The ecosystem approach to fisheries

Issues, terminology, principles, institutional foundations, implementation and outlook

ISSN 0429-9345

FAO FISHERIES TECHNICAL PAPER

443

PREPARATION OF THIS DOCUMENT

This desk review of relevant aspects of an ecosystem approach to fisheries (EAF) was specifically prepared to facilitate the work of the FAO Technical Consultation on the Ecosystem-based Fisheries Management held in Reykjavik (Iceland) from 16 to 19 September 2002. It was intended to be used as background material and source of definitions and references for the EAF guidelines to be elaborated at the meeting. A much shorter version was presented at the Symposium on Marine Fisheries, Ecosystems, and Societies in West Africa: Half a Century of Change, held in Dakar (Senegal) from 26 to 28 June 2002. The draft received comments and additional inputs during and after the meeting from many participants, particularly Drs D. Staples and K. Cochrane.

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Abstract

Garcia, S.M.; Zerbi, A.; Aliaume, C.; Do Chi, T.; Lasserre, G.
The ecosystem approach to fisheries. Issues, terminology, principles, institutional foundations, implementation and outlook.
FAO Fisheries Technical Paper. No. 443. Rome, FAO. 2003. 71 p.

Ecosystems are complex and dynamic natural units that produce goods and services beyond those of benefit to fisheries. Because fisheries have a direct impact on the ecosystem, which is also impacted by other human activities, they need to be managed in an ecosystem context. The meaning of the terms "ecosystem management", "ecosystem-based management", "ecosystem approach to fisheries" (EAF), etc., are still not universally defined and progressively evolving. The justification of EAF is evident in the characteristics of an exploited ecosystem and the impacts resulting from fisheries and other activities. The rich set of international agreements of relevance to EAF contains a large number of principles and conceptual objectives. Both provide a fundamental guidance and a significant challenge for the implementation of EAF. The available international instruments also provide the institutional foundations for EAF. The FAO Code of Conduct for Responsible Fisheries is particularly important in this respect and contains provisions for practically all aspects of the approach. One major difficulty in defining EAF lies precisely in turning the available concepts and principles into operational objectives from which an EAF management plan would more easily be developed. The paper discusses these together with the types of action needed to achieve them. Experience in EAF implementation is still limited but some issues are already apparent, e.g. in added complexity, insufficient capacity, slow implementation, need for a pragmatic approach, etc. It is argued, in conclusion, that the future of EAF and fisheries depends on the way in which the two fundamental concepts of fisheries management and ecosystem management, and their respective stakeholders, will join efforts or collide.

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INTRODUCTION

Any analysis of the state of fisheries and their resources needs to be undertaken in its broader aquatic context. In that respect, most aquatic environments indicate a lack of stewardship, illustrated by growing degradation, loss of habitat, lack of coherence in aquatic science policy, inadequate management-oriented research, poor or inexistent long-term monitoring, lack of strategic, integrated planning of conflicting uses, etc. The relative failure of conventional fisheries management has been abundantly described (Garcia, 1992; Garcia, 1996a; Garcia and Grainger, 1997; Sutinen and Soboil, 2003, and many others).

The realization of the need to exert some form of control over multiple uses of a sea area emerged during the late twentieth century as a result of concerns over the health of the oceans, the regulation of human activities, the allocation of space, resources, rights and responsibilities, and the growing occurrence of related conflicts. In the process, the division of resources among nations (through the establishment of sovereign rights) seems to have been given priority over the issue of their conservation for future generations. The process was accelerated by the technological boom in the 1950s, which increased dramatically the world fishing power and the risk of contamination from naval accidents. This is illustrated by the oil spills of the TORREY CANYON (1967) and AMOCO CADIZ (1978), as well as by fish stocks collapses such as the Indian sardinella (in the 1940s), Japanese sardine (in the 1940s and 1950s), South African pilchard (1965-66), Atlantic herring (1968-69), Greenland cod (1968), Georges Bank haddock (1968), Namibian pilchard (1970-71), Peruvian anchoveta (1972-73), Gulf of Guinea sardinella (1973-74) and Canadian Atlantic cod (in the 1990s).

The effect has been an increasing societal concern about the sustainability of fisheries and their environment during the last five decades. In order to improve the sector's image and sustainability, fisheries governance is required to become more effective and risk adverse, taking account of the ecosystem's limits as well as being responsive to environmental changes and conservative of ecosystem components. Fisheries development planning will need to be more integrated with the planning and management of the other sectors sharing aquatic space and resources. Institutions in charge respectively of fisheries and environmental management need to collaborate more effectively and improve substantially their effectiveness, better sustained by increased national commitments.

Implicitly or explicitly, most of the recently adopted instruments of relevance to fisheries call for an approach to fisheries giving more attention to the ecosystem. When considering the implications of such an approach, fishing and coastal nations will need to ensure that the content of the approach is in line with already agreed instruments (whether binding or not), complies with the sovereign rights of coastal States and does not imply obligations or duties beyond those already committed to. Most of the principles and conceptual elements of an **Ecosystem Approach to Fisheries (EAF)** are already contained in a number of binding or voluntary arrangements, agreements, conventions (global or regional), codes, etc., of direct or indirect relevance to fisheries. These instruments span from the 1982 UN Convention on the Law of the Sea (hereafter called the 1982 Convention) to the 1995 FAO Code of Conduct for Responsible Fisheries (hereafter called the Code) and its International Plans of Action (IPOAs), and from the 1971 Ramsar Convention to the 1992 Convention on Biological Diversity (CBD), including the 1995 Jakarta Mandate on Marine and Coastal Biological Diversity.

More recently, the FAO-Iceland Conference on Responsible Fisheries in the Marine Ecosystem, Reykjavik, October 2001 (Sinclair *et al.*, 2003) brought the issue to the forefront of fisheries requesting FAO to develop guidelines. Finally, the World Summit on Sustainable Development (WSSD, Johannesburg, September 2002) *"encourage(d) the application by 2010 of the ecosystem* *approach, noting the Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem and Decision V/6 of the Convention on Biological Diversity"*[1].

