the range of species exploited. This should be augmented with fisher interviews. Some species are harvested only occasionally by fishers and declared in interviews, but may be missed in landing surveys.
5. Perceptions by fishers of the average sizes of animals they captured did not always match the actual landing data. Monitoring programmes must also collect landing data to bring more realism into the understanding of sizes collected.

Source: S.W. Purcell.

Coral Sea Cucumber Fishery, Australia

The Australian Coral Sea Cucumber Fishery operates on remote, offshore, reefs east of the Great Barrier Reef. Owing to the cost of fishery-independent surveys, fishery logbook data is used to assess stock status. A Commonwealth Scientific and Industrial Research Organisation (CSIRO) study calculated CPUE for each species per day using data on hours fished and number of fishers for each operation (Hunter *et al.*, 2002). The average CPUE per trip, per vessel, was used for statistical comparisons and catch data from trips less than 3 days were pooled with data from the following trip. Logbook data which were not separated in these two modes (35% of records) had to be excluded from CPUE analyses because the two methods target different species and habitats.

Fishers free diving mostly caught black teatfish (*Holothuria whitmaei*), surf redfish (*Actinopyga mauritiana*) and lollyfish (*H. atra*), whereas fishers using hookah targeted white teatfish (*H. fuscogilva*) and amberfish (*T. anax*). Prickly redfish (*Thelenota ananas*) were caught using both methods. From early 2000 to mid-2001, the CPUE for black teatfish declined from 12 kg h^{-1} to <4 kg h^{-1} on 3 out of 4 reefs. Estimates of CPUE were variable for white teatfish (10–60 kg h^{-1}), prickly redfish (<1–30 kg h^{-1}) and surf redfish (<1–16 kg h^{-1}), and, although CPUE declined on some reefs, it increased on others. The findings prompted the management agency to reduce the TACs for several species. The study cautions that CPUE estimates may be unreliable as proxy measures of abundance for lower-value species (when high-value species are still targeted by fishers) because they were collected opportunistically (Hunter *et al.*, 2002).

The logbook data provided by fishers was considered fairly accurate, owing to few fishing operations and productive relationships between fishers and the management agency. Bias could arise when (a) assessing stocks of individual species because multiple species were caught, (b) fishers shifted preferences for certain species, and (c) different fishing methods were used. Hunter *et al.* (2002) therefore give the following lessons for setting logbook requirements:

1. Catches from hookah and free diving sessions should be recorded separately
2. Effort should be recorded as fishing hours
3. The number of divers per dinghy should be recorded
4. Catches should be weighed for each fishing session on each trip
5. The species that fishers targeted each day should be recorded

In conclusion, CPUE data is difficult to interpret. Therefore, managers should use a precautionary approach when developing or adapting regulatory measures from these fishery-dependent data.

Source: *T. Skewes, CSIRO, Australia.*

Galápagos Islands, Ecuador

Monitoring became mandatory in the Galápagos Islands in 1998 for the sea cucumber fishery. Initially, on-board logbooks were issued but had little support from the fishers and the data they recorded was inconsistent with dockside landing surveys. Therefore, fisheries observers from the Charles Darwin Foundation (CDF) and the Galápagos National Park (GNP) collected the data, which comprised fishing site, fishing method, number of fishers, hours invested in fishing, total catch (in weight or in units) and species caught. Data were recorded at the wharf through interviews with the fishers. The body lengths and weights were recorded for about 40 percent of the catch. By the end of each fishing season, the data were analysed and the results provided to stakeholders before the next year's season.

The data revealed the most important fishing sites, catch per unit of effort (CPUE), number of active fishers and boats per season and body sizes. The fishery-dependent surveys helped to determine when to close fishing (and start the seasonal closure) and when the TAC was nearing fulfillment. Furthermore the measurements of sea cucumbers were used to show what percentage of individuals had been caught under the minimum legal size limit.

From 1998 until 2006, the fishery-dependent surveys were conducted jointly by CDF and GNP. However, due to the high costs of maintaining this programme, CDF eventually pulled out and currently is under the sole responsibility of the GNP. Unfortunately, since 2006 only the total catch has been calculated from the data and there has been limited human resources to analyse other important statistics, such as CPUE and visitation frequency at fishing sites, which is limiting the decision-making process.

In summary, the logsheets were abandoned because data from fishers were inaccurate and the monitoring programme was very costly and faced difficulties because it relied largely on private donations to cover field expenses of the observers. In future, monitoring programmes need to invest in training fishers on how to fill in the logbooks and provide incentives for recording accurately. Alternatively, the data can be collected by fishery observers but must be adequately funded through the government (e.g. through tax revenue from the fishing industry).

Source: V. Toral-Granda.

6.1.4 Socio-economic surveys

Definition

The collection of data on responses from fishers and other actors in the fishery, to questions about social and cultural factors that affect the exploitation of stocks.

The surveys would commonly entail questionnaire-based interviews with fishers, processors, exporters and other stakeholders of the fishery. The data should allow the fishery manager to identify, for instance, the actors in the fishery, what fishing methods are used, what time and resources are invested to collect the animals, how the sea cucumbers are processed and sold/traded, what income is gained from fishing and processing and selling, knowledge of regulations and what are the stakeholders views on management of the resource.

Uses

Socio-economic surveys provide a basis for understanding the relationship between fisheries stakeholders and fisheries resources, and a means to obtain stakeholders' views about the fishery (Kronen *et al*., 2007; De la Torre-Castro *et al*., 2007). Managers are called to gather and analyse data on social, economic and institutional factors of fisheries, or commission/facilitate such work and base management decisions on such factors (FAO, 1995; Section 3.1). Importantly, socio-economic surveys allow the manager to choose regulatory tools that will be accepted by the fishers and other stakeholders. Analyses of data of socio-economic indicators can also serve to evaluate the performance of management strategies adopted and enforced (see Section 3.4).

The surveys should also supply valuable information on the species collected, catch rates, fishing zones targeted and the gears used for fishing. This information can augment fishery-independent surveys – for example, by improving the understanding of stock distribution through fishers' accounts of where species have been collected

(Purcell, Gossuin and Agudo, 2009a). Questionnaires to fishers can reveal breaches of fishing regulations or illegal practices that cannot be shown through landing surveys or compliance reports (Kinch *et al*., 2007). Compared to underwater visual census of stocks, socio-economic surveys are relatively cost-effective.

FIGURE 30
A researcher recording responses of a Filipino fisher to socio-economic questions about income gained from fishing

PHOTO: R. GAMBOA

The surveys can also show the geographic differences in resource use and dependence within the fishery (Kronen *et al*., 2007; Kinch *et al*., 2008a). For example, fishing will represent a more important part of the incomes of fishers in some localities than others, or some species may be targeted in some localities but not elsewhere. Such information could be used for adapting management regulations differently to suit the needs and current practices of fishers among regions within a fishery.

Socio-economic surveys should help to identify alternative income streams to meet the livelihoods of fishers or processors (Figure 30). Where fishery closures or limited entry rules are to be imposed, managers are thus able to support, or plan for, alternative economic activities for the fishers.

Education and communication programmes should be designed through some baseline socio-economic surveys. They may, for example, help managers to understand how fishers become informed about fishery regulations and what forms of media are best for educating them.

Limitations

An initial limitation can be in the capacity of fishery departments to design and conduct socio-economic surveys in a structured way that gives quantitative data for evaluating trends within and among fisher groups (see Section 2.3). As for underwater resource surveys, expertise is needed to conduct surveys that will give reliable, unbiased data.

A more serious limitation relates to the ability to collect representative socio-economic data that is non-biased with respect to sampling. Whereas sites for underwater resource surveys are easy to encounter, workers commonly find difficulty in finding fishers to conduct interviews. They may be in remote communities (Section 2.3) or at sea when fishery workers want to interview them. Those fishing less often may therefore be surveyed more frequently and so biasing the results of data analyses. This problem compounds when data averages from social surveys are extrapolated, or scaled-up, to infer the resource use by whole communities.

Unlike sea cucumbers on the sea bed, fishers can give false information (even unintentionally) or be reluctant to divulge information. This may be related to the style of the interviewer, and experience is required to know when interview responses may be misleading. A survey method called "triangulation"[1] can help to reduce falsity in socio-economic data. Many fishers are reluctant to divulge how much they catch or where they fish.

[1] *Triangulation* is a method in which different approaches are used to help validate data on the same issue/question. In the case of a socio-economic study, data could be collected from questionnaire-based interviews and fishery-dependent surveys to answer the same question. For example, fishers could be asked about the average length of sea cucumbers they collect and their responses could be validated by taking independent measurements of animals in their catch over replicate fishing trips. In the same sense, triangulation could consist of asking interview questions from different perspectives to obtain, and validate, certain data.

How to implement

Firstly, define the purpose of the survey and what information is required (De la Torre-Castro *et al*., 2007). While the fishery manager may want certain information from fishers (e.g. on catch rates, species and sites fished), other stakeholders will need data on different variables (e.g. trade routes and the state of product sold). It is also important to define the actors in the fishery prior to designing and conducting surveys. Ideally, the socio-economic surveys should cover a wide breadth of stakeholders, not just fishers. Some preliminary work is therefore needed to list the fishers, processors and exporters and how they can be contacted. A process can then be determined to representatively sample the fishers where they are numerous.

FIGURE 31
Household socio-economic and semi-structured interviews conducted at Iabam Island, Milne Bay Province, Papua New Guinea to determine marine resource dependency, particulalry sea cucumbers

PHOTO: J.P. KINCH

The questions and data variables for the socio-economic surveys should then be designed. This may be easiest by adapting an existing survey questionnaire for sea cucumber fisheries (e.g. Kinch *et al*., 2007; Kronen *et al*., 2007; Purcell, Gossuin and Agudo, 2009a). The manager should consult with other stakeholders, like trade officers and conservation agencies, to know what questions should be posed in interviews. Consideration needs to be given to whether the results should reflect fishers, or other actors, collectively, or whole communities. Social surveys may target fishers only, or be posed at households, or both (Figure 31). Household surveys should be used where there is subsistence fishing and many family members may be involved in fishing (see Kinch *et al*., 2007), and inappropriate where there are relatively few actors in the fishery and all sea cucumbers are sold for export. The questionnaires for households will differ from those for individual fishers, as will questionnaires for processors or exporters.

There should be a pre-determined design for sampling fishers or households, e.g. systematic or randomised, such that the samples (i.e. completed questionnaires) are representative of the entire pool of potential respondents. The same approach would apply to "selecting" communities, if a proportion of them are to be sampled and if the data are scaled up to regions or a whole country. Consider the limitations of extrapolating data from non-probability sampling techniques, e.g. "convenience" sampling or "snowball" sampling, if these are used. Kronen *et al.* (2007) outline the most common random sampling designs for socio-economic surveys:

- *simple random sampling* – when the entire population is relatively uniform,
- *stratified random sampling* – where there are sub-groups of households or fishers in the population with different characteristics, and
- *multistage random sampling* – where sampling is structured hierarchically, e.g. samples within villages and villages within provinces.

Questionnaires should be structured to furnish quantitative data – this means scoring responses so that they can be converted to counts, rank responses or binomial (e.g. yes or no) data. This will permit calculation of response averages and enable statistical analyses. Avoid questions that ask for volumes, percentages, or averages (e.g. "What is your average cost per fishing trip?"), because small-scale fishers, or those with a basic school education, will often have difficulty answering them, for a variety of reasons (Kinch *et al*., 2007). Visual aids and field identification guides will help to avoid ambiguity with terms and species (Kronen *et al*., 2007)

FIGURE 32
Using size cards of sea cucumber body lengths during socio-economic interviews of sea cucumber fishers at Andra, Papua New Guinea (left) and Abaiang, Kiribati (right)

PHOTOS: M. KRONEN, SPC PROCFISHIC

(Figure 32; Section 6.1.1). Care should be taken to choose questions wisely to acquire the key data without demanding too much time of the respondents, e.g. approximately 30–45 minutes. The fishery technicians should be appropriate trained in conducting the surveys, or partner institutions can be consulted to help in this task.

Some investment should be placed in communication with fishers about the socio-economic survey programme. Raising awareness will help to uncover all the actors for designing the sampling. As for resource surveys, it will probably be unfeasible to interview all fishers, so some prior rules should be set to allow representative sampling.

Following interview-based surveys, the data should be entered into a database and analysed. Managers may wish to firstly examine simple calculations of the data, separated by fisher groups, locations, gender or age of the respondents. Finally, the information should be validated and used for management purposes. Respondents will also want to see that the results are disseminated and used in the management of the resource.

EXAMPLES AND LESSONS LEARNED

Papua New Guinea

Relatively little research has been conducted on the sea cucumber fishery in Papua New Guinea, despite its economic importance for the nation and to coastal and island fishers, their families and their communities. In recognition of this shortcoming, the National Fisheries Authority (NFA) conducted socio-economic studies of the beche-de-mer fishery in the Western, Central and Manus Provinces in 2006–2007. The surveys aimed to describe the fishery operation to enable the NFA to refine the fisheries management. In particular, the fishery needed better compliance by fishers and companies, stronger benefits to coastal and island fishers and communities; and a more robust assurance of sustainability of sea cucumber resources.

The NFA has also conducted general socio-economic fisheries surveys in the Morobe, New Ireland and Milne Bay Provinces in 2005–2007, as part of its Coastal Fisheries Management and Development Program. These surveys were undertaken to provide basic information on the relative importance of fisheries to the livelihoods of people. They were also designed to provide information on the types and quantities of marine organisms being harvested in each province with a view to assessing the status of the resources and to identify threats and opportunities for the future.

Source: J.P. Kinch.

New Caledonia, France

In a recent project to assess two sea cucumber fisheries in New Caledonia, socio-economic surveys were conducted using questionnaire-based interviews (Purcell, Gossuin and Agudo, 2009a). The questionnaires were structured to provide quantitative data for analyses; i.e. responses as ticks to multiple choice responses or as numbers. Responses were recorded by a sociologist.

The fisher interviews took 30–40 minutes to pose questions within the themes of the type and places of fishing, the catch, the average fishing effort (duration), processing of sea cucumbers by the fishers, economic importance, historical context, and their knowledge and desires about fishery management regulations. Cards with drawings of various sized sea cucumbers allowed fishers to choose drawings for questions regarding the size of sea cucumbers they collected rather than guessing metric lengths and weights. Colour identification cards helped to associate local names of sea cucumbers to scientific names. Many of the interviews were held in conjunction with separate surveys of their landed catch, or by accompanying processors to a sale point to meet the fishers. Interviews were held with the fishers and do not reflect households.

PHOTO: S.W. PURCELL

Above: a biologist/sociologist at a processing station in New Caledonia, where sea cucumbers and *Trochus* topshell are being dried on mesh racks after boiling.

Interviews were also held with most of the fishery's processors (i.e. someone who regularly buys sea cucumbers – whole, gutted, salted or dried). Keeping processors informed on the project's progress was a key for gaining their cooperation. Meetings with fishers in some of the distant and isolated areas were possible thanks to this collaboration. These 20-minute interviews covered themes such as their experience in the industry, zones and problems in the purchase of sea cucumbers, species bought and prices, export context and export prices, and their desires about fishery management regulations.

Comparisons of interview responses with landing surveys showed that the perceptions by fishers of the sizes of animals they captured did not always closely match the sizes of animals in their landings. The lesson here is that monitoring programmes must also collect landing data to bring more realism into the understanding of sizes collected.

The study also showed that fishers listed a larger number of species that they collect than was recorded in landings. This is mostly attributed to the fact that landing surveys will rarely be able to represent catches at all times of the year at all sites. In addition, the interviews indicated a broader distribution of one species than shown by underwater visual census. The lesson is that fisher interviews can supply valuable information for understanding fishing impacts and building species inventories.
Source: S.W. Purcell.

