Part 1
Framework for using the FMSP stock assessment tools

1. Introduction

1.1 The new international legal regime

Most fisheries books seem to begin with an account of the poor state of the world's fish resources. There are certainly plenty of fisheries that are overexploited, many that are achieving less than their maximum potential and some that have collapsed outright. There are also, however, fisheries that remain healthy and productive, some perhaps by luck, but others by design. While fisheries management *can* be successful, this will surely only be maintained over the long term where clear management policies are implemented by a proactive management process. Where fishery managers are unaware of the status and potential of the resources under their responsibility, they are unlikely to act at the right time or to make the right choices. A suite of international instruments is now in place that promotes effective management action in *all* fisheries, regardless of their size and situation. Different strategies and approaches will work in different places but the requirement of good governance for all is now firmly established.

The legal basis for the management of fisheries was created in 1982 with the agreement of the UN Convention on the Law of the Sea (UNCLOS). Recognizing the need for international coordination for the management of straddling and highly migratory fish stocks, the UN "Fish Stocks Agreement" was signed in 1995. This requires states to cooperate in managing fishery resources both within and beyond their exclusive economic zones. The 1994 FAO "Compliance Agreement" addressed the problems associated with reflagging of fishing vessels as a means of avoiding conservation and management rules on the high seas (Cochrane, 2002b). Both UNCLOS and these two legal extensions to it are now in force and binding on those countries that have signed and/or ratified them.

In addition to these legal instruments, several non-binding guides have been developed to assist states in building good management practices. Chief among these is the FAO Code of Conduct for Responsible Fisheries, also finalized in 1995 (FAO, 1995a). This moves from the single-state, single species, MSY-based focus of UNCLOS into ecosystem management and the precautionary approach (de Fontaubert and Lutchman, 2003). The intentions of the Code are elaborated by the FAO Technical Guidelines for Responsible Fisheries. In particular, Guideline No. 2 deals with the precautionary approach to capture fisheries and species introductions (FAO, 1996, also 1995b; see Section 2.1.2); No. 4 (published in two volumes) addresses the general process of fisheries management (FAO, 1997). Caddy (1996) provides a checklist of fishery management issues seen from the perspective of the Code of Conduct.

Within the framework of the Code of Conduct are the four current FAO International Plans of Action (IPOAs) have been developed. These cover the reduction of incidental catches of seabirds in longline fisheries; the conservation and management of sharks; the management of fishing capacity; and the prevention of illegal, unreported and unregulated (IUU) fishing. National legislation for the formal implementation of these plans is now being developed in many countries.

Beyond the national level, most parts of the world's oceans are now covered by one or more regional treaties, commissions or fisheries management organizations. Only some of these have powers to set management measures that are binding on the fishing fleets of their member countries; many have only advisory functions (de Fontaubert and Lutchman, 2003). None has fully-effective enforcement capabilities, beyond the control exercised by flag states.

At a broader level, the legally binding 1992 Convention on Biological Diversity (CBD) provides guidance on the conservation, sustainable use, and equitable sharing of the benefits of biodiversity. Chapter 17 of the United Nations Conference on Environment and Development's (UNCED) Agenda 21 and the work programme of the CBD's 1995 Jakarta Mandate provide for the protection of the oceans, seas, and coastal areas. At the ten-year review of UNCED in 2002, the Johannesburg World Summit on Sustainable Development (WSSD) agreed a plan to "maintain or restore [fish] stocks to levels that can produce the maximum sustainable yield… where possible not later than 2015"; to "establish effective monitoring, reporting and enforcement, and control of fishing vessels"; to "eliminate subsidies that contribute to IUU fishing"; and to establish "representative networks" of marine protected areas by 2012.

With this legal and advisory regime in place, there is surely no lack of targets for states to work towards nor any lack of guidelines on how they may be achieved. More than ever before, coastal states are being called upon to focus intensively on fisheries management to secure the future of their fish resources and fishing industries. Some argue that the profusion of legal instruments may overwhelm small states with limited funding and capacity. The need to simultaneously achieve both fisheries development and ecosystem management goals presents challenges in turning all of the different concepts and guidelines into achievable operational objectives (Garcia *et al.,* 2003). Solutions can be found, however, by keeping a clear focus on the resource base of sustainable development (see Section 2.5.1). According to the FAO Web site,[1] as of June 2004, 52 countries reported having fisheries management plans in place that incorporate elements of the Code of Conduct, including measures to promote use of selective fishing gear, to prohibit destructive practices, and to ensure that permitted catch levels reflect the state of stocks and allow depleted populations to recover. The pace of uptake varies greatly between countries, but many states still need to put effective frameworks in place.