The Code offers a synthesis of the requirements of all the above instruments and provides the conceptual basis and institutional requirement for, *inter alia,* ecosystem and habitat protection; accounting for environmental factors and natural variability; reducing impacts of fishing and other activities; biodiversity conservation; multispecies management; protection of endangered species; accounting for relations between populations; reducing land-based impacts and pollution; integration in coastal area management; elimination of ghost-fishing; reduction of waste and discards; precautionary approach; delimitation of ecosystem boundaries and jurisdictions, as well as adapted institutions and governance.

Implementation remains the "acid test" of any approach to management. EAF implementation faces, and needs to resolve, a number of difficulties, many of which are already hampering the effectiveness of more conventional fisheries management. These difficulties relate to, *inter alia*: lack of information, lack of scientific assessment, non-matching of ecosystem and jurisdiction boundaries, appreciation of the role of protected areas, unclear or conflicting objectives, lack of consensus about ecolabelling, insufficient collaboration between institutions in charge of fisheries and environmental management at national or regional levels, lack of integration of fisheries in coastal areas management, need for more transparency and participation, lack of capacity for decentralization, redefinition (and strengthening) of the role of science, relations between trade and the environment (and the role of the World Trade Organization), and, last but not least, the potentially large socio-economic and political costs of transition.

This document reviews briefly: the evolution of terminology and underlying paradigms; some selected ecosystem characteristics; the impact of fisheries and of other activities with which fisheries compete; the institutional foundations of the approach with the particular role played by the Code; the conceptual objectives and principles of relevance for EAF; selected operational objectives and related measures and actions, and selected implementation issues. In conclusion, we discuss the likely evolution of the approach and the potential "fusion" or "collision" between the paradigms and overlapping groups of fisheries and ecosystem management stakeholders.

Acknowledgements

The authors wish to express their grateful thanks to the many colleagues who made comments and gave suggestions on the early draft of this document during and after the FAO Expert Consultation on Ecosystem-based Fisheries Management, Reykjavik, Iceland, 16-19 September 2002, and particularly to Drs K.L. Cochrane and D. Staples.

Thanks are also due to Ms Emanuela D'Antoni for the photomontage on the cover, made on the basis of material available in the FAO MediaBase and FishBase Best Photos (by J.E. Randall and JJPhoto).

[1] Paragraph 29d of the Plan of Implementation for the World Summit on Sustainable Development.

1. TERMINOLOGY AND PARADIGMS

In the expression "Ecosystem Approach to Fisheries (EAF)" the terms *ecosystem*, *approach*, and *fisheries* are defined in dictionaries and in the scientific literature. Used together, however, they imply a process using specific means to achieve selected objectives. These objectives are often not explicitly defined in conventional fisheries management and are even more difficult to define clearly in EAF. Following on the Reykjavik Declaration, EAF is recognized as a form of fisheries governance framework, taking its conceptual principles and operational instruments from conventional fisheries management on the one hand, and ecosystem management on the other hand. A number of expressions related to fisheries and ecosystem management have been used to describe related concepts such as: *ecosystem-based fisheries management* (EBFM), *ecosystem approach to fisheries* (EAF), *environmental management*, *biodiversity management* and *ecosystem approach* (in the CBD). As modern fields of science-based governance, they all find their roots in the concept and well-grounded academic disciplines of *natural resources management* (NRM) or *wildlife management* (Larkin, 1996; Lackey, 1999) but have evolved quite different operational paradigms. They also relate very closely to the already widely used concept of *integrated management*. These differences are briefly highlighted below.

1.1 Fisheries Management

Modern fisheries management, as practised since the early 1940s, is strongly based on the ecosystem theory but focuses primarily on fishing activity and target fish resources.[2] In inland waters, affected earlier and more strongly than marine waters by environmental problems, it developed as an extension of wildlife management (Lackey, 1999) and involves a substantial amount of direct intervention on the habitat, species composition, etc. In marine ecosystems, however, because the possibility of direct intervention on the ecosystem is limited, management strategies concentrated on controlling human intervention (fishing) while observing proxies for the state of an otherwise opaque ecosystem and fugitive resources. It is defined as "*the integrated process of information gathering, analysis, planning, decision-making, allocation of resources and formulation and enforcement of fishery regulations by which the fisheries management authority controls the present and future behaviours of the interested parties in the fishery, in order to ensure the continued productivity of the living resources*" (FAO, 1995b). It aims at optimizing the use of fishery resources as a source of human livelihood, food and recreation, dynamically regulating fishing activity, meeting resource-related objectives or constraints, mainly indirectly. It is science-based and has been evolving for 50 years with an increasing recognition of failures (Stevenson, 1973; Garcia 1996a; Goñi, 1998; Sutinen and Soboil, 2003).

Table 1 summarizes these features and offers a schematic comparison (perhaps caricatured) with ecosystem management. Such a comparison is complicated by the large variability observed in the application of these concepts, depending on the geographic area, the governance level (e.g. national, regional or global) and the institutions concerned.

[2] It is sometimes referred to as Target Resources Oriented Management (TROM; see FAO, 2003).

Table 1. Schematic comparison between fisheries and ecosystem management

Criteria		Fisheries management	Ecosystem management
Paradigm		Sector-based. Vertically integrated. Focusing on target resource and people.	Area-based. Holistic. Loosely cross-sectoral. Focusing on habitats and ecosystem integrity.
Governance	**Objectives**	Not always coherent or transparent. "Optimal" system output. Social peace.	A desired state of the ecosystem (health, integrity).
Governance	**Scientific input**	Formalized (particularly in regional commissions). Variable impact.	Less formalized. Less operational. Often insufficient. Stronger role of advocacy science.
Governance	**Decision-making**	Most often top-down. Strongly influenced by industry lobbying. Growing role of environmental NGOs.	Highly variable. Often more participative. Strongly influenced by environmental lobbies. Stronger use of tribunals.
Governance	**Role of the media**	Historically limited. Growing as fisheries crisis spreads.	Stronger use of the media.
Governance	**Regional and global institutions**	Central role of the Food and Agriculture Organization of the UN and regional fishery bodies.	Central role of United Nations Environment Programme (UNEP) and the Regional Seas Conventions.
Geographical basis		A process of overlapping and cascading subdivision of the oceans for allocation of resources and responsibilities.	A progressive consideration of larger-scale ecosystems for more comprehensive management, e.g. from specific areas to entire coastal zones and Large Marine Ecosystems (LME).
Stakeholder and political base		Narrow. Essentially fishery stakeholders. Progressively opening to other interests.	Much broader. Society-wide. Often with support from recreational and small-scale fisheries.
Global instruments		1982 Law of the Sea Convention, UN Fish Stock Agreement and FAO Code of Conduct.	Ramsar Convention, UN Conference on Environment and Development and 1992 Agenda 21, Convention on Biological Diversity and Jakarta Mandate.
Measures		Regulation of human activity inputs (gear, effort, capacity) or output (removals, quotas) and trade.	Protection of specified areas and habitats, including limitation or exclusion of extractive human activities. Total or partial ban of some human activities.