Western Indian Ocean

The regional WIOMSA/MASMA interdisciplinary project on sea cucumbers (2006–2008) (Conand and Muthiga, 2007) consisted of integrated socio-economic and ecological studies in five countries of the Western Indian Ocean (WIO) with contrasting conditions in their ecology and fisheries: from unexploited stocks in La Reunion to severe overexploitation in Madagascar; from small-scale fisheries in Kenya to industrial fisheries in the Seychelles. The methods used included structured questionnaires, semi-structured interviews and network analysis. Based on the results of these studies a conceptual model of the sea cucumber fishery dynamics was proposed (De la Torre-Castro *et al*., 2007). It encompasses multiple levels and takes into account the main features of the fishery, such as fishing and collecting grounds, resource users and other stakeholders involved in the fishery (e.g. fishers, middlemen and exporters), the links between stakeholders, villages and countries and the associated management initiatives at different levels. The holistic outlook of the model, that takes into consideration both social and ecological interactions, may be instrumental in supporting a regional management strategy for sea cucumbers.
Source: C. Conand.

6.1.5 Price monitoring

Definition

Regular examination over time of the prices of sea cucumbers and beche-de-mer along the marketing chains: i.e. from fishers, collectors, exporters and consumers.

Uses

Price monitoring can provide managers with an understanding of the social aspects in the fisher communities. For example, whether fishers are receiving a fair share of the export value of the sea cucumbers they catch and sell (e.g. Kinch *et al*., 2008b). Likewise, this information gives alternative data (e.g. compared to socio-economic surveys) on the income generated by the fishery and the economic importance to various actors.

By monitoring export prices through time, the market force can be better understood (see Sections 2.2 and 2.4). For example, the manager can receive delayed feedback about changes in the overseas demand for all, or certain, species over time. Such information can help to plan ahead for adapting management to avoid rapid overfishing due to increased demand of certain species. Similarly, monitoring of retail prices in Asian markets may open opportunities for fishers that are not apparent (Figure 33).

Monitoring along the whole “market chain”, from fisher to exporter, allows government agencies to verify or set appropriate taxes and duties.

Limitations

It may be difficult to force agents to provide reliable information on prices of sea cucumbers sold or exported. In some fisheries, trade confidentiality is a right of fishing companies. The remoteness of some fishers or buyers may make it difficult to gather price data.

FIGURE 33
Tropical sea cucumbers, as beche-de-mer, displayed at various prices in a dried seafood markets in Taipei, Taiwan Province of China (left) and at a wholesaler in Canton (Guangzhou), China (right)

PHOTOS: J. AKAMINE

There may be seasonal variation in the demand for certain sea cucumber products. Further, custom officers may lack the training to identify species and grades of sea cucumbers to attribute the export prices.

Data from overseas markets are not very easy to interpret, due to misreporting, underreporting and the re-export of traded beche-de-mer. For example, it has been estimated that underreporting of traded beche-de-mer in China, Hong Kong SAR, can bias the trade data by about 49 percent (Clarke, 2004).

How to implement

The manager must have a basic knowledge of the relationships between sellers, exporters and importers along the market chain. This may involve foreign financiers to fishing companies or exporters.

Managers should also seek to involve the trade ministry and customs departments in country to support or conduct monitoring of export prices of sea cucumbers. It would be useful to form a relationship with these groups to meet periodically to examine price data and the implications for actors in the fishery.

It is necessary to have a process by which price data from the international market can be obtained regularly. This could be facilitated through collaboration with international agencies involved in monitoring the trade of beche-de-mer (e.g. INFOFISH – www.infofish.org). They will be in a position to provide data and contacts for monitoring overseas market prices. The manager should be clear about whether the data refers to smoked, dried or salted sea cucumber products and that the species names correspond exactly to local species.

It may be advantageous to develop industry bodies, such as Management Advisory Councils (MACs) for the sea cucumber industry in country. They should be kept updated with summaries of price monitoring so they can participate in adaptive management.

EXAMPLES AND LESSONS LEARNED

The Philippines

Despite being one of the top exporters of beche-de-mer, the Philippines has not established any standardized national or local price monitoring scheme. The local middlemen dictate the price to fishers and their re-sale prices are dictated by the Manila exporters or their overseas partners. Most recently, the proliferation of non-Filipino direct exporters (such as Koreans and Japanese) has contributed to the increase in both demand and price. This has also posed stiff competition among local traders. In any case, the local fishers are the real financial loosers.

The absence of a price monitoring scheme in some fisheries is aggravated by the lack of a formal marketing system. There may be no receipts for the sales of sea cucumbers and no formal contracts between fishers and buyers for credit assistance – these business dealings can be based simply on trust and loyalty. As a result it is rather difficult for managers to reliably estimate, or validate, the overall value of exported beche-de-mer. An illustration of this problem is shown through a comparison of the import statistics in Singapore and the export data posted in national related agencies. The comparison indicates that export quantities reported from the Philippine fisheries agencies (based on formal sale records) are significantly less than the quantities actually exported from that country. In this case, correct export records through a more robust sale and trade reporting scheme could possibly elevate the importance of beche-de-mer from the eighth to forth most economically important marine export commodity in the Philippines.

Among the recommendations at the National Forum in Sea Cucumber Fisheries Management held in Dagupan, Pangasinan, in 2007 are: a) to set a national standard for sea cucumber products; b) perform a market study to generate a real picture of the industry; and c) conduct trainings on post-harvest processing for fishers to improve the quality of their products.

Source: R. Gamboa.

PHOTO: R. GAMBOA, UPMIN

Above: Sea cucumbers processed at the household are stored until the next visit of the middleman (with notebook) who dictates the grade and price.

Asian markets

The Asian centre for sea cucumber trade is China, Hong Kong SAR. In 2006, the region reportedly imported 4 180 tonnes of sea cucumber from 54 countries and regions. However, Hong Kong residents consume only a small part of the imports as most is re-exported mainly to mainland China. For example, in the same year, China, Hong Kong SAR re-exported 3 564 tonnes of sea cucumber to 13 countries and regions (of which about 87 percent was re-exported to China and 6 percent to Taiwan Province of China).

The area of the Hong Kong Island called Nam Pak Hong is where most of the imported sea cucumbers are traded. From there, products are ship to Guangzhou in Guangdong Province (China). Merchants in Guangzhou play an important role in distributing beche-de-mer throughout the country although more recently there are increasing traders now based in cities of Dalian and Qingdao in northern China.

Customers in northern China generally prefer the spiky sea cucumber known as "cishen", while un-spiky holothurians or "guangshen" are preferred in southern China. The Japanese *A. japonicus* is a typical cishen and is currently the most valuable traded sea cucumber species. Fifty dried sea cucumber pieces making up one "jin" (or 600 g) is the standard business transaction volume. Trade is also carried out by "picul" (or 60 kilograms) which is equivalent to 100 jin units. In mainland China one jin equals to 500 grams.

Sea cucumbers smaller than the standard size (i.e. 12 g) are traded at lower prices. Large specimens are more expensive and fetch better prices. Currently, the average price of *A. japonicus* based on trade statistics, is about JPY48 000/kg (2009 prices). However, products from Hokkaido, Japan, famous for its spikes and thick body walls is said to reach a market value of JPY80 000/kg. Retail prices are also differentiated by production site and size of the traded product.

Source: J. Akamine.

6.2 INSTITUTIONAL REQUIREMENTS

6.2.1 Support institutional arrangements for local-scale management

Definition

Aid to the development systems (formal or non-formal) for fishers or fisher groups to take joint, or full, authority in developing and implementing resource management.

The support could be through community organizations, co-operatives, or customary/community groups. Here, "local-scale management" means management decisions and actions conducted by community groups or fishing groups rather than centralised government agencies.

The establishment of institutions for resource management by fisher groups is part of co-management and community-based management and encouraged within an ecosystem approach to fisheries (Section 3.3). Broadly, *co-management* involves the participation of fisher groups or fishing communities with management agencies in the decisions and operation of resource management. In *community-based management* the authority to manage the resource is devolved to the fishing communities, including decision-making, monitoring and enforcement.

Uses

Hilborn (2004) argued that it is not the shortcomings of single-species management that has failed in collapsed or overexploited fisheries, but institutions using top-down (or "centralised") control. Improvements in the sustainability of marine resources through community-involved institutions of fisheries management arise, to a large extent, through better compliance and accountability (Shepherd *et al*., 2004). This is because the management decisions and outcomes are vested with fishers or fishing communities who value the long-term benefits of a sustainable resource. If governance structures are adequate and the appropriate incentives are in place, community management of resources is analogous to putting the farmer in charge of the farm (Hilborn, Oresanz and Parma, 2005). Co-management and community-based management arrangements will be particularly useful in small-scale fisheries where top-down, centralised systems have proved ineffective (Ostrom, 1990; Berkes *et al*., 2001).

Enforcement can improve with locally-management institutions (Shepherd *et al*., 2004). Self regulation by fishing groups and co-management can help to reduce the burden of conflict management that generally resides with management agencies. More direct and well-established modes of resolving conflicts will probably exist within communities compared to those between fishers and centralised management agencies. Owing also to pre-established relationships, co-management and community-based management schemes can foster better consensus building than ad hoc formulation of advisory groups. Appropriate management measures can be proposed that align with community aspirations and customs, and can be enforced with penalties that suit local customs.

A further benefit of devolving the management of resources to fisher groups is improvement in communication among the actors in the fishery. Support may be required from fisheries agencies so that fishers in fragmented fisheries can meet regularly. Within communities, fishery regulations can be better understood since they are developed through wide participation.

Limitations

Co-management and community-based management are not without their shortcomings. There is no guarantee that the group/community will act in its self-interest or that the management decisions will lead to good outcomes. Decision-makers within communities or fisher groups may lack the understanding of biological processes to aptly manage the resource compared to a trained fishery manager. In addition to capacity constraints, communities may lack the financial resources for proper monitoring or surveillance. Moreover, vested personal interests in the community may derail appropriate management strategies for personal gain or assign fishing rights inequitably.

Exclusive rights and devolved management can fail when there is a mismatch between the spatial scales of the management units and the scales at which stock-recruitment processes operate (Hilborn, Parrish and Litle, 2005). For example, the fishing practices in one community may affect the recruitment and sustainability of sea cucumber stocks in a neighbouring community. This may certainly be the case for many sea cucumber stocks that exist as metapopulations of numerous populations connected via larval dispersal. Co-management systems may therefore be more suitable for sea cucumber fisheries, whereby some coordination by centralised fisheries agencies ensures connectivity of populations with a metapopulation.

How to implement

Assess existing institutions in place (including leadership and governance structures). If deemed appropriate then assist in the formalization of the local-level institution. The appropriateness of the existing institutions should be clear if the management decisions are respected by fishers and foster good stewardship of the resources. This will generally mean some level of industry participation in decision-making (Parma, Hilborn and Oresanz, 2006).

The different types of fisher's organizations or stakeholders need to be listed and a plan drawn to show how they are structured or linked within the current management institution. Managers should seek to map out, for example in a flowchart, the decision-making process currently used in the fishery, or other similar fisheries. The stakeholders include more than just the fishers and fishing communities, e.g. conservation agencies, fisheries scientists, fishery managers and field workers. What are the inputs from the different stakeholder groups in decision-making and who has the decision-making authority?

As discussed in Section 6.1.5, the market chain structure should be well understood and preferably illustrated schematically for others to easily understand. How are sea cucumbers sold and exported from the country? Centralized processors and exporters should naturally be an element of participatory types of management, since their compliance is also needed.

Likewise, the legal frameworks need to be described. These would include processes by which management decisions are placed into law or customary regulatory systems, overarching national or international regulations (i.e. national constitutions and international treaties and conventions like CITES), and the process by which offenders are prosecuted for breaching fishery regulations.

Consider the spatial scale at which ecological processes operate in the sea cucumber populations within the fishery and try to match these with the spatial jurisdictions of management institutions. Management measures applied to sedentary animals (like sea cucumbers) near one community may likely, through larval dispersal, have a profound affect on populations managed by a second community. Since individual sea cucumber populations (e.g. on separate reefs) are probably interconnected within a larger "metapopulation" (e.g. the collective populations of one species within an entire reef lagoon), management should ideally operate at the local scale and involve coordination of management institutions at the larger (metapopulation) scale (Hilborn, Oresanz and Parma, 2005; Orensanz *et al*., 2005).

Determine if there is a need for a local-level institution to take authority for, or participate in, the decision-making processes and day to day management of the fishery. Co-management systems may prove more effective than community-based management systems because they allow for fisheries authorities to dictate some regulations that would be best harmonized among various fisher groups, e.g. the setting of minimum legal size limits and reporting requirements. Co-management also plans for scientific information from fisheries managers to be a compulsory part of decision-making. Meet with the fishers and fishing communities to see how best these institutions can be formed.

Seek legal help to delegate authority of some management decisions to local-level institutions (i.e. to fishing cooperatives or fishing communities) and clearly define which decisions they have authority over and which ones they do not.

Similarly, arrange to devolve other management activities, like surveillance and enforcement, and internalize "externalities", such as monitoring and research (Parma, Hilborn and Oresanz, 2006). Local-level management institutions should be required to develop a management plan associated to their fishing grounds, which would include monitoring, evaluation and enforcement (Hilborn, 2004). The fishers, or fishing communities, will be in a position to determine appropriate expenditure on research and enforcement (Hilborn, Oresanz and Parma, 2005). Some simple monitoring may be undertaken by fishing communities, but government fishery agencies may need to retain this role, perhaps through an industry levy to recover costs (FAO, 1995; Hilborn, 2004). Fisheries agencies should still allocate funding to support meetings and operationalise management decisions made by local-level institutions, and engage with scientists and NGOs to assist with information and training – this can be one of their roles in co-management.

Work with fisher groups and communities to foster collaboration and open communication. Forming fishers' cooperatives may, for example, be a better vehicle for gaining market access and product labelling than government-run programmes.

EXAMPLES AND LESSONS LEARNED

Galápagos Islands, Ecuador

In the Galápagos Islands, a Special Law in 1998 establishes a participatory management system for the Galápagos Marine Reserve (GMR). This administration system involves both, local and national management of the Marine Reserve. Locally, through the Participatory Management Board (PMB), a forum represented by five stakeholders: Artisanal Fisheries Cooperatives, Naturalist Guides, Chamber of Tourism of Galápagos, Scientific Sector (currently the Charles Darwin Foundation) and the Galápagos National Park Service (GNPS). These stakeholder groups participate actively in development of management measures for the GMR and all decision-making is based on consensus. The resolutions taken by the PMB are presented to a national forum, called the Inter-Institutional Management Authority (IMA), which makes a final decision through a vote system.

While the Galápagos has a complex institutional arrangement for participatory management, it has not been a single solution to the problem of overexploitation and significant challenges remain for the management of Galápagos' sea cucumber resource. The sea cucumber *Isostichopus fuscus* is showing severe signs of overexploitation and conflicts between the fishing sector and the scientists and conservation managers. Therefore, although participatory management has allowed fishers and other stakeholders to become a part of the management process, the lesson is that several other factors must be addressed for this management system to be successful:

- The participatory management process may take some years to work effectively and must be funded adequately.
- The decision-making process needs to be explicitly bound to follow the best scientific advice available and in accord with resolutions from meetings among stakeholder groups.
- The management process should be divorced from government politics. That is, the management process should be designed such that changes in a nation's political parties do not undermine the management decisions or implementation.
- The Marine Park Authority or fishery agency should be given a legal authority to enforce the management regulations. Enforcement should not rest with agencies that are unable to conduct routine and impromptu inspections of fishing vessels or landing and processing stations.
- Members of the stakeholder groups should be designated to serve on the management committees for a lengthy period (e.g. 2 years) to maintain consistency in representation at meetings and knowledge about past and future directions.