Much remains to be done then, particularly for small scale, artisanal fisheries. These are reported by FAO as producing about 50 percent of the world capture fisheries harvest that is used for human consumption, and as employing about 20 million fishers with many more in downstream, fishery-related jobs. These fisheries require more transparent involvement of stakeholders in the development of fishery management plans; the decentralization of decision making; and the coordination of inter-sectoral linkages between fisheries and the wider social and ecological systems. All fisheries require responsible management now to sustain their potential benefits to society.

1.2 Purpose and content of the guidelines

Fishery managers in both developing and developed countries are usually required to achieve policy goals aimed at sustainable production of fish yields for the benefit of fisher livelihoods, national food security and economic gain. Many different stock assessment models and software packages are available to assist managers in reaching these goals. These tools range from simple techniques for estimating parameters such as growth and mortality rates, to full simulation models of fishery systems allowing interactions between different species, fleets and gear types, and predicting the effects of different management strategies. The requirements of such tools, particularly the data inputs, vary greatly. Different tools are also applicable to different fisheries, depending on their operational structure, ecology and the intended management strategy. Fishery managers need to select and use appropriate decision-making support tools from the wide range of possible choices, bearing in mind their capacity to collect the necessary data and their ability to use the models and implement the management guidance produced. Finding the best tool, however, can be hampered by the diversity of choices available and the difficulty of comparing the costs (input requirements) and

[1] http://www.fao.org/newsroom/en/news/2004/45169/index.html

benefits (type and precision of management advice) of each tool. As a result, many fisheries in developing countries are either not managed, or are managed with only nominal regulations and without any real assessment of the status of fish stocks. Such countries risk losing the many benefits available from their resources.

This guide attempts to help fishery managers and their stock assessment advisors to choose decision-making support tools that will be appropriate to their circumstances and that will produce outputs that support responsible use of fishery resources, recognizing the need for a precautionary approach in the face of uncertainty. The guide focuses particularly on four software tools – LFDA, CEDA, Yield and ParFish – developed by the FMSP, but also makes reference to other guidance and tools developed both by the FMSP and elsewhere. Such tools are placed in a framework for fishery management and a related process for stock assessment. These are described in Chapters 2 and 3 respectively, and summarized in the following Section 1.3. Chapter 4 provides summary details on the main FMSP tools, concentrating on their main objectives, their data inputs and outputs and their relevance to particular circumstances. Part 2 presents further details about the software tools and Part 3 describes other FMSP analyses and guidelines.

Previous FAO stock assessment manuals for tropical fish stock assessment (Sparre, Ursin and Venema, 1989, and Sparre and Venema, 1998) have focused mainly on length based approaches. Both these manuals and that of Cadima (2003) have paid limited attention to the uncertainty inherent in fish stock assessment and the now widely-recognized need for precaution in decision making (see below). This stock assessment manual takes a different approach, giving less detailed coverage of the mathematical background of the different tools (already well covered in the manuals above-cited, and in textbooks such as Hilborn and Walters, 1992, Quinn and Deriso, 1999, and Haddon, 2001), and paying more attention instead to the estimation of uncertainty in parameters and its subsequent use in the decision making process.

Other software packages for stock assessment have of course been produced outside the FMSP, including the commonly used FAO/ICLARM FiSAT II software. Most fishery analysts will also have their own simple spreadsheets for modelling yield-per-recruit or other fishery indicators. The FMSP tools described here are believed to provide significant benefits over most such alternatives. Advantages include the use of non-equilibrium fitting methods and the inclusion of stock-recruit relationships and parameter uncertainty in the model inputs. All of the FMSP software packages are also now very well documented with their own help files and tutorials, illustrating step by step analyses of different example datasets. The introductions in Part 2 of this guide are essentially shortened versions of the software help files. During the more than 10 years since their first development, LFDA and CEDA have been well tested by many users in a wide variety of fisheries around the world. The current versions of these packages have been developed after extensive feedback from users in the field. Use of the FMSP software should therefore increase the likelihood of fishery analysts providing good and timely advice to their managers especially when they do not have the necessary background and resources to develop complex programming tools themselves.

1.3 A framework for fisheries management

This section outlines a comprehensive framework for fisheries management – including stock assessment – which sets the stage for the application of the FMSP and other stock assessment tools. A complete fishery management system must recognize a wide range of influences that affect the interaction between the fishery, its stakeholders, and the aquatic environment. The system adopted for each fishery must be well adapted to the specific conditions found at that location.