1.2 Ecosystem Management

Ecosystem management, as a concept, has been formally around since at least the introduction of conservation ethics by Aldo Leopold in 1966 (in Czech, 1996, and Czech and Krausman, 1997). The concept emerged strongly at global level in the 1970s, initially boosted by the 1972 Stockholm Conference on the Human Environment and strengthened by the 1992 Conference on Environment and Development (UNCED) and Convention on Biological Diversity (see Table 1).

Ecosystem management derives from *wildlife management*, born on land, in range management and forestry. The latter involved direct manipulation of the habitat and population in space and age structure, as well as of human activity — in space, structure and time — with the view to optimizing long-term returns to humans (Lackey, 1998 and 1999). It reflects a stage in a continuing evolution of social values and priorities. It is area-based, and boundaries must be clearly and formally defined, notwithstanding the difficulty. It aims at maintaining ecosystems in the sustainable condition necessary to achieve desired social benefits. To be effective, it requires scientific information as an element in a decision-making process that is fundamentally one of public and private choice. There are plenty of overlapping definitions (Christensen *et al.*, 1996) but a precise, universally accepted definition has yet to emerge (Lackey, 1999).

According to Lackey (1999), ecosystem management is also *"the application of ecological, economic, and social information, options, and constraints to achieve desired social benefits within a defined geographic area and over a specified period"*. Ecosystem management can also be more comprehensively defined as: *"a management philosophy which focuses on desired states rather than system outputs and which recognizes the need to protect or restore critical ecological components, functions and structures in order to sustain resources in perpetuity"* (Cortner *et al.*, 1994). It involves *"management decisions which involve a broad awareness of the consequences of fishing or other human actions to an ecosystem....used to infer the necessity of understanding multispecies interactions and questions of altered structure of the biological community" (ecosystem stability)"* (FAO-ACMRR, 1979). It aims at: (1) maintaining viable populations of all native species *in situ*; (2) representing within protected areas all native ecosystem types across their natural range; (3) maintaining evolutionary and ecological processes; (4) managing over periods of time of sufficient duration to maintain evolutionary potential of species and ecosystems; and (5) accommodating human use and occupancy within these constraints (Grumbine, 1994, cited by Larkin, 1996). The more recent literature tends to stress more the decision-making process (e.g. people's participation, transparency, adaptive management, precaution) than the elements to be conserved.

1.3 Ecosystem Approach

The term is usually used in the form of "ecosystem approach to..." as, for instance, in the ecosystem approach to fisheries (EAF) or to environmental protection (Gonzalez, 1996). Such an approach *"recognizes explicitly the complexity of ecosystems and the interconnections among its component parts"* (Fisheries and Oceans Canada, 2002). In general, the approach is taken as requiring: (1) definition and scientific description of the ecosystem in terms of scale, extent, structure, functioning; (2) assessment of its state in terms of health or integrity[3] as defined by what is acceptable to society; (3) assessment of threats; and (4) maintenance, protection, mitigation, rehabilitation, etc., using (5) adaptive management strategies.

The 1992 UN Convention on Biological Diversity (CBD) refers simply to the "ecosystem approach" and defines it as *"Ecosystem and natural habitats management... to meet human requirements to use natural resources, whilst maintaining the biological richness and ecological processes necessary to sustain the composition, structure and function of the habitats or ecosystems concerned. Important within this process is the setting of explicit goals and practices, regularly updated in the light of the results of monitoring and research activities"*.

It is also defined as *"a strategy for the integrated management of land, water, and living resources that promotes conservation and sustainable use in an equitable way"*, as well as *"a strategy ...to reach balance between... conservation, sustainable use, and fair and equitable sharing of the benefits arising from the utilization of genetic resources"* (Fifth Meeting of the Conference of the Parties to the Convention on Biological Diversity (COP 5), Decision V/6).

It recognizes that *"the ecosystem is a functional unit at any spatial scale... that humans are an integral part of many ecosystems... and requires adaptive management techniques."* (Secretariat of the Convention on Biological Diversity, 2000). Its content is defined by the Twelve Malawi Guiding Principles (see Annex 1). The operational guidance is to: (1) focus on the functional relationships and processes within ecosystems; (2) enhance benefit sharing; (3) use adaptive management practices; (4) carry out management actions at the scale appropriate for the issue being

[3] Note that the terms "health" or "integrity" have a different meaning than in general dictionaries and do not have an agreed operational meaning.

addressed, with decentralization to the lowest level as appropriate, and (5) ensure intersectoral cooperation.

1.4 Ecosystem-based Fisheries Management (EBFM)

The term has been defined (US National Research Council, 1998) as "a*n approach that takes major ecosystem components and services — both structural and functional — into account in managing fisheries... It values habitat, embraces a multispecies perspective, and is committed to understanding ecosystem processes… Its goal is to rebuild and sustain populations, species, biological communities and marine ecosystems at high levels of productivity and biological diversity so as not to jeopardize a wide range of goods and services from marine ecosystems while providing food, revenues and recreation for humans*". The term puts the focus for management on the users. What is managed is the economic activity. The term did not meet with consensus at the 2001 FAO Reykjavik Conference, possibly because some countries took it as implying that the "ecosystem" would become the new "foundation" of fisheries management. This may have been interpreted as giving to environmental considerations pre-eminence over socio-economic and cultural ones, raising concern about equity, political as well as socio-economic costs and feasibility.