Source: P.C. Martínez.

Papua New Guinea

The National Fisheries Authority (NFA) through the Coastal Fisheries Management and Development Project (CFMDP) recently attempted to accommodate changes to the 1998 *Fisheries Management Act* that would support local-level fisheries management. Under the proposed changes, the rights of the customary owners of fisheries resources and fishing rights would be fully recognized within three nautical miles of the baseline. The regulations also attempted to provide authority for customary owners in all transactions affecting the resource or the area in which their rights operate, including any relevant fishery management plans developed by them, and designated community-based fisheries management areas, as long as they were consistent with and not in conflict with existing national management plans. Technical assistance, if required would have been provided by the NFA, provincial or local level governments, or competent non-governmental organizations.
Source: J.P. Kinch.

New Caledonia, France

In 2007, the fishery service of the Northern Province cooperated with one community (Tribu Boyenne) to have some authority to manage the sea cucumbers on reefs in their [de-facto] jurisdiction, through a process of co-management. The fishers must still abide by the provincial fishery regulations (e.g. size limits, prohibition of SCUBA or hookah and night diving). On the other hand, it is the community that decides when certain fishing grounds can be open to fishing sea cucumbers and when they are closed to fishing. The community also appoints persons to help with periodic population surveys on the reefs to determine if densities and body size have reached pre-determined levels to warrant opening the fishing closure. This is done in cooperation with technicians from the Provincial Fishery Service. In addition, the community is also encouraged by the Fishery Service to undertake some simplified visual censuses to estimate sea cucumber densities on the reef to monitor their recovery after fishing episodes.
Source: S.W. Purcell.

6.2.2 Establish management advisory committees

Definition

Support to enable the formation of multidisciplinary bodies of stakeholders that provide information and advice on the best practices for the management of the fishery.

Some of the members of management advisory committees (MACs) may be directly involved in the fishery whereas others are not. They can include fishing cooperative representatives, fishery managers, scientists, local representatives, decision-making authorities and social workers.

Uses

One use of MACs is to bring a wider range of views and aspirations into the decision-making process. In this sense, they also provide integrated information on technical aspects, such as marketing, population dynamics and socio-economic drivers, to enable management decisions with a holistic view on the fishery. They are also a vehicle for bringing forward advice on the feasibility of management options and monitoring of the fishery. Through the process of open discussion, progress can be made towards overcoming mistrust that may exist between fishers and fishery managers and researchers.

Consultative Committees (CCs) are similar to MACs and tend to be used for smaller or developing fisheries (Smith, Sainsbury and Stevens, 1999). MACs and CCs provide a forum for assessing the potential consequences, costs and practicality of various scenarios of management regulations through "risk analysis" or "management strategy evaluation" (Smith, Sainsbury and Stevens, 1999). Risks may come in the form of uncertainty about: (1) sea cucumber stocks and the environment; and (2) dynamics and feedbacks that determine the future stock levels, including human factors (Grafton *et al*., 2007). Through such processes, key uncertainties can be brought to the fore and group members are able to agree upon performance criteria by which the management scenarios can be judged. Setting clear performance criteria at the onset allows for a more objective process of adaptive management later on.

An operational advantage of advisory committees is subsequent compliance by fishers and other stakeholders for that matter. Because the management decisions, or at least recommendations, are formed through mutual agreement of the committee members, MACs gain broader acceptance and ownership of management decisions than top-down systems (Smith, Sainsbury and Stevens, 1999).

Limitations

Unless they are carefully composed, advisory bodies may not be in the best interests for the long-term sustainability of the resource or detached from the reality facing fishers and their aspirations. Members may have vested interests or the committees may be inappropriately biased towards one stakeholder group (e.g. composed of too many scientists). Advisory committees may simply lack the required expertise for certain roles, e.g. experienced social scientists or fisheries biologists.

Owing, in part, to the multisector nature of advisory committees, it may be difficult to reach consensus about management decisions. In fact, it may be equally difficult to reach consensus among scientists or fishery managers. Disputes, or differences of opinion, can stall the decision-making process. Full consultation with industry and other interest groups through MACs can often be time-consuming (Smith, Sainsbury and Stevens, 1999). In this respect, MACs should be formed by stakeholders that are prepared to negotiate to achieve acceptable compromises where necessary.

While advisory committees may easily reach consensus, they are, after all, bodies to provide advice and usually lack the authority for decision-making. The advantage of the committees may be lost where advice is not taken by decision-makers, and this can undermine motivations for involvement.

How to implement

If MACs or CCs do not currently exist, managers should firstly develop a list of credible and skilled stakeholders and experts and decide on the make-up of the committee. Members should have seniority and standing in each field of expertise and, preferable, an intimate knowledge of the fishery. Participants include fisheries scientists, conservation biologists, economists, sociologists and industry representatives. A chairperson should be assigned, which could be a fishery manager, scientist or an independent facilitator for neutrality. Other members should be assigned, perhaps through a rapid consultative process. Committees should best comprise a relatively small number of selected key experts and industry representatives, e.g. 5–10 members.

Define and decide on committee purpose, objectives and protocols (e.g. establish meeting schedules). It may be useful to develop a series of broad management objectives and a code of practice, and get the MAC or CC members to sign their acceptance of the code formally (Smith, Sainsbury and Stevens, 1999). The code could include principles of confidentiality, a willingness to negotiate and seek compromises with other group members and a declaration that their involvement will exclude personal agendas and other subjectivities.

Notify stakeholders of intending meeting dates, to enable adequate preparation of stakeholder concerns. Disseminate the contact details of all representatives. Develop a process by which the key concerns and decisions from meetings can be disseminated to other stakeholders. The manager may need to develop a summary of the state of the fishery, to brief the MAC members prior to meetings. Likewise, the legal framework for decisions and the existing legislation related to the fishery should be summarized for MACs.

Ensure that MACs have adequate funding. Ideally, MACs or CCs should be fully funded from the industry via taxes or levies on transactions of sea cucumber harvests. There may need to be some incentives for members to attend and plan for involvement in advisory committees.

EXAMPLES AND LESSONS LEARNED

Japan

Sea cucumber fisheries are managed by different prefectures, managed by a fishery cooperative association under the authority of the prefectural governor. Each fishery cooperative association has to obey the Fishery Adjustment Regulation issued by the Sea-area Fishery Adjustment Commission (SFAC) of each prefecture. Various regulations (e.g. fishing gears, fishing zones, closing periods and size limits) are specified for each species by each SFAC. The SFAC is generally composed of fifteen commissioners; nine of whom are elected fishermen and six others (four fishery scientist and two members of the public) appointed by the governor. The SFACs play an advisory role in the fisheries and all matters handled by the administrative agency with regard to fishery regulations. Fishery rights and permits are not processed until advice is received from the SFAC, which has the authority to decide on the arbitration, instruction and authorization of permits, etc.
Source: J. Akamine.

Great Barrier Reef, Australia

On the Great Barrier Reef, the Harvest Fisheries Management Advisory Committee (Harvest MAC) provides advice on the management of Queensland harvest and developmental fisheries to the state's Department of Primary Industries and Fishery (DPI&F). The committee includes representatives from industry, DPI&F, the Great Barrier Reef Marine

Park Authority (GBRMPA), Queensland Park and Wildlife Service (QPWS), Queensland Boating and Fisheries Patrol (QBFP), recreational fishers, scientists and a permanent observer from the Department of Environment and Heritage (DEH). The Harvest MAC meets twice a year to discuss recent developments in the fishery and data collected, and to consider the adequacy of management arrangements. At the request of the Harvest MAC, a beche-de-mer working group is occasionally held to discuss a particular issues relating to the sea cucumber fishery. The working group generally consists of a scientist, the DPI&F fishery manager and representatives from industry (e.g. fishers), GBRMPA, QPWS, QBFP and DEH.
Source: S. Uthicke.

Papua New Guinea

Under the 2001 *National Beche-de-mer Management Plan* (NBMP), a National Management Advisory Committee (NMAC) was formed in 2002 to provide advice to the Managing Director on the management of the sea cucumber fishery. The NMAC is responsible for proposing TACs, closed seasons, reporting, restrictions and trade regulations. It includes stakeholders across Papua New Guinea to provide advice on management measures and revisions to the management plan, deemed necessary through consultation with relevant stakeholders.

The NBMP also allows for the formation of Provincial Management Advisory Committees (PMACs) in all coastal provinces. These are established to advise the NMAC on province-specific management. The PMACs may, in consultation with their respective provincial government, develop a plan for any additional management controls that are needed for their sea cucumber fishery. The National Fisheries Board can then endorse these plans if they are consistent with the NBMP. The participation of the NMAC and PMACs is indicated below:

NMAC membership	PMAC membership
2 NFA representatives	1 Provincial administration representative
1 Fisheries scientist	1 District administrator
2 Customary fisher representatives	3 Customary fisher representatives
2 Company representatives	2 Company representatives
1 NGO representative	1 NFA representative
1 Representative from the 4 Region Fisheries Secretariats	1 Provincial fisheries officer
	1 NGO representative

Source: J.P. Kinch.

Western Indian Ocean

During the developing stage of the sea cucumber fishery in the Seychelles the management followed a top-down approach where the Fisheries Authority took the decisions (Aumeeruddy and Conand, 2008). Now there is an Advisory Management Committee composed of representatives from different government departments, boat owners, divers, processors and one NGO.

In Madagascar various actions have been taken during the last two decades to involve different participants of this fishing sector, including fishers, exporters, managers and scientists (Rasolofonirina, 2007; Conand, 2004, 2008). The National Association of Sea Cucumber Producers (Organisation nationale des exploitants des trépangs et holothuries – ONETH) was created in 1996 through a pilot operation. ONETH encountered several problems at its inception but it is now an active association.
Source: C. Conand.

6.3 LEGAL REQUIREMENTS

6.3.1 Legislation of management regulations

Definition

Facilitate and support processes that enable fishery management measures to be formalised into legal instruments or documents whose conditions and consequences are well understood and can be enforced and monitored. Interventions could be conditions of local ordinances or international conventions such as CITES.

Uses

Managers should take appropriate actions to ensure that management decisions are properly set in to the legal framework of the managing institution (e.g. be it a government fishery service or a community group) so that they are duly respected and can be legally enforced. Through the process, regulations can be more specifically defined because the wording is carefully considered in a legal context. Fisheries enforcement officers can be empowered through regulations in legislation as they are less subject to fishers demanding partiality or leniency.

By facilitating management regulations into the legal framework, they are thereby endorsed by local, national, regional, international institutions. For example, regulations placed into local legislation carry thereafter the endorsement of the local legislative body, in addition to the fishery managers. Regulations ratified by international bodies, like CITES, oblige other organisations to abide by the regulations because non-compliance can be sanctioned in international meetings. Setting regulations into the legislative framework therefore promotes responsible action. In addition, management decisions placed into legislation beckon accountability, because the legal institution is responsible for prosecuting non-compliance.

The effectiveness of regulatory measures can be improved through dissemination of legislative regulations, as these are often made public. They are commonly accessible via fishery bulletins, libraries or the Internet.

Limitations

There may be poor legal support in some regions or countries for placing management regulations in to legislation in a timely fashion, or aptly prosecuting fishers, processors or exporters that breach the regulations. Similarly, limited capacity of fishery services (Section 2.3) or local management institutions may make it hard to clearly define the regulatory measures. They may, alternatively, lack the know-how or motivation to place management decisions into law.

Unfortunately, there may be much motivation by advisory committees or management agencies to impose certain regulations, but these may be undermined thereafter by political manipulation (and unwillingness) and corruption.

Legal advice may be limiting for many community-based management institutions to set regulations into correct legal frameworks that make them binding and allow offenders to be prosecuted.

How to implement

Initiate an assessment of policy and planning needs for the fishery. This should include a review of the processes by which resource management is placed into legislation, at the level of the managing institution. Find out what are the requirements of the legal system and the common timeframes for getting regulations set into legislation.

Draft the fishery regulations in a concise manner in simple terms that can be understood by everyone. Critically judge the wording for ambiguities or loopholes, whereby fishers, processors or exporters could argue around the wording to avoid prosecution. If possible, seek technical and legal advice (including appropriate instruments for penalties) once the fishery regulations have been drafted. Communicate with decision-makers at a high level to seek their endorsement of the draft regulations and advice about the process for submission.

Once the wording of the draft regulations has been finalised, submit the finalised regulatory measures to the legislative council or government body.

EXAMPLES AND LESSONS LEARNED

Solomon Islands

In the past, fisheries management in the Solomon Islands has been reactive rather than proactive; usually addressing a problem after it had arisen. Previously, there was no formal management plan for the sea cucumber fishery despites its importance as an income source to rural coastal and island peoples and revenue generation for the national government.

In December 2006, the Permanent Secretary for Fisheries closed the sea cucumber fishery because of evidence of severe over-harvesting and stock declines. The plan was for it to stay closed until regulatory measures were developed for the fishery. This changed with the occurance of an earthquake and tsunami in April 2007, which dramatically reduced the income of communities in rural areas, led to the fishery being opened in May. It was declared that an interim management plan for the fishery would be developed quickly, for 2007, and that the fishery would stay open until December 2007, after which it would be reviewed and operated under a more permanent set of management arrangements.

If the Solomon Islands government decides to implement a *National Beche-de-mer Management Plan* under its new *Fisheries Management Bill,* it is envisaged that management arrangements will involve two levels, national and community. National-level regulations will apply uniformly across the country or provinces (size limits, fishing closures, seasonal opening, etc.), while at the community level, communities will decide on area closures – or may decide to have closures for particular species; as long as they do not conflict with the national regulations.

Source: J.P. Kinch.

Galápagos Islands, Ecuador

With the passing of the Special Law of the Galápagos (SLG) in March 1998, along with creating the Galápagos Marine Reserve (GMR), the SLG established a participatory and adaptive management plan for the GMR. This system promoted regulatory measures and interventions into legalisation as it empowered decision bodies to implement and enforce such regulations.

Any decision pertaining the management of the GMR must be evaluated first in the Participatory Management Board (PMB) which takes decision based on the consensus of the five major local stakeholders of the GMR (Fishing, Tourism, Management – Galápagos National Park Service (GNPS), Science, Conservation and Education, and Naturalist Guides). These decisions are then evaluated at a Ministerial level or Inter-institutional Management Authority (IMA), with decisions made under a voting system. The final resolution is then re-directed back to the GNPS, who has the mandate to put such decision into a legal framework (or "*Resoluciones*") that will apply to the activity in question. This "*Resolución*" is then made public and it will contain the regulations and management tools to be used in the regulation of any activity.

Source: V. Toral-Granda.

6.3.2 International agreements and CITES

Definition

Binding or non-binding arrangements between governments that promote cooperation towards common interests and objectives.

Uses

Management and conservation of sea cucumbers might need international support because the geographic distribution of most species goes beyond political boundaries and trade involves international markets.

One example of international agreement towards the control of trade in species of conservation concern is the Convention for International Trade of Endangered Species (CITES). CITES aims to ensure that trade in wild animals is commensurate with their conservation. It does this by providing a legislative and regulatory framework for international cooperation in controlling trade of animals listing in Appendices I, II and III of the Convention (FAO, 2004). At present, *Isostichopus fuscus* of the eastern Pacific is the only sea cucumber species included in CITES, with Appendix III listing (Toral-Granda, 2008b). Listing of species under one of the three Appendices will afford certain levels of control on trade (FAO, 2004; Sant, 2006):

Appendix I: offers the highest protection for species that are threatened with extinction from international trade. Trade of listed species is only authorized in exceptional circumstances.