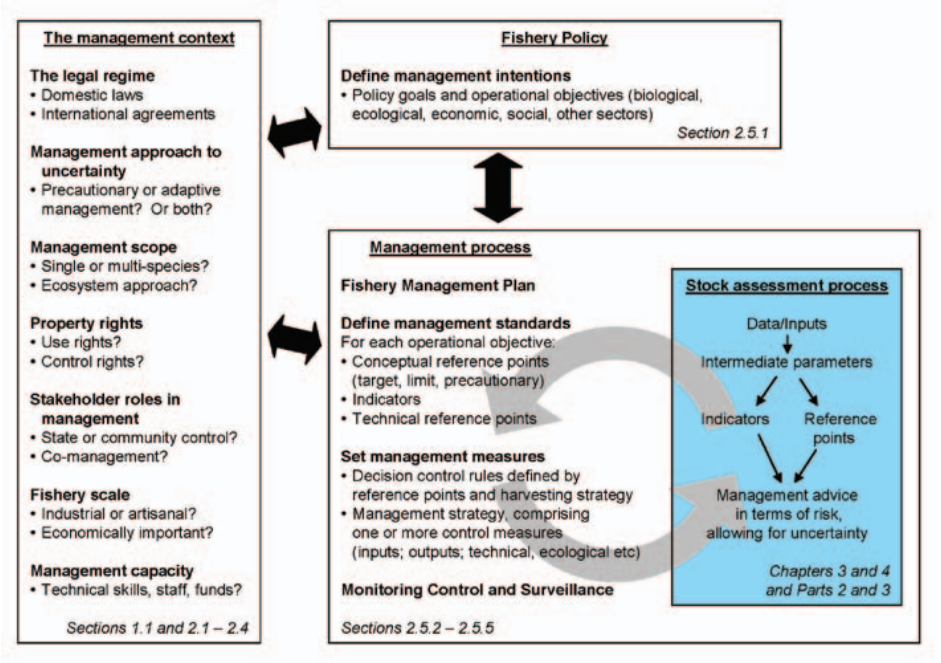
The main components of a modern fishery management framework are illustrated in Figure 1.1. Governing the process, and hence at the head of the framework is the

fisheries policy, including the goals and objectives that the management system is intended to address. Interacting with the fisheries policy are two boxes: the management "context" and the management "process". The context box on the left includes a range of factors that are fundamentally important to the way in which the fishery is managed. For example, the last decade has seen the start of a slow but steady move forward from the single stock- and single species-based focus often taken in the past, towards management systems that consider broader conservation goals and more integrated ecosystem-based objectives. Governance regimes are also changing from top-down "command and control" approaches towards more participatory, co-management arrangements, particularly for small-scale fisheries, and to market based measures and property rights for industrial-scale fisheries (Berkes *et al.*, 2001). Decisions taken on these fundamental issues and others listed in the context box will clearly influence the elements needed in both the policy and process boxes.

The management process box in the centre of Figure 1.1 includes the decision-making processes and the specific measures that are used to control the fishery. The stock assessment and research that provide the scientific and technical basis for the management framework are placed in their own box as a key element of this management process. The stock assessment box is central to the effective functioning of the framework, providing a quantitative basis for decision-making at every level. This is the part of the framework to which the four FMSP tools described in this guide contribute.

The arrows connecting the three main components of the framework are bi-directional, in recognition of the intimate and mutually reliant relationships between them. The circular arrow within the process box emphasizes that stock assessment should guide the management process by a regular and routine feedback process. Management measures could for example be adjusted each year, driven by the observed state of the system as measured by the "indicators" and "reference points". The overall system should also be assessed about every 3-5 years with more strategic and holistic analyses, but at a lower frequency than the main stock assessment – management cycle.