1.5 Ecosystem Approach to Fisheries (EAF)

The term "Ecosystem Approach to Fisheries" (EAF) was adopted by the FAO Technical Consultation on Ecosystem-based Fisheries Management held in Reykjavik from 16 to 19 September 2002 (FAO, 2003) for various reasons: (1) the reticence expressed by the Reykjavik Conference vis-à-vis the EBFM terminology (see next section); (2) the convenient parallel this term offers with the "Precautionary Approach" to fisheries; and, last but not least, the fact that the term EAF, not being limited narrowly to management, could easily cover also development, planning, food safety, etc., better matching the breadth of the FAO Code of Conduct. The term "approach" indicates that the concept delineates a way of taking ecosystem considerations into more conventional fisheries management, in line with the Reykjavik Conference wisdom. The EAF could be defined as the way, the spirit in which the Code ought to be implemented.

EAF is defined by Ward *et al.* (2002) as "*an extension of conventional fisheries management recognizing more explicitly the interdependence between human well-being and ecosystem health and the need to maintain ecosystems productivity for present and future generations, e.g. conserving critical habitats, reducing pollution and degradation, minimizing waste, protecting endangered species*". The Reykjavik FAO Expert Consultation (FAO, 2003) agreed that the "*purpose of an ecosystem approach to fisheries is to plan, develop and manage fisheries in a manner that addresses the multiplicity of societal needs and desires, without jeopardizing the options for future generations to benefit from a full range of goods and services provided by marine ecosystems*". Therefore, "*an ecosystem approach to fisheries strives to balance diverse societal objectives, by taking account of the knowledge and uncertainties about biotic, abiotic and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries*".

Despite the distinctions between ecosystem management and fisheries management described above, the underlying concepts remain still fuzzy and tend to overlap. The review above illustrates the fact that the various expressions refer to what appear to be in practice very converging, if not totally similar, processes, aiming at largely overlapping sets of objectives. All ecosystem-based approaches to management of economic activities "*rely on similar precepts: the need for sound science, adaptation to changing conditions, partnerships with diverse stakeholders and organizations, and a long-term commitment to the welfare of both ecosystem and human societies*" (Kimball, 2001). The various terminologies reflect the relative importance, explicit or not, given respectively to fisheries objectives and to ecosystem conservation in their narrow interpretation.

1.6 Integrated Management (IM)

The ecosystem-related concepts mentioned above have a lot in common and relate very closely to the already widely used concept of integrated management. The latter involves comprehensive planning and regulation of human activities towards a complex set of interacting objectives and aims at minimizing user conflicts while ensuring long-term sustainability. It implies the use of a collaborative/participative approach involving the main stakeholders in a flexible, responsible and transparent planning process, respectful of existing rights and duties. It recognizes the need to protect the ecosystem and the implications of multiple uses and aims at sustainable development. Taking account of uncertainty, it complies with the precautionary approach. It takes account of natural and economic areas and not only administrative or political ones. It specifically identifies ecosystem-oriented objectives and indicators. It acknowledges the fragmentation of the sectoral approaches and the linkages between inland, coastal and ocean uses. It integrates data collection, information and research (assessment) and recognizes traditional knowledge. It develops processes for stakeholders' interaction, particularly in objective setting, planning and implementation, including conflict resolution. It explicitly considers the cumulative effects of human activities, and its implementation is based on *integrated management plans* (IMPs) (see for instance Fisheries and Oceans Canada, 2002). This reading indicates clearly that EBFM and EAF are subsets or aliases of IM, possibly with a greater emphasis on the ecosystem implications.

2. ECOSYSTEM CHARACTERISTICS

There are two major sets of challenges to the adoption and implementation of EAF. The first set is rather familiar to all fisheries managers as it is at the origin of the conventional management failure. It relates to the adjustment of fishing capacity to the resources' productivity and its implications in terms of use rights and resource allocation. The problems and the potential solutions are well known and thoroughly dealt with elsewhere in the literature. We shall not dwell on them here. The second set is "new", at least to the fisheries arena, or has recently got a new and higher level of priority in policy, the media and with a growing fraction of society at large. It relates to ecosystem issues of key relevance to EAF such as: (1) the characteristics of ecosystems, their complexity, structure, functioning, natural variability and boundaries, and (2) their modification and degradation by fisheries and other land- and sea-based economic activities. Both are further elaborated below.

2.1 Definition

An ecosystem is a very complex entity with many interactive components. It can be defined as "*a system of complex interactions of populations between themselves and with their environment*" or as "*the joint functioning and interaction of these two compartments (populations and environment) in a functional unit of variable size*" (Odum, 1975; Ellenberg, 1973; Nybakken, 1982; Scialabba, 1998). In this review, and in EAF, we will consider "populations" as including people, and especially people involved in fisheries, with their technology and institutions (see Figure 1).

2.2 Scale and Boundaries

Ecosystems may be considered at different geographical scales, from a grain of sand with its rich microfauna, to a whole beach, a coastal area or estuary, a semi-enclosed sea and, eventually, the whole Earth. As stated by Lackey (1999), ecosystems are defined at a wide range of scales of observation "*from a drop of morning dew to an ocean,… from a pebble to a planet*". Ecosystems defined at a given geographical and functional scale are therefore nested within larger ones and contain smaller ones with which they exchange matter and information. Fisheries stocks, operations and management (including EAF) are relevant at intermediate geographical scale (from a few to thousands of kilometres).

While mapping ecosystems is one of the prerequisites of their management, their geographical boundaries are not easy to determine. They depend on the scale considered and can never encompass all the relevant processes. Boundaries may also be variable as the ecosystem's extension and location change seasonally or from year to year under changing climatic conditions (see below). This variability is higher in the pelagic than in the demersal domain.