Appendix II: offers moderate protection for species that could become threatened if their trade is not effectively regulated. It does this by placing a condition on the trade of listed species, whereby countries must demonstrate that the trade is non-detrimental to the survival of the species in the wild. Only animals obtained in compliance with national laws can be traded.

Appendix III: provides assistance to countries (or a "Party") in the enforcement of its national trade regulations, e.g. if illegal trade is an issue. It does this by obliging other parties to apply their own domestic laws to ensure that trade is consistent with the laws of the State (i.e. country) of origin for that species.

One of the objectives of CITES is to safeguard the use of aquatic species in food security, employment and income generation (FAO, 2004). A common use of international agreements, such as CITES, is to deter illegal fishing and trade that jeopardise livelihoods or the survival of species on which they depend (Bruckner, 2006a). For instance, countries may sign agreements (e.g. CITES Appendix I or Appendix II listing) to ban or limit the trade of certain sea cucumber species, although there are no examples of this at present. Some sea cucumber species are relatively rare and some high-value species have been overfished in most localities. CITES Appendix I listing for such species would be one way to protect them from extinction. Such conventions also help to ensure that fishing practices are sustainable to allow exports, enhance opportunities for technical assistance and capacity building and raise awareness among stakeholders and decision-makers (Bruckner, 2006a; Toral-Granda, 2008b).

International agreements may place certain restrictions on trade through requirements for trade reporting (e.g. through CITES Appendix III) (Toral-Granda, 2008b). This can improve the standardization of trade codes and quality of trade reporting. CITES, in particular, can create an impetus for harmonising trade codes and data collection among countries (Toral-Granda, 2008b). International trade in CITES-listed species is controlled by a system of trade permits and certificates (FAO, 2004).

International agreements can help enforce national regulations. This arises through obligations and responsibilities to enforce certain fishing, processing or exporting practices. They can also be a channel for international scientific collaboration. The agreements can promote standardization of research methods and international scientific cooperation.

Limitations

Lack of political will to pursue agreements will be a significant hurdle for many managers of sea cucumber fisheries. Politicians may be unwilling to risk future constraints to fishing that international agreements may pose. There may also be conflicts of interests between potential partner countries. Where there is political will, agreement may be based on political reason and not on sound management.

Agreements may not be put into practice at the national level. They may present an administrative or economical burden (unfunded mandates) (Toral-Granda, 2008b). Implementation of the agreements may require unacceptable costs, or be met with capacity and logistics constraints at the local and national level. For example, CITES listing can place a burden on both the exporting and importing countries by requiring permitting, training for customs and trade officers for trade interdiction and specimen identification and other regulatory measures for compliance (Bruckner, 2006a; Toral-Granda, 2008b).

The problem of identifying specimens of listed species in international trade is a significant one (FAO, 2004), especially so for sea cucumbers which can be difficult to identify without proper training. Technical needs of implementation such as guides for species identification and the work to report non-detriment findings (for Appendix II listed species) require a certain level of investment in administration and science (Sant, 2006). Inability to correctly identify sea cucumbers, or their organs, by customs and other officials can present an opportunity for illegally obtained animals to be fraudulently labelled or laundered under other names (FAO, 2004).

In cases where signatory countries are non-compliant with CITES regulations or reporting timeframes, the CITES Secretariat undertakes consultation with them about the problems. The challenges in complying with CITES should not detract countries from being signatories. Some assistance may be made available by CITES to countries, in certain cases, to help them in implementing the Convention (FAO, 2004).

In cases where stringent protocols for declaring exports are in place, such as in the Seychelles, controls may be sufficient already to ensure responsible fishing and trade (Aumeeruddy and Conand, 2008). Choo (2008b) discussed that CITES listing of some sea cucumbers may cause serious socio-economic problems in the Philippines. When an animal is listed under CITES, the national legislation prohibits trading of the species irrespective of the Appendix within which it is listed. In such cases, CITES listing of certain sea cucumber species within Appendix III could deprive fishers of an income and spur some to fish illegally and trade sea cucumbers on the black market (FAO, 2004; Choo, 2008b).

As yet, there are few regional and international agreements on sea cucumbers by which to use as templates for new ones. Fishery managers may be unable to initiate such agreements because of the time required in literature searching and review to write and develop the agreement. Lessons learned from listing of *Isostichopus fuscus* on CITES Appendix III are invaluable in this regard (Toral-Granda 2008b).

How to implement

Fishery managers should help to broker the process of developing international agreements for the exploitation and trade of sea cucumbers, as advocated in the Code of Conduct for Responsible Fisheries (Section 3.1). What is the national and international legal framework by which agreements can be made and enforced? Who in the country would need to sign the agreement and what can be done to brief them so they can make an informed decision?

Obtain reliable assessments of the national status of the fishery and the global status of the species being fished. See if there are any problems or limitations to trade that could benefit from an international agreement. Studies using underwater visual censuses of the sea cucumber stocks should give an indication of species that are critically depleted, rare or endemic (Section 6.1.2). International agreements may be a useful tool in preserving these stocks. For the different CITES listings, the fishery manager should find out if any of the species in the fishery are threatened with extinction or could become extinct if the current trade practices are not adequately regulated.

Examine the advantages and disadvantages of an international agreement, like CITES. Assess what the likely costs will be to develop the agreement and implement it. For example, for CITES Appendix III listing, the country with the listed species must issue an export permit that is endorsed by the management authority once it is satisfied that the specimens were obtained legally. Other Parties (i.e. signatory countries) must accompany a Certificate of Origin with exports of that species, if they have not also listed the species. Importing countries must confirm that imports of that species have an export permit of Certificate of Origin. Re-exports also require similar certification (Sant, 2006). Managers should get a clear definition of terms of reference between parties. They should also consult literature explaining the implications of CITES listing (e.g. FAO, 2004; Bruckner, 2006a).

Form a good technical-legal committee that will draft the agreement. It may be best to seek sound legal and technical advice and use templates based on other agreements. Managers wanting to propose certain sea cucumber species for CITES Appendix III listing can do so unilaterally at any time through their respective government body. On the other hand, proposals to list species in Appendix II will undergo a review and require two-thirds majority support to be accepted at a meeting of the Conference of Parties (Sant, 2006).

Put in place monitoring measures to assess whether the conditions of the agreement are being implemented. For example, develop a schedule and methodology for checking beche-de-mer exports and export data to ensure that contraband species are not being traded.

EXAMPLES AND LESSONS LEARNED

Galápagos Islands, Ecuador

Ecuador is the only country that has listed a sea cucumber species (*I. fuscus*) in a CITES appendix. This species was included in Appendix III on 16 October 2003 and since then most of the catches from capture fisheries from the Galápagos Islands have been recorded in CITES permits. However, in mainland Ecuador there are both capture fisheries and aquaculture production that has been exported to the oriental market, with no records of a CITES permit. Mainland exporters and fishers claim that the species collected is not *I. fuscus* – this illustrates one of the problems of the listing with little or no training for export agents, border patrol and custom officers.

The listing of *I. fuscus* in CITES Appendix III has shown advantages and disadvantages (Toral-Granda, 2008):

Advantages:

(i) Certainty of the legality of the catch of the exported goods
(ii) Increased awareness of the need to conserve and manage sea cucumber populations
(iii) Possibility of identifying trade bottle necks where illegal catch may be laundered to
(iv) Better opportunities for technical assistance, targeted research and capacity building
(v) Creating and putting into place standardized and comprehensive trade reporting codes and data gathering amongst countries
(vi) Catch and export data are centralized in one area, allowing faster analysis and quicker returns for the analysis of trade bottlenecks
(vii) Understanding of the trade route when it leaves Ecuador

(viii) Understanding that international trade is the major force behind the exploitation of *I. fuscus* in the GMR
(ix) Curtailing international trade by means of an attached CITES permit that ensures the legality of the catch.

Disadvantages:
(i) Increased burden to CITES administrative officers (i.e. processing of permits, compilations and submission of annual reports to the CITES Secretariat)
(ii) Increased costs to train and educate managers, border patrol and custom officers
(iii) Problems in identification to species level, as many processed sea cucumber look alike
(iv) The lack of communication between the Galápagos and mainland Ecuador CITES Administrative Authority offices, has created some conflict of interest and delayed response in certain cases
(v) Aquaculture production from mainland Ecuador claims that their species in trade is not *I. fuscus*, hence all exports leave the country without a permit. This could be solved if there will be more trained personnel in mainland Ecuador that could clearly identify the species traded
(vi) Delay in acquisition of the CITES Secretariat trade reports on CITES species

Currently, Ecuador has no intentions on up-listing *I. fuscus* to any of the other two Appendices. Perhaps greater success with such listing could be achieved if all *I. fuscus* range States would decide to include the species in the same appendix, so as to deter illegal shipments from other countries and to promote greater awareness and conservation.
Source: V. Toral-Granda.

Pacific, Micronesia
An example of a non-binding international agreement of relevance to the conservation of sea cucumber stocks in the Pacific is the "Micronesia Challenge". The "Micronesia Challenge" is a regional intergovernmental initiative in the western Pacific region aimed to facilitate the effective conservation of marine and forest resources in Micronesia. On 5 November 2005, President of Palau Tommy E. Remengesau Jr. called on his regional peers to join him in the "Micronesia Challenge", which would conserve 30 percent of near shore coastal waters and 20 percent of forest land by 2020. Joining the initiative were Palau, the Federated States of Micronesia and Marshall Islands and the United States of America territories of Guam and Northern Mariana Islands. These nations and territories represent nearly 5 percent of the marine area of the Pacific Ocean and 7 percent of its coastlines.
Source: K. Friedman and The Nature Conservancy.

6.4 ASSIGN ACCOUNTABILITY

Definition

Assigning to named persons, or entities, the obligation to demonstrate and take responsibility for performance of the fishery in light of commitments and expected outcomes.

Uses

Assigning accountability for the success or failure of management provides a foundation for decision-making process. It promotes more commitment to act responsibly and take ownership of the consequences for poor judgement in fisheries management. Accountability gives strength to the management system and credibility to participants.

Accountability can help in identifying the decision-makers in co-management or community-based management systems. It is used not just to lay blame on those responsible if the stocks collapse, but rather to identify mistakes and errors so that they can be remedied (Grafton *et al*., 2007).

Accountability also extends to the provision of scientific information. Nominating who is accountable for scientific advice will afford more care in the advice given, how it is worded and the associated conditions or uncertainties. Likewise, there may be official accountability for communication or enforcement of regulations. For example, fisheries officers may be made accountable for ensuring that all fishers and processor are aware of the regulations, whereas customs officers can be made accountable for checking shipments of beche-de-mer for undersized product or shipment of contraband species.

Limitations

Turnover of decision-makers, e.g. by elections or political appointments, erodes clarity about who is accountable for fishery performance. Without strong governance, accountability may foster a reluctance to take hard decisions. Conversely, there may be a lack of political will to take actions against those accountable for decisions, scientific information, surveillance or enforcement.

Qualified people, such as fisheries scientists, might be deterred from participating in management if they will be held accountable for inaccuracies in their advice.

How to implement

The legal framework by which people can be held accountable and penalised needs to be understood. What are the legal consequences for improper decisions, actions or advice? Likewise, the legal framework and process for assigning accountability should be determined and understood.

Next, define clear reference points by which accountability can be judged (Section 3.4). There should be little room for interpretation about the reference points. Define the duties and responsibilities of various participants in the management process.

Set clear performance indicators at various levels: ecosystem, fish stocks and economics so as to identify the effects of regulatory measures and management actions (Grafton *et al*., 2007; Section 3.4). Ideally, operational accountability in the management of the fishery should rest at the management level, with the people most qualified to make the decisions, but politicians should also be made accountable for ensuring adequate funding and the governance structure. Ensure that those accountable and responsible have the appropriate authority to make decisions (Grafton *et al*., 2007).

Define and implement meaningful sanctions, or remedial action, for breaches of responsibilities and enforce these consistently. Such sanctions should be clear to participants at the onset. Ensure that best practise and best available information protects participants in case of failure (to encourage experts to participate).

Promote transparency by making the accountability public. Also, provide a forum for feedback about accountability.

EXAMPLES AND LESSONS LEARNED

Accountability in fisheries co-management: lessons from Asia

"Co-management means having a process in which business is conducted in an open and transparent manner. All partners must be held equally accountable for upholding the co-management agreement. The partners have common access to information. Venues are provided for public discussion of issues and to reach consensus. There needs to be

accepted standards for evaluating the management objectives and outcomes. Without strong accountability, decision-making can become corrupt and arbitrary. A body outside of the community, such as government or an NGO, may need to monitor and evaluate the co-management process. This outside body can serve to provide checks and balances to make the process more accountable in a formal way. Formal agreements will require a structure for legal accountability among the partners."
Source: Pomeroy, Katonb and Harkes, 2001.

6.5 ENFORCEMENT

Definition

Intervention to ensure that users comply with management regulations and enable penalties to be asserted to offenders.

Enforcement may entail physically checking catches, gear used on boats, or the areas being fished, and imposing fines or other sanctions if the catch or fishing gears are not in accord with the regulations.

Uses

Enforcement of regulations is an often-neglected aspect of fisheries management (Hilborn, Oresanz and Parma, 2005). Its goal is to ensure that all actors in the fishery, from fishers to exporters, comply with management regulations. For example, enforcement can serve to protect resources in areas closed to fishing (e.g. within no-take reserves), or protect small individuals (through enforcement of size limits), or protect certain species (via species-specific bans or TACs). Most usually, some form of enforcement is needed for the management measures to be followed.

A further use of enforcement is to confirm that fishing practices correspond with management regulations and principles. Managers are called upon to implement effective fisheries monitoring, control, surveillance and law enforcement measures (FAO, 1995; Figure 13, Section 3.1). Breaches of fishery regulations can be shown via reports from enforcement officers to allow managers to adapt the management regulations.

Enforcement can also enhance compliance by providing an example that offenders will be prosecuted for breaches. For instance, if one processor/exporter is fined, or has his/her licence revoked for one year, due to undersized beche-de-mer being found in bags for export, other processor/exporters will likely comply more vigilantly.

Limitations

A common reason, or excuse, for poor performance of management in sea cucumber fisheries is a lack of resources for adequate enforcement. This arises commonly in top-down (government-run) management systems when the responsibility for enforcement resides with the national fisheries agency, where the geographic scale of the fishery is large and where inadequate funds are given by government. There are commonly too few funds to cover the employment of enough enforcement officers and inspection costs, particularly for inspections at sea. Alternatively, the managing body may be constrained by technical capacity of the fishery officers to conduct inspections and understand the laws (see Section 2.3). In some sea cucumber fisheries, fishery officers or customs officers need to identify many different species, which are in a processed form.

Enforcement meets conflict with fishers if they do not understand or have not been made aware of the regulations. Conversely, it may be unclear who has authority and responsibility for enforcement. These problems are particularly evident when there are multiple regulatory measures in the fishery, or where the regulations vary from one region to another. Conflicts may arise if fishers, processors or exporters argue that they have not been informed about the regulations. Simple and consistent fishery regulations will be easier to enforce.

There may be a lack of political will to enforce the regulations (i.e. prosecute offenders). In addition, sanctions may not be appropriate or severe enough to discourage offenders. In some countries, there may be opportunities for corruption of the enforcement process, undermining its effectiveness for sustaining the resource.