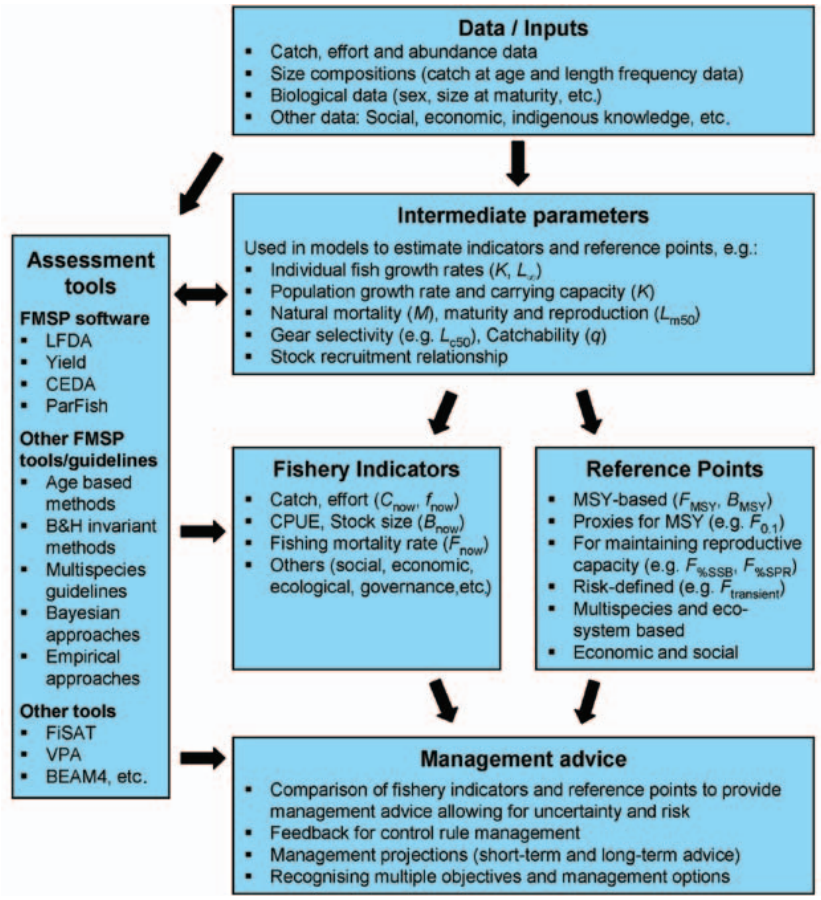
FIGURE 1.1
A framework for fishery management, showing the different elements to be addressed in establishing a fishery management system



Chapters 2 and 3 of this document describe in detail the component parts of the management framework and the stock assessment process. Readers unfamiliar with the concepts and methodologies in Figure 1.1 should refer to the sections indicated to provide the necessary level of understanding for informed use of the FMSP stock assessment tools. The FMSP tools themselves are introduced in Chapter 4, with additional details provided in Parts 2 and 3.

Figure 1.2 expands on the stock assessment and research box in Figure 1.1 giving examples of the different elements in the stock assessment process. As shown in the figure, the FMSP and other standard stock assessment tools use fisheries data to assist in the estimation of intermediate parameters, fishery indicators and/or reference points. Management advice is then usually based on the relative values of the fishery indicators and the reference points, as described in detail in Section 2.5.

FIGURE 1.2
Examples of the different elements in the stock assessment process outlined in Chapter 3, showing the general flow of information towards the provision of management advice



With this generalized stock assessment process, different tools are used for different types of analyses. Some tools estimate intermediate parameters while others estimate indicators and/or reference points. Some tools may need to be used in combination with others to provide a full fishery assessment (e.g. LFDA and Yield, see Figure 4.1), while others may be used on their own (e.g. CEDA and ParFish, see Figures 4.5 and 4.10). Table 1.1 provides a ready reference showing the potential contributions of the four FMSP software tools to the different elements of the stock assessment process. Other FMSP tools and guidelines listed in Figure 1.2 and described in Part 3 provide further alternatives or guidance for specific situations.

TABLE 1.1
Summary of the alternative outputs provided by the four FMSP software tools (see Chapters 3 and 4 for details of methods and notation, etc.)

FMSP Tool	Method(s)	Outputs		
		Intermediate Parameters	Indicators	Reference Points
LFDA	Length Frequency Distribution Analysis	Von-Bertalanffy growth parameters (seasonal and non-seasonal); Total mortality, Z	F_{eq}	
CEDA (Catch Effort Data Analysis)	Biomass Dynamic models; Depletion models; Stock projections	r, K, q	B_t, N_t	MSY, B_{MSY}, F_{MSY}
Yield	Analytical models; Stochastic stock projections		B_t, N_t [1]	F_{max}, $F_{0.1}$, $F_{0.x}$, $F_{\%SPR}$, F_{MSY}, F_{crash}, $F_{transient}$
ParFish	Biomass dynamic model with additional Bayesian priors	r, K, q		f_{lim}, C_{lim}, f_{opt}, C_{opt}

[1] The Yield software will project future trajectories of biomass and numbers resulting from a given catch strategy, based on current estimates of these values, but will not provide those current estimates.