2.3 Dynamics and Natural Variability

Ecosystems are dynamic, composite entities within which large quantities of matter, energy and information flow, within and between components, in a way that is not yet completely understood. These flows depend on the ecosystem structure and determine it. There is not yet agreement as to whether the flows are controlled primarily by: (1) top predators' feeding behaviour (top-down control); (2) primary producers (bottom-up control); (3) some numerically abundant species somewhere in the middle of the food chain (wasp-waist control); or (4) some combination of some or all of these, depending on systems and their possible states (Cury *et al.*, 2003).

Ecosystems' structure, species composition and functioning change seasonally (a type of change well understood by fisheries) as well as between years (a major source of uncertainty). Those changes can appear as quasi-cyclic (e.g. 11-12 years' cycles related to sunspot activity) with multiple frequencies (Klyashtorin, 1998) or as sudden shifts between apparently alternative "stable" states. Some well-known environmental fluctuations are those causing El Niño events, which change the patterns of Eastern Pacific ocean currents and affect global weather every few years. These long- and medium-term natural fluctuations result in changes in distribution, abundance and physiology of marine organisms, associated with changes in the extension, localization, structure, productivity and other characteristics of the ecosystems in which they live.

Environmental changes can produce effects similar to those of fishing, and it is often difficult to distinguish between them. Although they cannot be controlled directly, they exert a fundamental influence on the stability and resilience of marine ecosystems and their resources and they must be taken into account by managers. As most of these changes are not predictable with the available knowledge, they create uncertainty as to the future states of the system or its reaction to exploitation and management, leading to potential errors and consequent risk for the people and the resources (Cury *et al.*, 2003; Christensen *et al.*, 1996).

2.4 Biological Organization

The functioning of an ecosystem results from the organization of its species communities, consisting of species populations having their own dynamics in terms of abundance, survival, growth, production, reproductive and other strategies. The community's resilience depends on its capacity to adapt to the physical environment and on its relations with the other communities, e.g. through competition or predation. Communities are interdependent and interconnected as trophic networks (resulting from predator-prey relationships) depending on environmental variables. Food-web analysis and estimates of consumption are essential for understanding possible reactions of the ecosystem to exploitation regimes as well as rebuilding strategies and, during the last decade, the information on this matter has greatly improved (Trites, 2003). However, uncertainty about the structure and functioning of food webs remains a major concern in EAF. The interactions between populations and the environment in which they live lead to a hierarchy of abundance and to the organization of the community. This organization is one of the measurable elements of biodiversity, related to the health or integrity of the ecosystems.

2.5 Structure

The description of the fishers' interaction within the ecosystem requires identification of four main ecosystem compartments: (1) a biotic compartment, including target fish resources, associated and dependent species and the living habitat (seagrass, algal beds, corals); (2) an abiotic compartment, characterized by its topography, bottom types, water quality and local weather/climate; (3) a fishery compartment, in which harvesting and processing activities take place, with a strong technological character, and (4) an institutional compartment, comprising laws, regulations and organizations needed for fisheries governance. Humans are part of the biotic component of the ecosystem from which they draw resources, food, services and livelihood as well as part of the fishery component which they drive. These components interact and are affected by: (i) non-fishing activities; (ii) the global climate; (iii) other ecosystems, usually adjacent, with which they exchange matter and information; and (iv) the socio-economic environment as reflected in the market, relevant policies and societal values. A simplified diagram of the interactions involved in an exploited ecosystem is given in Figure 1 below.