How to implement

Fishery managers should do the following:

1) Determine the technical and human-resource capacity of the management institution.
2) Assess whether skills, personnel time and fund are available for fishery officers, customs agents, or community "sea rangers".
3) Provide sufficient funds for the enforcement, as advised in the Code of Conduct for Responsible Fisheries (FAO, 1995).
4) Assign the authority for enforcement – e.g. authority to inspect sea cucumbers of fishers at sea or beche-de-mer in bags for export. This may be given, for example, to officers in fisheries departments or conservation departments, or to local "sea rangers" in communities.

Problems arise when fishery officers and research staff have the task of enforcing regulations in addition to their responsibilities in management (King, 2007). Compliance is usually higher when stakeholders have been involved in developing the management and better again in community-managed fisheries (King, 2007). Where centralised agencies are vested with the task of enforcement, separate sections for compliance should be formed. For example, within Seychelles Fishing Authority (the managing agency), a Monitoring, Control and Surveillance section is responsible for random inspections of sea cucumbers at processing factories and inspection of consignments of beche-de-mer before export (Aumeeruddy and Conand, 2008). The enforcement officers should be given training to understand the regulations, the methods they can use to inspect sea cucumbers or fishing activities and the rights of the actors. If locally relevant identification guidebooks are not available (see Section 6.1.1), prepare some suitable reference material, even simple sheets for identifying fresh and dried sea cucumbers. Moreover, support and coordinate training sessions or workshops in identifying the various species in different forms. The fishery manager may also need to support or facilitate the governance structures of the communities and stakeholder groups so that enforcement is effective.

Decide how the regulations will be enforced. For example, will there be inspections at sea and inspections of processed sea cucumbers before export? Inspecting processed and semi-processed sea cucumbers at processing centres will generally be easier than inspecting landings of fishers, and will have logical flow-on effects to fishing activities (Friedman *et al*., 2008a; Purcell, Gossuin and Agudo, 2009a). In contrast, inspections at sea require several people, involve more travel time and incur substantial costs in boat use and maintenance. Inspections of fishers may therefore be best at landing points, if these are centralised (e.g. at town boat ramps). The use of Vessel Monitoring Systems (VMS) can be an auxiliary tool for enforcing space-based management measures, especially in more industrialized fisheries.

Develop inspection sheets to record what has been done and said. The enforcement body should also establish a periodicity for inspecting catches and exports of sea cucumbers – who will do the inspections and how often.

Set out the penalties for various infringements, which may consist of a range in penalties depending on the severity of the infringement. Find out from fishers or communities what penalties will be realistic and a deterrent for infringements of various regulations, as well as the potential conflicts in enforcement and applying penalties. For example, a fisher with two undersized sea cucumbers would naturally expect a less severe penalty than one with two hundred. For small-scale fishers with community-level management institutions, penalties may be the removal of certain privileges or payment in traditional commodities (pigs or crops). In more modern fisheries, penalties could be monetary fines, loss of boat, cancellation of fishing licence for one or more years, or a partial loss of fishing privileges for a certain time (e.g. a reduction in their quota by a certain percentage in the following year). Above all, penalties should be clear and imposed consistently.

Ensure that all actors in the fishery (i.e. fishers, processors, exporters) have been given ample notice of the fishery regulations and understand how the sea cucumbers or their activities may be inspected and by whom. They should also be told about the wording of the laws and the penalties that can be imposed.

EXAMPLES AND LESSONS LEARNED

Bolinao, The Philippines

The municipality of Bolinao through its organized Bantay-Dagat has been primarily responsible for the enforcement of fishery laws in its municipal waters. Regular patrolling duties are allocated by the municipality and the enforcers are also linked to an inter-Local Government Unit system of enforcement among several municipalities. On the other hand, the monitoring of landed catches is carried out by the Bureau of Fisheries and Aquatic Resources (BFAR). The municipality of Bolinao admits to technical and financial limitations to conduct regular monitoring. Recently, a Conservation Partnership Agreement and other instruments appear to have facilitated better compliance to the fisher registration and licensing.
Source: R. Gamboa.

Papua New Guinea

Papua New Guinea manages its sea cucumber fishery via the 2001 *National Beche-de-mer Management Plan* through the statutory authority, the National Fisheries Authority (NFA). Management regulations in the *National Beche-de-mer Management Plan* include licensing and reporting requirements, access restrictions, minimum legal size limits, gear restrictions, a closed season from the 1 October to 15 January each year, and total allowable catches (TACs) at the Provincial levels.

Despite these management mechanisms, monitoring and enforcement costs incurred to the NFA have progressively increased. Most cases are brought forward to the NFA include illegal buying (and storage) and seizure (and shipment). The activities infringe the management plan, which states that the beche-de-mer fishery in Papua New Guinea is reserved for the use of citizens only, and only Papua New Guinea citizens and Papua New Guinea citizen enterprises may hold an export licence to trade beche-de-mer. Shipments of beche-de-mer products between provinces is not permitted except with written authorization from the Managing Director of NFA.
Source: J.P. Kinch.

6.6 EDUCATION AND COMMUNICATION WITH STAKEHOLDERS

Definition

The exchange of information about the management of sea cucumbers in order to improve stakeholders' understanding and acceptance of management principles and to incorporate their concerns and knowledge in the management process.

Communication with fishers means far more than just informing them of the fishing regulations – it also allows for discussion about the biology of sea cucumbers (e.g. to understand stock recovery), information on the status of stocks in the fishery and principles behind the management regulations (Figure 33).

Uses

Communication with fishers and processors has an obvious use in ensuring that they know the fishery regulations, but it should go much further (Purcell, Gossuin and Agudo, 2009a). Communication about regulatory measures should be accompanied by some education from fisheries officers about why the regulations are in place and how they act towards sustainability and efficiency of the fishery (Figure 13; Section 3.3). The process of educating all stakeholders in biological and management principles helps to dispel misconceptions. Giving stakeholders a better understanding of management principles and about the basic reproductive biology and ecology of sea cucumbers will foster better adoption and compliance of regulatory measures (Figure 34). It is only when the regulations make sense that people will follow them unreservedly.

FIGURE 33
A sociologist from a sea-ranching research project in Mindanao, Philippines, discusses with members of a fishing community about the potential benefits and uncertainties of growing hatchery-reared sandfish (*Holothuria scabra*) in leased coastal sandflats

PHOTOS: R. GAMBOA

FIGURE 34
Communicating sea cucumber fisheries management with artisanal fishers in Bougainville, Papua New Guinea (left) and Pangasinan, Philippines (right)

PHOTO: J.P. KINCH

PHOTO: S.W. PURCELL

A communication programme within the fishery creates an enabling environment for better management decisions, through consensus building. Informed stakeholders are in a better position to manage their resources in co-management and community-based management systems. It also provides a vehicle for feedback to identify issues of stakeholders and information that might not be gained from underwater visual census or landing surveys. Scientists and managers need to appreciate the use of fishers' knowledge about sea cucumber populations and marine ecosystems (FAO, 2003; Section 3.1). Here, we use communication in the broad sense to include dissemination of leaflets, radio programmes, roving theatrical presentations, local presentations and newspaper articles or comics.

Limitations

Communication programmes need people with skills in communication and in-depth understanding of the fishery, biology and management principles, which do not always go hand in hand. Effective implementation is therefore as significant a hurdle as development of the communication strategy.

In some countries, there may be many different dialects or cultural disparities among fisher groups. Education materials may, therefore, need to be tailored to suit cultural sensitivities or local language dialects. Science has its own language, and the biological information on reproduction and populations' dynamics of sea cucumbers (Section 2.1) needs to be "translated" into simple terms that can be understood by non-scientific stakeholders.

There may be a lack of adequate and appropriate education materials. Managers may need to invest in developing these.

How to implement

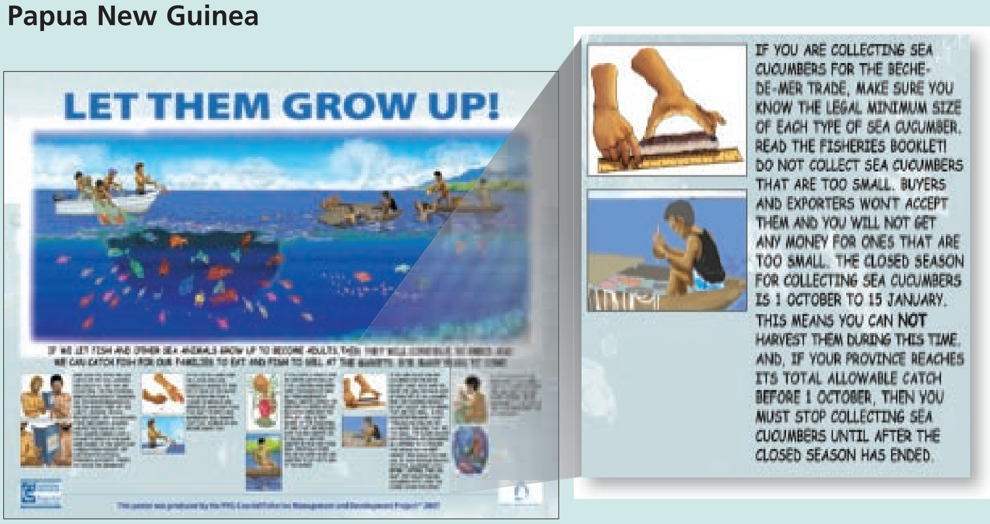
Develop a communication strategy of how fishers will be informed and what methods will be most cost-effective. Set aside funding within the fisheries management system for communication and education. Train fishery officers in communication techniques and provide them with the resources (materials, travel expenses) to visit fishers and processors regularly. A communication plan should set a periodicity at which fishery officers and other agents interact with fishers.

Identify existing education materials used in other fisheries and seek to adapt these to the local fishery. For example, comic books of fishers discussing the principles of fishery management regulations in local languages may prove more effective (e.g. *Closed Season*, published by the Papua New Guinea National Fisheries Authority). If necessary seek assistance from appropriate agencies to assist in the development and delivery of appropriate (and targeted) education and communication strategies. Try to gather feedback from the fishers, i.e. using structured data sheets, about changes in the species, sizes, catch rates and sites where they fish.

Trial the educational material on some fishers and adapt them as needed. Monitor the effectiveness of education by questionnaires to see if fishers have a correct understanding of basic biology of sea cucumbers and the principles behind the management regulations.

EXAMPLES AND LESSONS LEARNED

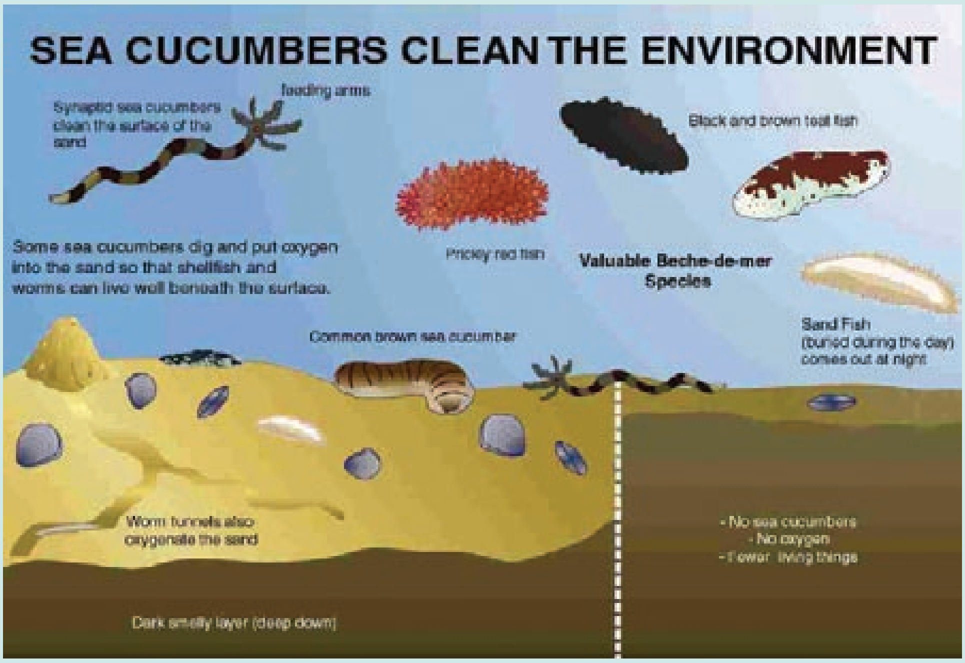
Papua New Guinea



Poster designed by the National Fisheries Authority, Papua New Guinea.

Comic book designed by the National Fisheries Authority (Papua New Guinea): left – front cover; right – example page.

Pacific



Poster designed by the Foundation of the Peoples of the South Pacific-International.
Source: J.P. Kinch.

6.7 IMPROVE QUALITY OF PROCESSING THROUGH TRAINING

Definition

Support or facilitation of training for fishers and processors in best practices for processing sea cucumbers into beche-de-mer or other marketable forms.

Processing means the transformation of live sea cucumbers into a product form that can be exported or sold for consumption (e.g. salted, frozen, dried and canned). Processing of sea cucumbers more often results in a dried product (called "beche-de-mer" or "trepang"), which can be more easily stored and transported, and is a way of value-adding of raw products suitable to the market. Processing may, however, involve canning, methods for preparing a salted product, or ways of preparing body parts (e.g. organs or muscle bands) for sale (see Section 2.4). To improving the quality of processing, managers should provide reference material, actively support training workshops (to better train fishers and processors), or improve the contacts between experience processors and fishers.

FIGURE 35
Left: small, poorly processed sandfish (*Holothuria scabra*) from the southern Philippines. The calcareous spicules expelled from the dermis of the animals after the first boiling have not been adequately removed and the body forms are contorted. Right: large, well-processed sandfish in New Caledonia

PHOTOS: S.W. PURCELL

Uses

Promoting better processing of sea cucumbers provides a number of direct and indirect benefits. Managers should promote the adoption of technology for the best use and care of the catch (FAO, 1995; Section 3.1). Improving the quality of processing of sea cucumbers allows fishers to make more money out of the animals they harvest (see Section 2.2), thus enhancing household incomes and the proportionate gains for national revenues through taxes.

Indirectly, improvement to processing can ease the stress of fishing on sea cucumber populations. Fishers may harvest fewer animals because they have made sufficient money out of fewer well-processed animals. Additionally, fewer animals are discarded through careful processing, resulting in fewer animals being removed from the wild to meet fishers' livelihoods (Figure 35).

Effectively, better processing shifts the emphasis of income generation from harvesting to processing. By paying more attention to the money that can be made (or lost) through processing, less time can be spent at sea and more time is spent in adding value to the catch. This shift can open up job opportunities through processing.

Improved processing, on a broad scale, helps to raise and standardise, the quality of all sea cucumber products coming out of a country. Training fishers and processors that are processing poorly works to ensure that low-quality product is not tainting the overall exports.

The training could initially focus on best-practice methods and later include new processing methods, e.g. arising from changes in market preference. Training may also look at alternative ways of discarding the guts and liquid from processing or find alternative uses for the waste products.

Limitations

Experienced processors may want to keep their methods confidential, to maintain market competitiveness. Fishery technicians/officers may then need to do the training with information they can gather from literature or advice from processors. There may be little interest from the larger processing companies and buyers to train fishers in rural areas (Figure 36).

It is evident that there is no single "best-practice" method for processing sea cucumbers. This is partly due to the fact that the product preferred by importers varies among regional and global market centres. Therefore, not all buyers want the same processing methods, so training must either present a range of methods or be tailored to suit the preferences of the exporters. Processing methods have evolved considerably

FIGURE 36
Boiling of sea cucumbers in rural communities in the Western Province (left and centre) and Milne Bay (right), Papua New Guinea

PHOTOS: J.P. KINCH (LEFT AND CENTRE)

PHOTO: G. MCKIE (RIGHT)

in recent years, so some training may either fail to embody recent changes or become obsolete as new methods arise. Alternatively, fishers may be relatively transitory, in which case workshops need to be repeated because the expertise is lost over time.

