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

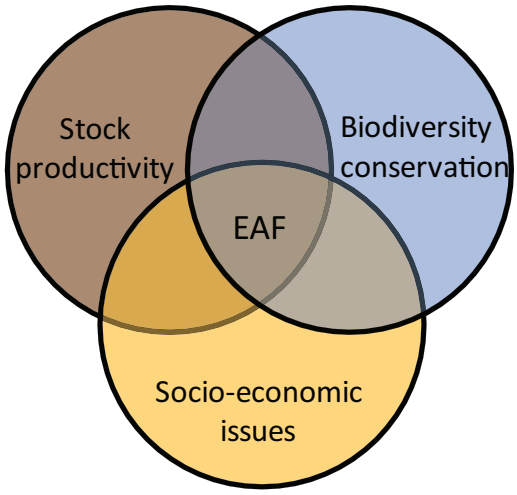
Ecosystem approach to fisheries (EAF) arose from the global awakening to the shortcomings in managing fisheries by focusing primarily on the resource (i.e. fish or sea cucumbers) or so called "target resource-orientated management" (TROM). The broad purpose of the EAF is to accommodate societal expectations 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).

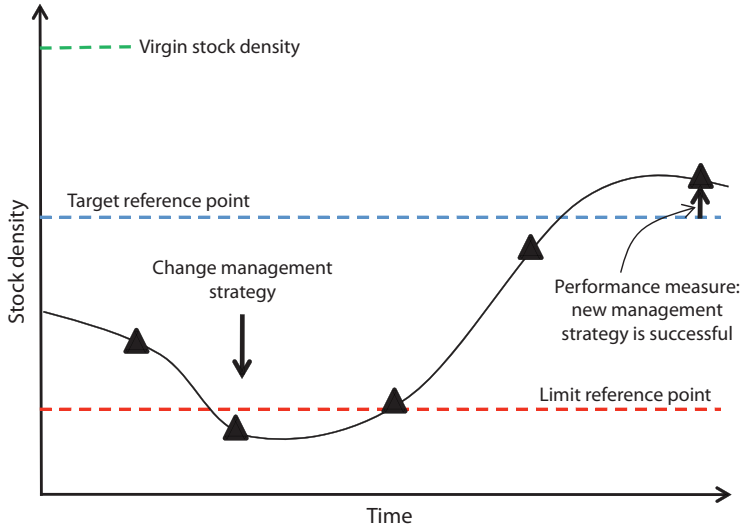
Broad objectives should be translated into "operational objectives" that have practical meaning in the context of the fishery and against which the performance of management strategies can be evaluated (FAO, 2003). For example, a broad objective could be to ensure that sufficient breeding populations 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.

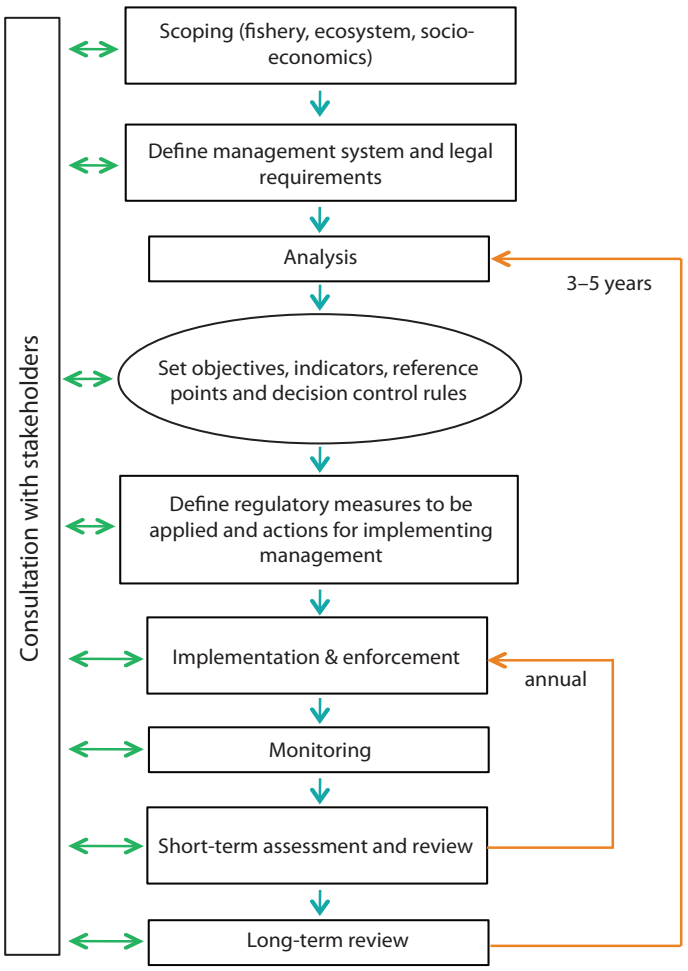
In open access fisheries, fishers have little incentive to leave juveniles and maintain breeding adults above a certain level because those animals they refrain from taking will most likely be collected by some other fisher. This ethos is the cause of the "tragedy of the commons" (Hardin, 1968) and a 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.