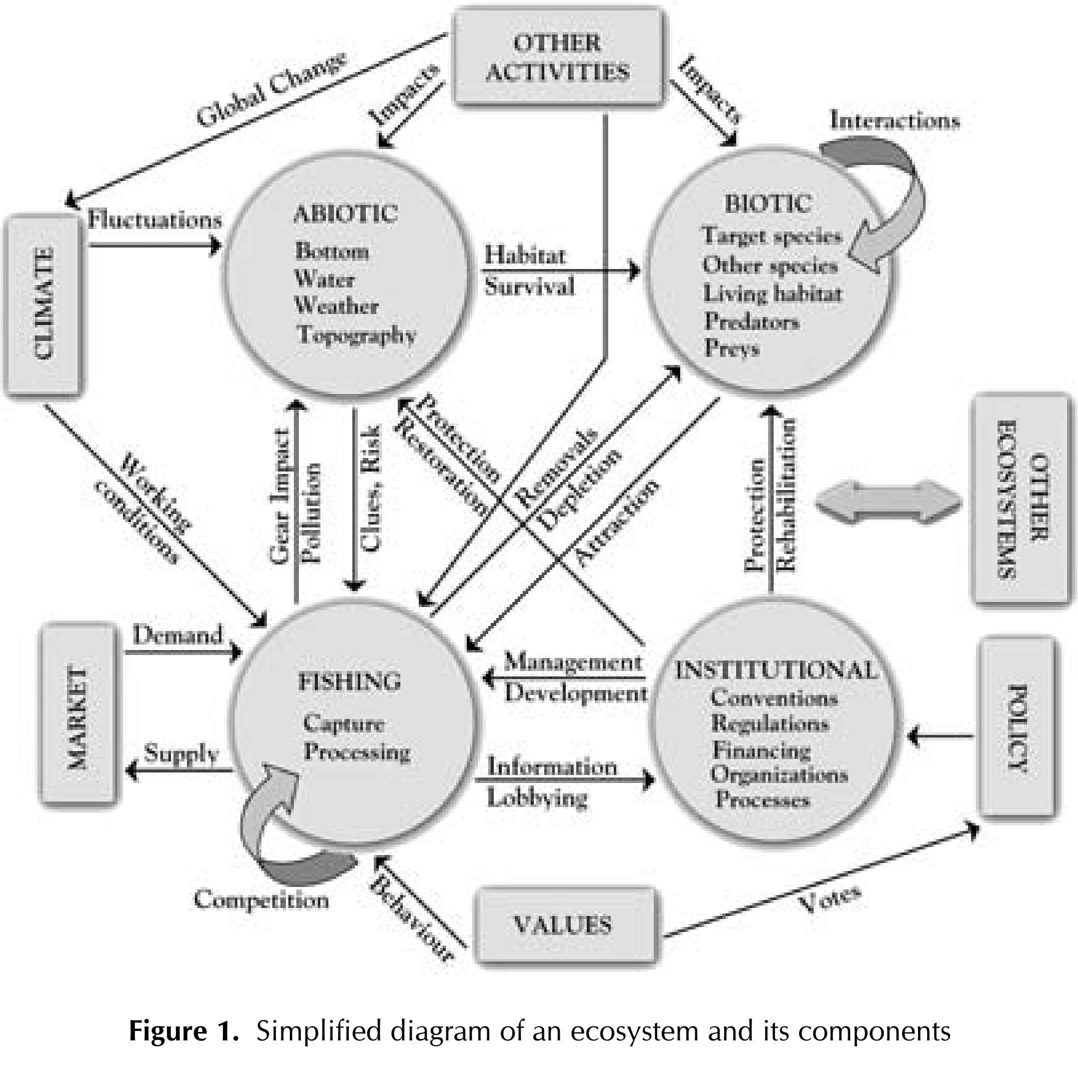

Figure 1. Simplified diagram of an ecosystem and its components

3. FISHERIES IMPACT ON THE ECOSYSTEM

The ecosystems that support fisheries, together with other economic activities, are subject to a number of alterations of significant relevance to their functioning and resilience and to the goods and services they can provide. Because of our imperfect understanding of ecosystem structure and functioning, as well as the inherent difficulty of distinguishing between natural and human-induced changes, the latter are not always perfectly predictable and/or reversible (Christensen *et al.*, 1996). The following sections elaborate briefly on some types of alteration.

3.1 Overall Impacts

Impacts from fisheries on the environment have been abundantly described and reviewed (Dayton *et al.*, 1995; Goñi, 1998; Kaiser *et al.*, 2003; Gislason, 2003; Agardy, 2000). More specifically, capture fisheries impact target resources. They reduce their abundance, spawning potential and, possibly, population parameters (growth, maturation, etc.). They modify age and size structure, sex ratio, genetics and species composition of the target resources, as well as of their associated and dependent species. When poorly controlled, fisheries develop excessive fishing capacity, leading to overfishing, with major ecosystem, social and economic consequences.

Fishing may also affect ecological processes at very large scale. The overall impact has been described as comparable, in aquatic systems, to that of agriculture on land in terms of the proportion of the system's primary productivity harvested by humans (Pauly and Christensen, 1995). Overfishing transforms an originally stable, mature and efficient ecosystem into one that is immature and stressed. This happens in various ways. By targeting and reducing the abundance of high-value predators, fisheries deeply modify the trophic chain and the flows of biomass (and energy) across the ecosystem (e.g. Pauly, 1979). They can also alter habitats, most notably by destroying and disturbing bottom topography and the associated habitats (e.g. seagrass and algal beds, coral reefs) and benthic communities.

The alteration of the habitat by various human activities may be physical (e.g. by adding artificial structures like artificial reefs, oil rigs, aquaculture installations), mechanical (e.g. through the "ploughing" effect of dredges and trawls), or chemical (e.g. through injection of nutrients, pesticides, heavy metals, drugs, hormones). Fishing may result in changes in productivity of resources (some positive and some negative) and affects associated species. Some aspects of fisheries can have significant and long-lasting effects, e.g. destructive fishing techniques using dynamite or cyanides or inadequate fishing practices (e.g. trawling in the wrong habitat); pollution from fish processing plants; use of ozone-depleting refrigerants; dumping at sea of plastic debris that can entangle marine animals or be swallowed by turtles; loss of fishing gear, possibly leading to ghost fishing; lack of selectivity, affecting associated and dependent species, resulting in wasteful discarding practices, juvenile mortality, added threat to endangered species, etc. Poorly-managed large-scale mariculture can damage coastal wetlands and nearshore ecosystems, often used as nurseries by key capture fishery resources, and contribute to ecosystem contamination with food residues, waste, antibiotics, hormones, diseases and alien species.

3.2 Impact on Associated and Dependent Species

The Law of the Sea provides that fisheries management must take care also of associated and dependent species. The impact of fishing on these species has been documented in some areas (Goñi, 1998; Gislason, 2003) but is still frequently unknown or only partly understood. The decline of primary productivity consumers low in the food chain removes important forage species needed higher in the food web, with cascading effects for the ecosystem. Conversely, the removal of top predators such as mammals, tuna or sharks, may release an unusually large abundance of preys at lower levels with cascading and feedback effects on the food chain and species composition (Trites, 2003; Cury *et al.*, 2003). For example, as most sharks and some batoid fishes (angel fishes) are predators located at or near the top of marine food webs, their depletion modifies the intricate trophic interactions of their ecosystems (Pauly and Murphy, 1982; Jackson *et al.*, 2001). The removal of predators through fishing in Kenyan reefs resulted in the expansion of sea urchin population, which apparently led to a decrease in live coral and to loss of topographic complexity, species diversity and fish biomass (McClanahan and Muthiga, 1988). Goñi (1998) reports that the hunting of sea otters (*Enhydra lutris*) in the Northeast Pacific caused a large-scale expansion of sea urchins, the increased grazing of which caused the decline of the important kelp forest. She also reports that, in the Bering Sea, the expansion of the fisheries on pollock (*Theragra chalcogramma*) during the 1970s has been considered as a probable cause of the decline of several populations of marine mammals, e.g. sea lions (*Eumetopias jubatus*) by 76%, seals (*Callorhinus ursinus*) by 60% and (*Phoca vitulina*) by 85%, as well as the decline of several seabird populations *(Urea algae, U. lomvia, Rissa brevirostris, R. tridactyla*). All these non-fish species compete directly with the Pollock fisheries since the target species represent 21-90% of their diet. Impacts can be particularly serious on cartilaginous fish populations, which have a lower productivity and resilience than bony fishes. As a consequence, fisheries targeting shark have a low record of sustainability and some species of skates, sawfish and deep-water dogfish have been virtually extirpated from large regions (Garcia and Majkowski, 1990; Stevens *et al.*, 2000).