The processing of sea cucumbers into beche-de-mer requires substantial supply of fuel wood which is sometimes not available, especially in small islands. In some cases the demand for fuel wood can become a cause of deforestation and ecological impacts (see *Examples and lessons learned* below).

Management agencies may lack the resources or expertise to conduct training themselves, and so rely on contracted trainers. Qualified consultants may be relatively costly.

Information needed

Naturally, there must be a need in the fishery for fishery managers to intervene in processing. In some fisheries, there are few fisher/processors and sea cucumbers are already being processed to a high standard. In other fisheries, a small number of processors may do most of the processing work but some fishers may still prefer to, or need to, process sea cucumbers and not practice good handling techniques (Purcell, Gossuin and Agudo, 2009a). Therefore, fishery managers should assess what grades of sea cucumbers (albeit salted, frozen or dried) are being exported, whether some exports are of lower grade due to processing, and whether there is wastage in some poorly-processed animals being occasionally discarded. This information can be sought from overseas buyers and the local processors themselves.

If poor processing is a problem, identify where this occurs. It may also be useful to conduct a study on the economic returns to fishers for their time in processing and whether they can process to a high enough standard. If the fishers have the skills and equipment to process well, then it is probably better to train them and have processing done locally. But the economic trade-offs of this should be examined.

Prior to any training, the manager should know which processing types are preferred by the importer or overseas buyer. For instance, Singapore importers do not want smoked product whereas China, Hong Kong SAR, buyers like smoked beche-de-mer (Figure 37).

The modes of training should be evaluated. Are workshops the best approach, or would it be better to disseminate booklets in local languages? Contact appropriate research and development institutions to see what reference information (manuals, articles, leaflets) already exist on processing methods. Where they exist, support and strengthen co-operatives for training the processors. Develop a simple information product (e.g. manual, handbook, species pamphlets), which details minimum handling

FIGURE 37
Left: woman drying and smoking a local catch of sea cucumbers at Tsoi, Papua New Guinea. Right: a mixture of sea cucumber species being sun dried in a village in Tonga

and processing requirements. If companies require a specific type of product then they should provide this further training. Managers should obtain a list of reputable processors or experienced consultants for workshops. Do the processors have skills appropriate for training people, including speaking local dialects? Would it be best for the consultants go to the communities or should fishers be supported to travel to venues to demonstrate processing procedures?

Compile information on coherent protocols for processing sea cucumbers. This should cover methods starting from the post-capture handling and gutting all the way to the final processed product. Consider providing a few "recipes" for the gutting, cooking and drying sea cucumbers that are also efficient with time and fuel wood for boiling. Help to incorporate methods in the workshops or reference material about handling the waste from processing.

EXAMPLES AND LESSONS LEARNED

Papua New Guinea

In the Western Province, large quantities of mangroves are cut each season on Bristow Island to supply fuel wood to beche-de-mer processors on neighbouring Daru. The cutting of mangroves, whilst being an important economic activity for some groups who do not have the assets to actively engage in the collection of sea cucumbers, is causing deforestation of some areas where mangroves are more accessible. The production of beche-de-mer requires a large supply of fuel wood – 10 tonnes of fuel wood is believed to be needed to process one tonne of beche-de-mer.

On smaller islands in the Milne Bay Province, much of the fuel wood is obtained from driftwood. However, once this has been exhausted, fishers cut timber from the interior and foreshore. Removal of vegetation from the foreshore is having a negative impact on islands, especially smaller atolls and cays, as they are now exposed to increased wave action and thus erosion. Fuel wood has been such a problem in the Milne Bay Province, that companies sometimes send shipments of sawmill off-cuts to smaller islands to enable fishers to process their sea cucumbers into beche-de-mer.

The lesson from wood use in Papua New Guinea is that training in processing needs to extend beyond just methods of handling, boiling and drying sea cucumbers. Fishers and processors should also be trained on ways to cook sea cucumbers that require less wood, to help reduce deforestation.

Source: J.P. Kinch.

Above: mangrove fuelwood on sale in Daru, Western Province, Papua New Guinea.

Above: small atoll island in Milne Bay Province, Papua New Guinea, showing sparse trees and bushes that are easily depleted to supply firewood for processing sea cucumbers.

New Caledonia, France

The recent project by the WorldFish Center on the sea cucumber fishery of La Grande Terre, New Caledonia, used socio-economic surveys to evaluate the need the Provincial Fishery Services to promote training in processing by fishers (Purcell, Gossuin and Agudo, 2009a). The interviews with processors pointed to a need for training of fishers in processing methods, since two-thirds of processors responded that sea cucumbers that they bought from fishers were sometimes poorly processed.

Above: artisanal processing of sea cucumbers in the Northern Province of New Caledonia.

Roughly half of the fishers near the main processing centres in Noumea sell their catch as gutted (fresh) animals or gutted and salted. Conversely, most fishers in the far northern regions of the country sell their catch after they have fully processed the sea cucumbers into dried beche-de-mer. This is mainly attributed to the fact that the fishers are much

further from processors and cannot easily sell fresh animals, nor store salted animals in large quantities. One lesson is that training workshops to improve the quality of processing by fishers will need to target remote communities in particular.
Source: S.W. Purcell.

Seychelles
Processors are well equipped and produce good quality beche-de-mer from salted sea cucumbers bought from fishers. The fishers prefer to conduct long fishing trips, given the distance they have to travel and keep their catch in salt until they return to land. The sea cucumbers are then sold, as gutted and salted animals, to processors. In this case, there is some value adding that is lost by fishers because processing is done by local industrialized processors. Presently there are four licensed processors.


PHOTOS: C. CONAND

Above – Left: sea cucumbers in salt sold by licensed fishers to processors. Right: sea cucumbers processed (mostly the high valued teatfish "pentard") by a licensed processor.

One lesson is that the fishers get enough money, given the present high commercial value of the catch and the processors have to report their purchases and exports.
Source: C. Conand.

6.8 RESTOCKING

Definition

Stock rebuilding through the translocation of adults, or release of juveniles, to create or increase densities of protected adults that breed and enhance recruitment of new sea cucumbers in the fishery.

Other potential classes of interventions (e.g. improving habitat, decreasing predation) are not discussed here. Several definitions are given to distinguish different types of direct "enhancement", following Bartley and Bell (2008) and Bell *et al.* (2008). *Restocking* is the replenishment of a fishery through the release of juveniles, or translocation of adults, to form nucleus breeding populations that subsequently supply larvae to enhance recruitment to fishing grounds. The released animals are fully protected, e.g. within a no-take zone (NTZ), and they serve to "fast-track" the rebuilding of stocks in the fished areas through effective breeding and export of larvae. In contrast, *sea ranching* would involve the release of sea cucumbers into unfenced/unbounded areas of private access with an aim to harvest all released animals once they reach market size – it is a "put-grow-and-take" activity and replenishment of the fishery is secondary (Pickering and Hair, 2008). Another put-and-take activity is *sea* *farming*, where sea cucumbers would be released into sea pens, or other bounded areas in the sea, and harvested after they reach a good market size (Bell, Purcell and Nash, 2008; Lavitra *et al*., 2009). *Stock enhancement* has also a primary goal of increasing the year-class of wild animals and enhancing short-term yields to fishers through broad release of animals but occurs in open access areas, and again differs from restocking because there is no direct intention to form protected breeding populations.

Uses

Despite the use of artificial propagation (i.e. restocking with cultured juveniles) to facilitate the recovery of depleted stocks, it should not be used as a substitute for a precautionary approach to management. Managers should take actions to prevent fishing pressure that depletes stocks to the point where such corrective action is needed (FAO, 1995; Section 3.2).

Restocking is used to fast-track the recovery of wild sea cucumber stocks to a state where breeding populations are dense enough that the fishery can once again support conservative exploitation (Battaglene and Bell, 2004). It could also be employed to recreate a fishable population where a stock has become locally extinct through overfishing or natural disaster.

Managers should consider restocking with hatchery-produced juveniles (Figure 38) only as a "last-resort" intervention, when the densities of breeding animals in the wild have been depleted far too low to expect natural recovery of the stock using other management measures (Lovatelli *et al*., 2004; Conand, 2006a; Bell, Purcell and Nash, 2008). The use of cultured juveniles should be considered only where it seems that breeding populations cannot be created in the wild using other means and when the costs of hatchery production are justified (Battaglene and Bell, 2004; Purcell and Simutoga, 2008).

Where there are sufficient wild adults, but at densities too low for effective mating, some adults may be collected by fishery workers and aggregated into NTZs (Bell, Purcell and Nash, 2008). This alternative mode of restocking is faster and more cost-efficient than a captive-release programme at creating the necessary nucleus breeding populations to reinitiate recruitment in the fishery.

A further mode for restocking may arise, inadvertently, from breeding populations of adults created by sea-based aquaculture of sea cucumbers. Programmes to growout of hatchery-reared sea cucumbers in sea pens ("*sea farming*") (Figure 39) or in exclusively managed areas of natural habitat ("*sea ranching*") (Figure 40) are arising in the Indo-Pacific region and Indian Ocean for the purpose of providing income

FIGURE 38
Left: early hatchery-produced juvenile *Stichopus (Apostichopus) japonicus* in northern China for mass release into coastal areas where mariculture takes place. Right: hatchery-produced juvenile sandfish ready for release in the wild, New Caledonia

PHOTO: A. LOVATELLI

PHOTO: S.W. PURCELL

FIGURE 39
Left: transferring hatchery-reared juveniles into sea pens at Antseragnasoa, Madagascar. Right: the villagers of Ambolimoke, Madagascar, harvesting the sea cucumbers from the first experimental pen, December 2008

PHOTO: G. CRIPPS

PHOTO: G. ROBINSON

FIGURE 40
Hatchery-produced juvenile sea cucumbers (*Holothuria scabra*) being released into exclusively managed coastal areas in an initial sea ranching programme in Australia

PHOTOS: B. GIRASPY

for coastal livelihoods (e.g. Robinson and Pascal, 2009; Lavitra *et al*., 2009; Pickering and Hair, 2008). Although profit from these "put-and-take" ventures is the aim, these programmes could result in small, but dense, breeding populations that improve egg production for rebuilding sea cucumber stocks in neighbouring fishing grounds.

Limitations

In some places, stocks have been depleted so far that programmes cannot find enough broodstock to allow captive breeding or aggregation (see Section 2.4). In these instances, fishery managers may need to consider translocating stocks from the nearest related populations and accept the potential irreversible changes to the genetic structure of remnant local stocks (see Uthicke and Purcell, 2004). Where restocking with local sea cucumbers is possible, managers should avoid interregional or intercountry translocation. The genetic integrity of local stocks should be preserved wherever possible (FAO, 2003; Section 3.1). In some areas, sea cucumbers are genetically different over small spatial scales: for example in tropical species, e.g. *H. scabra*, and temperate species, e.g. *C. frondosa* (Section 2.1).

Running a hatchery is costly in equipment and trained personnel, making each juvenile expensive to produce. In addition, the availability of hatchery technology and costs of producing juveniles are fundamental limitations to the restocking of sea cucumbers using hatchery produced individuals (captive-release restocking). There are just a handful of species for which commercial-scale breeding technology is well documented:

- *Stichopus (Apostichopus) japonicus* (Wang and Cheng, 2004; Liu *et al*., 2004),
- *Holothuria scabra* (Battaglene, 1999; Agudo, 2006; Rasolofonirina, 2007; Lavitra *et al*., 2009),
- *H. lessoni* (previously named *H. scabra* var. *versicolor*; Giraspy and Ivy, 2005),
- *H. spinifera* (Asha and Muthiah, 2005), and
- *Isostichopus fuscus* (Mercier, Hidalgo and Hamel, 2004).

Producing juveniles is the first large step to captive-release restocking – then the juveniles must be released into the wild in ways that result in high survivorship to maturity (Purcell, 2004b; Purcell and Simutoga, 2008). Juvenile sea cucumbers may need different microhabitats than adults, which may necessitate some investment in scientific studies to define these confidently. The optimal size-at-release should also be determined, since too small juveniles may suffer unacceptable mortality while large juveniles will be expensive to produce (Purcell and Simutoga, 2008).

A further key limitation of restocking, either with cultured juveniles or aggregated wild adults, is that the animals must be protected within NTZs. These may be difficult to establish, e.g. due to socio-cultural reasons, or impractical to enforce. To gain the full return on investment of restocking of a whole fishery, the aggregated or released sea cucumbers should be protected in a network of moderately large no-take reserves for their entire lives (Purcell and Kirby, 2006). In some cases, e.g. in China for *A. japonicus*, modification of habitat (e.g. to create artificial reefs) may be needed for restocking.

Animals stocked into new habitats may have unforeseen affects on the benthos or competing species. Although sea cucumbers are not predators, the potential effects of the introductions on the ecosystem should be considered and may be deemed too risky to permit releases of foreign stocks. Much care should also be taken to ensure that hatchery practices do not result in the introduction of disease (FAO, 2003).

Restocking can lead to false expectations and conflicts among the stakeholders. For example, fishers may exploit stocks more because they believe the restocking has rebuilt populations. Alternately, they may be reluctant to accept other management measures because they already sacrificed some optimal (previously fished) areas for the NTZs and contributed to other costs or services to rebuild the breeding populations.

How to implement

Firstly, managers should consider the costs and timeframes for restocking and whether a restocking programme is likely to add value to other forms of management (FAO, 2003; Bell, Purcell and Nash, 2008). What will be the costs of producing and protecting the animals, and are these costs likely to outweigh simply waiting a longer time for stocks to recover under a moratorium? Next, managers should perform a cost/benefit analysis on captive breeding versus adult aggregation. This may be rather simple and should also consider the logistic and capacity constraints of the fishery service.

Underwater censuses or fishery-dependent surveys will help to show whether restocking is needed and whether it can be achieved more cost-effectively by aggregating remnant wild adults in NTZs (Sections 6.1.2 and 6.1.3).

Methods for culturing juveniles at semi-commercial scales in hatcheries must be known and include the technology to produce larvae and newly-settled juveniles as well as the nursery methods to grow them efficiently to appropriate sizes for release

(Purcell and Simutoga, 2008). If the juveniles are to be produced in a government-operated hatchery, managers should critically assess the technical capacity of staff to operate a hatchery (a hatchery manager, skilled technicians and aides).

There must be a sound understanding of the habitat requirements of the species and appropriate release strategies (Purcell, 2004b). If such information is lacking, managers may need to invest in scientific studies to determine the optimal release strategies. Most importantly, the optimal release size and microhabitat for the juveniles needs to be determined. Thousands of juveniles will probably be needed to furnish each nucleus breeding population, since many will die in the first period after release, and multiple sites should be stocked to mitigate restocking failure at some sites (Purcell and Simutoga, 2008). The juveniles should be marked (Purcell, Blockmans and Nash, 2006; Purcell and Blockmans, 2009) to allow some "mark-recapture" monitoring to verify survival rates and to identify restocked animals (see photograph in Box below).

Managers should get information on the reproductive biology of the species to be restocked (e.g. Conand, 1993) and dominant water currents in the fishery. Sites for restocking should permit the larvae from the breeding adults to travel with the currents to target fishing grounds. Managers should also consult or commission studies to understand the delineation of genetic strains of the stocked species within the fishery.

Enforcement and improved management are required before restocking programmes are implemented. If the progeny from restocked animals are only to be overfished again, then the broader aim of restocking will be missed. A stock recovery programme should include the establishment, or use, of NTZs for stocked breeding groups and strict regulations for fishing outside reserves. More conservatively, this would entail a well-policed moratorium on the fishing and export of sea cucumbers in the whole fishery to allow stock rebuilding (Battaglene and Bell, 2004). Perhaps the depleted species could be banned and regulated fishing could be permitted for other species. At the onset, managers should agree with stakeholders on the target densities or abundance that populations should reach before fishing is again permitted.

Managers are urged to avoid the translocation of stocks from distant populations, in order to preserve the genetic structure of local stocks (FAO, 1995; Uthicke and Purcell, 2004). States are also called upon to undertake efforts "to minimise harmful effects of introducing non-native species […] into waters under the jurisdiction of other States as well as waters under the jurisdiction of the State of origin" (FAO, 1995). This means that managers and governments should take steps to avoid inappropriate translocations in their own waters, and from their waters into those of neighbouring regions and countries.

Monitoring of populations of the stocked species outside the stocked NTZs should take place before and after stock rebuilding. The moratorium on fishing should be lifted only once animals outside the NTZs have grown to maturity and populations in the fishery have generally returned to the pre-determined densities.

EXAMPLES AND LESSONS LEARNED

New Caledonia, France

Following studies in the Solomon Islands to further develop methods for culturing sandfish (*Holothuria scabra*) in hatcheries, a multidisciplinary project was conducted in New Caledonia to determine optimal methods for releasing the juveniles in the wild for restocking. Releases in the wild were not intended to restock the fishery, but instead were at an experimental scale to provide directions for future restocking projects by using the releases to define the conditions in which juveniles survive and grow well.

PHOTOS: S.W. PURCELL

Above – Left: thousands of juvenile sandfish ready for marking with fluorochrome chemicals prior to being released into the wild. Right: a small piece of skin is excised from a sandfish recaptured one year after release, as part of monitoring to analyse whether it was one of the released cultured animals.

The final studies of the project examined the survival and growth of cultured juveniles up to one and a half years after release, using chemical marking of the juveniles (Purcell and Simutoga, 2008). The key lessons from the study were:

- Experimental releases are critical for defining the successful release methods, but some uncontrollable factors (e.g. environmental variations) can dictate the survival of cultured juveniles in the wild.
- Success on one occasion does not guarantee success at that site on another occasion.
- Success from short-term experiments is no guarantee for success of large-scale releases over longer timeframes; some key causes of mortality occur infrequently.
- Restocking programmes should expect failures at some sites or occasions, so multiple release sites and repeated releases should be used.
- The size-at-release of the cultured juveniles is important, but there may be a threshold to how strongly it affects survival. For sandfish, juveniles should be grown to >3 g before release.
- Microhabitat is another key criteria to specify in restocking sea cucumbers. It is the release *microhabitat*, more than the "habitat" that needs to be determined and targeted for releases.

Source: S.W. Purcell.

Gilbert Islands, Kiribati

Commonly known in Kiribati as "white teat", *Holothuria fuscogilva* is a high-value sea cucumber species that has been heavily fished by local fishers and fishing companies using compressed-air diving. Depletion of white teatfish, prompted the Kiribati Ministry of Fisheries and Marine Resources Development (MFMRD) to develop technical capacity for restocking. Through assistance from the Government of Japan (via the Overseas Fisheries Cooperative Foundation), a project was initiated in 1995 to master the hatchery methods for culturing white teatfish juveniles.

Several thousands of juveniles were released in lagoon shoals over a number of years. However, there is little evidence that many of the released animals survived to maturity or contributed to augmenting local stocks. The juveniles are highly cryptic and rarely found during monitoring, and tagging/marking methods were not available (until recently) to distinguish recaptured white teatfish from wild stock. Additionally, the knowledge of juvenile habitat preferences is lacking. Lessons from a recent project in Kiribati were:

- Future restocking requires some preliminary studies to determine microhabitats that provide juveniles with shelter and food, to allow them to grow and avoid being eaten.

- Cultured juveniles need to be marked or tagged to allow them to be distinguished from wild individuals in order to monitor their survival to maturity.
- Juveniles need to be released into no-take reserves to ensure they are protected from fishing once they grow to maturity, so they can act as breeders to replenish the stocks more broadly.
- Restocking needs to be placed within the broader framework of resource management, which must address the initial causes of depleted stocks.


PHOTOS: S.W. PURCELL

Above – Left: raceway tanks used to culture juveniles for restocking. Right: a white teatfish broodstock held in a hatchery facility.
Source: S.W. Purcell.

Madagascar

In 1999, a sea cucumber mariculture project was launched in Madagascar. A hatchery at the Toliara marine sciences institution (Institut Halieutique et des Sciences Marines – IHSM) was functional in 2003 and currently produces tens of thousands of juveniles of the valuable sea cucumber *Holothuria scabra*. In 2004, a programme was initiated in which hatchery-produced sea cucumbers are grown to market size in sea pens by coastal villagers.

Management of the sea pens by farmers is ensured by scientists working in the company and by people from non-governmental organizations (NGOs) based in the Toliara region (Eeckhaut *et al.* 2008). The experience of this village-based mariculture appears very positive and demonstrates the social and economic viability of a new model for alternative livehood creation. The village participants receive hatchery-produced sandfish (*H. scabra*) and grow them in pens in shallow sandy habitats. One attribute to the success at this stage is that each of the four villages involved in the mariculture project has designated the area around the pens as a permanent no-take reserve protected by a local law. Only the pen owners and researchers are allowed access to the sea pens in the reserve, which limits poaching. At some sites, sandfish juveniles have grown from a release weight of 15 g, at 5-months old, to an average weight of 350 g during 8 months in the sea pens. This approach will be extended to many villages on Madagascar's west coast and will hopefully establish protected spawning aggregations. Although the purpose is mariculture, the creation of spawning populations in nearshore waters should inadvertently support stock rebuilding (Robinson and Pascal, 2009), and serve as an example for other countries in the Indian Ocean.

The lesson from this example is that mariculture of sea cucumbers can involve local communities, not just aquaculture businesses. The success in Madagascar seems to be due, in part, to a novel partnership between local communities, NGOs and private sector stakeholders.
Source: C. Conand.

7. Conclusions

The development of this paper and management guidelines was prompted by the poor status of sea cucumber fisheries management in numerous countries and the recognition of an urgent need for technical guidance in the development of management strategies and for good governance.

Like many other fisheries, the present management approaches and systems in sea cucumber fisheries are struggling to achieve sustainability. One important step towards improvement is to define clear objectives, reference points and indicators of sustainability. Managers need to then conduct periodic assessments of how the stocks and fishers have responded to the management measures and adapt management measures in the light of poor performance.

Sea cucumber fisheries have widely different characteristics and unique management issues. Their sustainable management requires practical regulatory measures and joint effort from different sectors. In elaborating best practices management measures in this document, efforts were made to distinguish the different settings under which some measures are likely to be more applicable than others.

To build a management plan based on the regulatory measures and actions for implementing management advised in this technical paper, managers need to adopt measures that can work in the specific circumstances of the fishery. They must also respond in a balanced way to the need to maximize the long-term benefits to fishers and to conserve resource biodiversity. In this context, the following are some key "take-home" messages for managers when developing management plans for sea cucumber fisheries:

1. Generally, a suite of management regulations should be used to control fishing.
2. Establishing some form of user rights, or privileges, helps to avoid the "race for fish" to promote better stewardship of sea cucumber stocks.
3. Promoting local-level management institutions improves many aspects of compliance, surveillance and accountability, but centralised fishery agencies must continue to support these systems and may need to retain authority over some management roles.
4. Management regulations should be strict enough so that stocks of high, medium and low value species are maintained at productive levels and drastic interventions can be avoided.
5. If the fishery is depleted, managers must instigate a ban for several years and weigh up the costs and benefits of various methods for rebuilding the stock.
6. Managers should oblige fishers, processors and exporters to provide data of catches and exports in all fishery situations.
7. Size limits are strongly recommended in any active fishery and enforcement through inspections of processors and exporters will be more efficient than inspections of fishers.
8. Marine protected areas that exclude fishing of sea cucumbers (i.e. no-take reserves) should serve as a valuable safeguard, in most scenarios, for maintaining some recruitment in the fishery, but should be accompanied by other regulations.
9. Industrialized fisheries often have greater resources for the development and enforcement of management regulations. For this reason, they can have a greater number of management regulations and actions for implementing management than small-scale fisheries.

10. Small-scale fisheries that involve poor and low-income fishers can suppress stocks to extirpation because fishers can still maintain some profitability at low stock densities. For this reason, instigating bans early and having no-take zones to safeguard some breeding groups, is a stronger imperative than in industrialized fisheries.
11. Almost all of the potential management tools can be applied in small-scale and industrial (high-tech) sea cucumber fisheries. However, it is better to choose a subset of companion tools (see Annex 10.2 for examples).
12. The overriding actions by sea cucumber fishery managers in any situation are to: 1) invest in education programmes to give fishers and exporters an understanding of management principles; 2) ensure strong enforcement of the regulations; 3) conduct some socio-economic surveys; 4) carry out underwater visual censuses to monitor stocks; and 5) monitor the national catches and exports.

Some, perhaps most, of the regulatory measures discussed in this paper are unproven as tools to ensure the sustainability of sea cucumber fisheries. One research priority, therefore, is to critically evaluate the efficacy of management measures. Studies could compare the sustainability of stocks between locations with different management systems and/or regulations within a fishery or monitor densities of sea cucumbers before and after new regulatory measures are imposed (see Section 6.1.2).

Lack of enforcement is a continual problem in many developing and low-income, countries. There is little benefit of a well-developed management plan if fishers do not comply with it. To tackle this problem, management agencies need to invest more resources in compliance officers and have the backing of a vigilant system to enforce penalties on fishers and processors for non-compliance. Alternatively, managers may decide to devolve the management authority and accountability to fishing communities and hope that access rights and local-level management will provide incentives for responsible stewardship of sea cucumber resources. Government agencies will probably still need to help local-level management systems, through some form of co-management. Such cooperation allows support to implementing local-scale management and a conduit for informing fishers and communities about the science needed for sustaining stocks and the ecosystems in which they live.

Amidst the trend of stock depletion through excessive fishing, it is encouraging that some countries have taken drastic action to prevent extirpation of breeding populations. National sea cucumber fisheries have been recently closed in Costa Rica, Solomon Islands, Vanuatu, Papua New Guinea, Panama, mainland Ecuador, Venezuela, India and Tonga (recently re-opened). The application of moratoria shows that fisheries management agencies are willing to take stringent actions for the long-term interest of the fisheries. Unfortunately, some severely depleted stocks may take decades to recover to productive levels (Battaglene and Bell, 2004). Managers should be acutely mindful that a moratorium underscores inadequacy of past management strategies, or enforcement, and a responsibility to develop radically different approaches to circumvent repeated stock depletion after the moratoria are lifted.

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9. Glossary

Beche-de-mer	meaning "spade of the sea", this term refers to dried sea cucumbers after earlier stages of gutting and boiling, and in some cases after salting and smoking.
Benthic	in relation to, or living in close association with, the sea bottom.
Capacity	(*capacity in fisheries*) – the ability, or potential, to take the maximum amount of animals out of the sea over a period of time by all the fishers.
Capacity	(*capacity in management institution*) – the level of competence, skills and resources to develop and implement the management plan.
Decision control rules	Rules agreed at the onset of developing a management plan about what management actions will be taken in light of the level of performance relative to reference limits.
Depleted stock	Populations of sea cucumbers within a fishery that have decline to levels whereby the rate of natural reproduction and population replenishment is poor, or unable to keep pace with mortality losses, due to low densities of breeding adults.
Effort	the total amount of fishing activity over a period of time.
Exploitation	use of the resource for personal gain, whether for subsistence or commercial purposes.
Fishery	the sum of all fishing activities on a given resource (e.g. a sea cucumber fishery), or the activities of a certain style of fishing on a particular resource (e.g. a dive fishery).
Fishing	this term is used interchangeably with "collecting" and "harvesting" to describe the act of removing sea cucumbers from the wild for commercial or subsistence purposes.
Gonad	male or female reproductive organ that produces sperm or oocytes.
Hookah	equipment to allow divers to breath underwater using hoses delivering compressed air from compressors onboard a boat above them.
Indicator	a variable that can give a measure of the state of the system at any one time, instead of measuring a response directly. For example, declining exports is an indicator that stocks have decreased, even though the stock itself is not measured.

In the context of reviewing the effectiveness of a management strategy, an indicator is a variable that shows the present state of a component of the fishery, e.g. abundance of valuable sea cucumbers in fishing grounds.

Management measure specific control or action applied to the fishery towards the objectives, including technical measures, input controls, output controls and user rights.

Management tool another term for *management measure,* because these are "instruments" used by managers to achieve the fishery objectives.

Manager here, refers to the person charged with, or responsible for, the stewardship of the fishery, including the formation of management regulations, monitoring and enforcement. They generally would be the leader of the *Managing institution*.

Managing institution the group of people in charge of developing management plans for the fishery and responsible for monitoring, and adapting to, changes in the status of resources. It could be the fishery service of the country or province, in the case of centralized management, or a group of community leaders in the case of community-based management.

Marine protected area a portion of the marine benthos and water, with its associated biota, reserved to protect part or all of the designated environment. The protection may allow for regulated levels of extraction (fishing) of plants and animals.

Maximum sustainable yield the highest theoretical limit at which sea cucumbers can be harvested without significantly affecting the reproductive process or the natural replenishment of the population.

Mortality death of sea cucumbers in the population due to fishing or natural events.

No-take zone used in the same sense as "marine reserve" to denote an area of subtidal or intertidal habitat, and its occupants, fully protected by law from the removal or harm of animals, plants and habitat.

Objective statements that defines and quantifies the fishery management goals. It is a broad statement about what the management strategy is trying to achieve.

Oocytes female sexual cells or unfertilized eggs released from females.

Overfishing a state where fished populations are not able to easily recover to the pre-harvest number of animals or to levels where the populations can increase in numbers, i.e. a state of negative per-capita population growth.

Recruitment	the addition of young sea cucumbers to the population, here considered as the addition of juveniles to a population after post-settlement mortality.
Reference point	a benchmark against which to assess the performance of management in achieving the objectives. A *limit reference point* is a level of a certain parameter to avoid going beyond.
Spatial	referring to things, or processes, in geographic space.
Sperm	male sexual cells.
Stakeholder	any person with a legitimate interest in the use and future of the resource. It includes but is not limited to fishers, processors, buyers, resource stewards, conservationists and conservation agencies, tourism agents, scientists and resource managers.
Status of stocks/resource	the abundance and sizes of individual sea cucumbers in wild populations within the fishery relative to healthy levels at which the animals would be breeding successfully and at which populations could withstand some losses from fishing without undermining population recovery. Stock status can be defined relative to fishing impacts, i.e. underexploited, fully exploited or depleted.
Stock	a group of individual sea cucumbers occupying a well-defined spatial range independent of other populations of the same species. A stock would normally be regarded as an entity for management or assessment purposes – thus, populations in different areas (e.g. individual reefs) that are normally connected through dispersal would be considered a single stock.
Trepang	a term used in Indian Ocean countries for dried sea cucumbers; a synonym of *beche-de-mer*.