A well documented example of direct impact on benthic species is that of modern towed gear (trawls and dredges) which caused, *inter alia*, long-term changes in abundance and species composition in the Wadden Sea (Goñi, 1998) and Australia (Moran and Stephenson, 2000). The mortality of benthic species associated with or preyed upon by target bottom fish resources resulting from the use of trawls can vary greatly, depending on how the gear is built or rigged (Moran and Stephenson, 2000). For example, the addition of a tickler chain on a commercial beam trawl will allow it to catch more of its bottom-fish target but, at the same time, will detach and uproot more benthic species (as bycatch) (Kaiser *et al.*, 1996 and 1998; Dayton *et al.*, 1995). Likewise, some gear modification can reduce fishing mortality. For example, operating a semi-pelagic trawl 15 cm above the sea bottom has no measurable effect on the benthos community, while the standard demersal trawling dragging on the bottom reduces benthos density by 15.5% (Moran and Stephenson, 2000). Finally, fishing can have significant impact on the genetic diversity of resources and can permanently change populations characteristics (Kenchington, 2003).

3.3 Impact on the Environment

Fishing gear can change the living and non-living environment within which the target and other related resources live. Environmental damage may come from the very nature of the fishing technology (e.g. in the use of dynamite or poison) or from the inappropriate use of an otherwise acceptable gear (e.g. using trawls in coral reefs or seagrass beds).

The use of dynamite and other explosives for "blast fishing" is still common in parts of Asia, Africa, Caribbean and South Pacific. A relatively small explosive (beer–bottle size) is capable of destroying a three-metre circular area of stony corals (Goñi, 1998). These practices are generally officially banned by fisheries regulations and laws but often persist because the people involved have little, if any, alternative livelihood.

The impact on the habitat depends on the gear and sediment type. Highly dynamic, soft bottoms (e.g. coarse sand, hydraulic dunes) may suffer limited damage even when exploited by heavy (including hydraulic) dredges. On the contrary, stable, hard, and highly structured habitats (such as coral reefs, seagrass beds, sponge beds) will be easily damaged. One well-documented example is the use of modern towed gear (trawls and dredges) which caused, *inter alia*, destruction of seagrass beds (*Posidonia oceanica)* in the Mediterranean and destruction of the oyster (*Cassostrea virginica*) habitat in Chesapeake Bay (Goñi, 1998). Damage is also related to fishing frequency, gear weight and rigging. Addition of heavy tickler chains to the trawl ground rope increases bottom abrasion and turbidity (Kaiser *et al.*, 1996 and 1998; Dayton *et al.*, 1995) while adding rollers reduces it. The use of sodium cyanide in the Philippines to catch marine tropical fishes for the aquarium trade has led to the destruction of the coral reef habitat and decline of aquarium and food fish.

3.4 Poor Selectivity, Bycatch and Discards

Fishing generates bycatch and discards. A first attempt to address the issue at global level was made in the late 1990s by FAO (1997c) and the first estimate of the global extent of the problem (about 27 million tonnes of resources dumped per year) was published by this Organization (Alverson *et al.*, 1994). A recent review of the issue has been undertaken by Cook (2003). Most fishing activities are not selective enough to remove from the ocean only the desired targets and will probably never be. This leads to accidentally catching other species (bycatch), part of which has little or no use (at least in the local context) and will be dumped overboard (as discards) together with the offal from fish processing at sea. The effect is to increase availability of food to scavenger species (including sea birds) and, when concentrated over time, may cause local anoxia of the seabed environment. The resulting amount of organic material may not be negligible. On the North Pacific shelf and upper slope, the amount of offal generated by at-sea production of surimi (a protein extract of fish) is very significant, since the technology used extracts less than 50% of the wet weight from the total catch, the rest being dumped. In the North Sea, 6.5 to 12.5% of the groundfish caught is dumped at sea. Some of this is consumed by sea birds, but a certain amount of offal becomes available to benthic scavengers. The increase in abundance of dogfish (*Scyliorhinus canicula*) in northern Spain fisheries and that of *Raja radiata* in Greenland shrimp fisheries has been associated with increased discards. Oxygen depletion due to excess organic loading from discards has been recorded in the New Zealand fisheries for hoki (*Macruronus novaezelandie*) as well as in the North Eastern Atlantic (Goñi, 1998).

Bycatch mortality also affects many non-fish species which are relevant to the functioning of the overall ecosystem. For example, surface and sub-surface driftnet and long-line fisheries have serious negative effects on populations of sea birds, e.g. albatrosses and petrels in long-line fisheries in the North Pacific and in the Southern Ocean. High seas drift nets have had a considerable impact on sea birds in the northern Pacific as have gillnets in southwest Greenland, eastern Canada and elsewhere.

3.5 Gear Loss and Ghost Fishing

Voluntary dumping or loss of fishing gear may lead to ghost fishing. The scale of the impacts of ghost fishing is basically unknown but there are indications that the effects are not negligible (Goñi, 1998). Species affected by discarded gear include not only teleost fish but sea birds, marine mammals and turtles. For example, the incidence of entanglement of marine mammals in floating synthetic debris in the Bering Sea has been related to growing fishing effort and increased use of plastic. Fowler (1987) concludes that entanglement is the principal cause of the current decline in the fur seal population of the Pribilof Islands, accounting for 15% of the mortality of youngsters. As an average, a northern fur seal (*Callorhinus ursinus*) is expected to encounter 3-25 pieces of net debris along the 800-km yearly migration in the Northeast Pacific. Fish traps, unless made of biodegradable material, contribute to the problem. To illustrate this problem, 31 600 pots were lost in the Bristol Bay crab fishery in a period of two years (Kruse and Kimber, 1993; Goñi, 1998).

4. FISHERIES VERSUS OTHER IMPACTS

4.1 Overall Impacts

The ocean is used for a wide range of human consumptive and non-consumptive uses providing recreation, food, livelihood, energy and pharmaceuticals. It is also used for activities such as transportation, defence, mining, conservation and scientific research (Richardson, 2003; Rosenberg, 2003). Ample documentation of these uses can be found on the web-based UN Atlas of the Oceans (http://www.oceansatlas.com/index.html). Non-fishing activities, whether coastal or continental, may have major impacts on the aquatic ecosystems through contamination, habitat modifications and alteration of freshwater flows (FAO, 1995a). The relevance to EAF stems from the fact that most of these impacts will threaten fisheries sustainability, either reducing resource productivity, stability and resilience to fishing, or reducing the quality of the fish as food through contamination.