10. Annexes

10.1 Main species of sea cucumbers commercially exploited and traded around the world

	Species	Family	Commercial value	Common name
1	*Actinopyga agassizi*	Holothuriidae	Medium	
2	*Actinopyga echinites*	Holothuriidae	Medium	Deep water redfish
3	*Actinopyga lecanora*	Holothuriidae	Medium	Stonefish
4	*Actinopyga mauritiana*	Holothuriidae	Medium	Surf redfish
5	*Actinopyga miliaris*	Holothuriidae	Medium	Blackfish
6	*Actinopyga palauensis*	Holothuriidae	Medium	Panning's blackfish
7	*Actinopyga spinea*	Holothuriidae	Medium	Burying blackfish
8	*Bohadschia argus*	Holothuriidae	Low	Leopard fish, Tiger
9	*Bohadschia atra*	Holothuriidae	Medium	
10	*Bohadschia bivittata*	Holothuriidae	Low	
11	*Bohadschia marmorata*	Holothuriidae	Low	
12	*Bohadschia similis* *	Holothuriidae	Low	Brownspotted sandfish
13	*Bohadschia subrubra*	Holothuriidae	Medium	
14	*Bohadschia tenuissima* *	Holothuriidae	Low	
15	*Bohadschia vitiensis* *	Holothuriidae	Low	Brown sandfish
16	*Pearsonothuria graeffei*	Holothuriidae	Low	Flowerfish
17	*Holothuria arenicola*	Holothuriidae	Low	
18	*Holothuria atra*	Holothuriidae	Low	Lollyfish
19	*Holothuria cinerascens*	Holothuriidae	Low	
20	*Holothuria coluber*	Holothuriidae	Low	Snakefish
21	*Holothuria edulis*	Holothuriidae	Low	Pinkfish
22	*Holothuria flavomaculata*	Holothuriidae	Low	
23	*Holothuria fuscocinerea*	Holothuriidae	Low	
24	*Holothuria fuscogilva*	Holothuriidae	High	White teatfish
25	*Holothuria fuscopunctata*	Holothuriidae	Low	Elephant trunkfish
26	*Holothuria hilla*	Holothuriidae	Low	
27	*Holothuria impatiens*	Holothuriidae	Low	
28	*Holothuria kefersteini*	Holothuriidae	Low	
29	*Holothuria leucospilota*	Holothuriidae	Low	White threadsfish
30	*Holothuria mexicana*	Holothuriidae	Low	Donkey dung
31	*Holothuria nobilis*	Holothuriidae	High	Black teatfish
32	*Holothuria* sp.	Holothuriidae	High	Pentard
33	*Holothuria notabilis*	Holothuriidae	Low	
34	*Holothuria pardalis*	Holothuriidae	Low	
35	*Holothuria pervicax*	Holothuriidae	Low	

Annex 10.1 (continued)

	Species	Family	Commercial value	Common name
36	*Holothuria rigida*	Holothuriidae	Low	
37	*Holothuria scabra*	Holothuriidae	High	Sandfish
38	*Holothuria lessoni* +	Holothuriidae	High	Golden sandfish
39	*Holothuria spinifera*	Holothuriidae	Medium	Sandfish
40	*Holothuria theeli*	Holothuriidae	Medium	
41	*Holothuria whitmaei*	Holothuriidae	High	Black teatfish
42	*Astichopus multifidus*	Stichopodidae	Low	
43	*Isostichopus badionotus*	Stichopodidae	Medium	
44	*Isostichopus fuscus*	Stichopodidae	Medium	Brown
45	*Parastichopus californicus*	Stichopodidae	Medium	Giant red
46	*Parastichopus parvimensis*	Stichopodidae	Low	Warty
47	*Stichopus chloronotus*	Stichopodidae	Medium	Greenfish
48	*Stichopus horrens*	Stichopodidae	Medium	Dragonfish or Warty
49	*Stichopus herrmanni*	Stichopodidae	Medium	Curryfish
50	*Stichopus monotuberculatus*	Stichopodidae	Low	
51	*Australostichopus mollis*	Stichopodidae	Low	
52	*Stichopus naso*	Stichopodidae	Low	
53	*Stichopus ocellatus*	Stichopodidae	Low	
54	*Stichopus pseudohorrens*	Stichopodidae	Low	
55	*Stichopus vastus*	Stichopodidae	Low	Brown curryfish
56	*Stichopus (Apostichopus) japonicus*	Stichopodidae	High	
57	*Thelenota ananas*	Stichopodidae	Medium	Prickly redfish
58	*Thelenota anax*	Stichopodidae	High	Amberfish
59	*Thelenota rubralineata*	Stichopodidae	Low	
60	*Athyonidium chilensis*	Cucumariidae		Pepino de mar
61	*Cucumaria frondosa*	Cucumariidae	Low	Pumpkins, Orange footed
62	*Cucumaria japonica*	Cucumariidae	Low	
63	*Pattalus mollis*	Cucumariidae		Pepino de mar
64	*Pentacta quadrangulis*	Cucumariidae		
65	*Pseudocolochirus axiologus*	Cucumariidae	Aquaria	Sea apple
66	*Pseudocolochirus violaceus*	Cucumariidae	Aquaria	Sea apple

* species with taxonomy to be revised.
+ previously described as *Holothuria scabra* var. *versicolor*.

Annex 10.2 Examples of issues to take into account when considering regulatory measures and actions for implementing management

Regulatory measures	Particularly useful when	Good companions	Hard to implement when	Good alternatives	Sections
Area and user access rights	• Pressure from external users • Boundaries can be defined. • Establishing a new fishery • Relatively few fishers or fishing groups	• Support institutional arrangements for management by fisher groups	• Excluding users will lead to social conflict • Strong political manipulation • Legal framework not in place	• Catch controls by limiting effort, gears and catch quotas, where conditions allow • MPAs	5.2; 5.3; 5.4; 5.7.1; 5.7.3; 6.2.1
Effort and capacity control	• Social structure allows it (e.g. target group well identified) • Other income generation is possible • Can stop new entrants (especially at start of new fishery)	• "Market chain" licensing and reporting • Socio-economic surveys	• Small-scale fisheries • Enforcement is weak (i.e. for controlling effort)	• Short-term closures • Catch controls by limiting gears and catch quotas, where conditions allow	5.2; 5.3; 5.4; 5.5; 5.6.1; 6.1.4
Gear limitation and development	• Stocks depleted in shallow areas • No training for compressed air use • Objective to protect sensitive habitat and limit bycatch (e.g. by trawl fisheries)	• "Market chain" licensing and reporting • Enforcement	• Weak or lack of enforcement • Gear used at time or places difficult for surveillance	• Catch controls by limiting effort and access	5.2; 5.3; 5.5; 6.5
Size limits	• In most cases. • Poor control over amount of catch	• Short-term closure • Enforcement • Market chain licensing and reporting • Training to improve processing quality	• No legal framework • Weak enforcement	• Limiting catches through quotas • MPAs • Area and user access rights • Gear limitation (e.g. mesh size, SCUBA ban)	5.1; 5.2; 5.4; 5.6.1; 5.7.1 ; 5.7.3 ; 6.5; 6.7
Seasonal and short-term closures	• Need to periodically review status of fishery • Well defined spawning season or other sensitive seasonal process • Demand is seasonal	• Reduction of total catch • Restrict effort so catch rates do not increase in fishing season • Size limits	• Weak or lack of enforcement (e.g. remote areas) • Target group depends on fishery for regular income	• Limiting catches through quotas and effort control	5.3; 5.6.1; 5.4

Annex 10.2 (continued)

Regulatory measures	Particularly useful when	Good companions	Hard to implement when	Good alternatives	Sections
Rotational closures	• Well segregated fishing grounds • Relatively few fishers • Rotational plots can be large • Stock surveys not easy to do • Local decline of catches • Effective enforcement or strong compliance exists	• Effort control (setting minimum target value for CPUE) • Local institutions for co-management of rotational plots	• Access rights in place	• MPAs • Limiting catches through quotas and effort control	5.3; 5.4; 5.7.1; 5.7.2; 5.7.3; 6.2.1; 6.5
Bans	• Stocks are depleted	• Enforcement • Fishery-independent stock surveys • "Market chain" licensing and reporting • Trade agreements like CITES	• Usual	• No good alternatives	5.5; 5.6.2; 6.1.2; 6.3.2; 6.5
MPAs	• Should be always present • Understanding the effects of fishery on stocks and ecosystem • Well defined source populations and nursery areas	• Fishery-independent stock surveys • Short-term closures • Size limits • Gear limitation	• Weak or lack of enforcement • Area used for multiple purposes that alter the environment • Multispecies fisheries, as they would require a diverse number of areas under protection	• No good alternatives (high priority)	5.6.1; 5.7.1; 6.1.2
Catch quotas	• Industrialized fishery • Few fishers and/or landing sites • Well organized fishery	• "Market chain" licensing and reporting • Fishery-independent stock surveys	• Many small-scale fishers • Multispecies fisheries. • Poor monitoring of population status • Fishery operating in large areas	• Market licensing and access rights • MPAs • Gear limitation and other measures limiting catches or effort	5.1; 5.2; 5.3; 5.4; 5.5; 5.7.1; 5.7.3; 6.1.2
"Market chain" licensing and reporting	• Usual (priority for products monitoring)	• Institutional arrangements for management by fisher groups • Training, including on quality of processing • Enforcement • International trade agreements, e.g. CITES	• Many trade licenses (or many middlemen) • Competition between collectors • Trade routes not clear	• No good alternative (high priority)	5.5; 6.2.1; 6.3.2; 6.5; 6.7

Annex 10.2 (continued)

Actions for implementing management	Particularly useful when	Good companions	Sections
Assessment and collection of basic information about stocks	• All scenarios	• "Market chain" licensing and reporting • Fishery-independent stock surveys • Fishery-dependent stock surveys • Socio-economic surveys (including market surveys)	5.5; 6.1.1; 6.1.2; 6.1.3; 6.1.4
Socio-economic surveys	• Preparing or evaluating management plans and measures	• Fishery-independent stock surveys • Fishery-dependent stock surveys • Establish advisory committees • Education and communication with stakeholders	6.1.2; 6.1.3; 6.1.4; 6.2.2; 6.6
Price monitoring	• Many agents involved • Fishers not well informed • Market prices fluctuating	• Fishery-dependent stock surveys • Education and communication with stakeholders • Support institutional arrangements for management by fisher groups	6.1.3; 6.1.5; 6.2.1; 6.6
Support institutional arrangement for management by fisher groups	• Limited fishing area • Weak regulatory framework	• Market chain licensing and reporting • Education and communication with stakeholders • Socio-economic surveys • Fishery-independent stock surveys • Fishery-dependent stock surveys • Management advisory committees	5.5; 6.1.2; 6.1.3; 6.1.4; 6.2.1; 6.2.2; 6.6;
Establish advisory committees	• To prepare or evaluate management plan/ measures • Assist with communication strategy	• Education and communication with stakeholders • Training, including improving quality of processing • "Market chain" licensing and reporting	5.5; 6.2.2; 6.6; 6.7;
Improve quality of processing through training	• Low or decreasing quality of products • Change of species • Change of market demand	• Price monitoring • Education and communication with stakeholders	6.1.5; 6.6; 6.7
Education and communication with stakeholders	• Usual (high priority)	• Socio-economic surveys • Fishery-independent stock surveys • Fishery-dependent stock surveys • Price monitoring	6.1.2; 6.1.3; 6.1.4; 6.1.5; 6.6;
Promoting regulatory measures and interventions into legislation	• Informal regulations not effective • New regulations can be added	• Enforcement • Operating legal system • International agreements and CITES • Education and communication with stakeholders	6.3.1; 6.3.2; 6.5; 6.6;
Enforcement	• Usual	• Market chain licensing and reporting • Legalizing regulatory measures • Education and communication with stakeholders • Fostering sense of ownership by users through access rights • International agreements like CITES	5.5; 5.7.3; 6.5; 6.2.1; 6.6; 6.3.1; 6.3.2

Appendix 1

Fishery-dependent landing data sheet
Community Fisheries Management Development Programme – Papua New Guinea

Data are recorded by researchers or fishery officers for fishery-dependent assessments

Unit = Whole catch brought in by person / group

Coastal Fisheries management & Development Project

SEA CUCUMBERS

PROVINCE ______ BUYER ______ DATE ______

Latitude ______ Longitude ______ Interviewer / person collecting data ______

Collector's name ______ ♀♂ Age ______ Village ______ # others in group ______

(# other people who were collecting during this trip)

Collected from: ______

(give best estimate of sites fished, including multiple sites if used)

Time collecting (hrs) ______ Time processing ______ Total number cucumbers ______

CUCUMBERS

Sp ID #	Species	Length (cm)	Weight (g)	Length (cm)	Weight (g)	Length (cm)	Weight (g)	Length (cm)	Weight (g)	Length (cm)	Weight (g)	Unit of sale: kg	Pce	Box	Price

Appendix 2

Data sheet for recording landings of fishers (Purcell, Gossuin and Agudo, 2009a).
Data are recorded by researchers or fishery officers for fishery-dependent assessments

Date:	Fisher name:	Recorder:
Collection sites or area:		
No. Fishers:	Total catch (kg):	Hours spent fishing: Hours diving/day: Hours spent travelling to site:
Form of product: Fresh: ☐	Salted: ☐ Dried: ☐	Gutted: ☐

																					Species
																					Est: kg of catch
Len	Wid	Wt	Len	Wid	Wt	Len	Wid	Wt	Len	Wid	Wt	Len	Wid	Wt	Len	Wid	Wt	Len	Wid	Wt	
																					Ind 1
																					Ind 2
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																					Ind 24
																					Ind 25

Len= length (cm±0.5cm) Wid=width (cm ±0.5cm) Wt.=weight (grams)

Comments:

Appendix 3

A logsheet used in the sea cucumber fishery in Newfoundland and Labrador, Canada.

Data are recorded by fishers, who submit the form to the Department of Fisheries and Oceans after each landing

Sea Cucumber Fishing Log

Sea Cucumber Trip # ________
Vessel Name/CFV # ____________________
Crew Onboard ________

Date of Sailing ______________
Time of Sailing ______________
Port of Sailing ____________________

Date of Landing ______________
Time of Landing ______________
Port of Landing ____________________

Page # ___________
Observer ________________________________
Skipper Signature ________________________________

Activity/ Tow #	Grid #	Date M/D	Tow (hrs)/GPS Position				Course	Depth (fms)	Speed	Distance Covered (GPS)	Bottom Type	# Tote Pans cucumbers	# Tote Pans Discarded Cucumbers	Sea State	Bycatch Species	Bycatch #	Bycatch Wt. (lbs)	Remarks, hook-ups, problems with gear, etc.
			Start Tow	Position (GPS)	Finish Tow	Position (GPS)												
				Start Latitude		End Latitude												
				Start Longitude		End Longitude												
				Start Latitude		End Latitude												
				Start Longitude		End Longitude												
				Start Latitude		End Latitude												
				Start Longitude		End Longitude												
				Start Latitude		End Latitude												
				Start Longitude		End Longitude												

MAIL TO RESOURCE MANAGEMENT, DEPARTMENT OF FISHERIES & OCEANS, P.O. BOX 5667, ST. JOHN'S, NL, A1C 5X1, CANADA – FAX NO. 772-3628

Sea cucumbers are important resources for coastal livelihoods in more than 40 countries. Sadly, widespread overexploitation of wild stocks risks biodiversity loss and the long-term viability of fisheries. Spawned from an FAO international workshop of experts, this document presents a "roadmap" to guide fishery managers in choosing appropriate regulatory measures and management actions for sea cucumber fisheries. It elaborates on their use, limitations and modes of implementation, with *Examples and lessons learned* from various fisheries. Achieving sustainable management of sea cucumber fisheries requires an ecosystem approach to fisheries (EAF), precautionary regulations, improved enforcement and stronger commitment of fishery managers and policy makers.

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