Through land drainage, sewage, river outflow, wind and rainfall, such economic activities as agriculture, manufacturing or chemical industries, incineration of toxic wastes, human settlements, etc., release excess nutrients (e.g. nitrates, phosphorus) as well as contaminants (e.g. polychlorinated biphenyls (PCBs), mercury, dioxin), radioactive wastes, oil, antifouling paints (tributyl tin), human pathogens (e.g. cholera, salmonella), plastic and other debris. Coastal activities, including human settlements and tourism, often result in conversion and destruction of habitats of high relevance to fisheries such as estuaries or coastal wetlands used by fishery resources as reproduction, nursery or feeding areas, reducing fisheries productivity and resilience. Irrigation and production of hydroenergy reduce freshwater inflows into the oceans, resulting in modification or suppression of seasonal floods (as in the Nile), reducing or eliminating key environmental signals and reducing influx of nutrients. Dams and drying-up of streams, together with mining of gravel and sand and deforestation, modify the quality of habitats and alter or interrupt the reproductive migration processes of many species of marine fish (e.g. salmon, sturgeon). Together, these impacts result in eutrophication, harmful algal blooms (red tides) (for more details on harmful algal blooms, see http://www.IOC.unesco.org/hab), accidental death of animals through entanglement in (or ingestion of) debris; food contamination, human diseases, climate and sea-level changes; UV and temperature changes with impacts on primary productivity and biological habitats (such as coral bleaching) and can lead to total eradication of productive habitats (e.g. in the dried up Aral Sea).

4.2 Relative Importance of Fisheries and Other Impacts

Assessing the scale of fisheries effects relative to other impacts can be difficult, because of confounding and interacting combinations with other anthropogenic effects (e.g. pollution, habitat degradation, climate change) and natural variability of environmental factors. In the early 1970s, pollution and habitat degradation originating from land-based activities were considered to be the main factors of fisheries degradation (Stevenson, 1973). More recent publications hold that excessive fishing has become the main destabilizing factor of ecosystems, directly, through removals and associated impacts, as well as indirectly, through the aggravation of eutrophication and subsequent oxygen depletion (Jackson *et al.*, 2001).

While fishing activities are generally fairly well described and their impact on resources have been studied and documented for decades, land-based sources pollution and their impact on the marine ecosystem and on fisheries are very poorly documented. As a consequence, fisheries impacts tend to be the ones more “visible” to the public. Because the fisheries sector is economically and socially weaker than the agricultural or industrial sector, there is a risk that governments and NGOs target it primarily when looking for short-term solutions to the growing environmental problem, raising the issue of intersectoral equity.

4.3 The Black Sea Example

The combined impacts from fisheries and land-based activities represent a very significant threat to aquatic ecosystems and to fisheries. The evolution of the Black Sea ecosystem provides an illustration of the problem. The freshwater input from land (346 km^3 per year) is higher than the evaporation (323 km^3 per year) and the bottom is covered with a stratum of anoxic salt water with a high methane and hydrogen sulphide content.

The Danube, Dniestr and Dniepr rivers carry to the Black Sea about 280 km^3 of fresh water per year, representing 85% of the total input of fresh water into that sea. The watershed of the three rivers covers an area (1.4 million km^2) that is 22 times larger than the Black Sea itself, and the

Danube alone carries the waste water of 80 million people. At the end of the 1960s, the Black Sea was the most productive area of the Mediterranean, with a high diversity of pelagic and benthic fauna. After 1970, a very strong modification of the chemical and biological habitat occurred as a consequence of industrial development and intensive agriculture. Inputs of phosphorus and nitrate increased threefold and tenfold respectively while the input of silicate decreased fivefold. This resulted in a significant modification of the structure and functioning of the coastal ecosystem, including a change in dominance of the algal communities from diatoms to small- size dinoflagellates *(Dinophysis* spp.).

At the beginning these modifications appeared favourable for the ecosystem and fisheries. Phytoplankton production and copepod abundance increased and with them the abundance of plankton-feeding fishes. Fishing effort increased, leading initially to an increase in catches from 200 000 tonnes in 1970 to 600 000 tonnes in 1985 but resulting finally in overfishing. The ultimate consequence was an explosion of carnivore jellyfish (*Aurelia aurita* and *Mnemiopsis leidy*) consuming eggs and larvae and occupying the ecological niche formerly occupied by the small pelagic species depleted by overfishing The biomass of jellyfish increased from one million tonnes in 1970 to 700 million tonnes in 1985 (about 5 kg/m^2). These jellyfish, having no predators, are a trophic "dead end", and their mortality generates an important bacterial activity and a large quantity of anoxic water near the bottom, reducing further the habitat for fishery resources (Bouvier, 1998).

4.4 Impact on Diadromous Fish

Diadromous fish, using both the inland and marine environments, illustrate the impact of non-fishery activities on fisheries. Habitat alteration, degradation and outright destruction by non-fishery activities are probably the primary cause of extinction in diadromous fishes (Jonsson *et al.*, 1999). For example, among the diadromous species, the sturgeons are particularly threatened, with 13 of the 15 existing species being endangered, and restoration programmes and restocking will not lead to recovery unless the fundamental sources of decline (in addition to overexploitation), such as pollution and habitat degradation, are addressed (Jonsson *et al.*, 1999). Many changes in fish stocks can be seen to result from changing of river runoff or influx of a layer of warm water (Mann, 1993). For example, the collapse of commercial snook fisheries in Florida during the 1950s has been attributed to habitat alteration and reduction of freshwater flow (Zerbi, 1999). Major environmental disturbances responsible for the decline of *Salmo salar* populations include the development of hydroelectric dams, which impede migration to spawning grounds, and acid rain, which degrades quality of nursery grounds. The poor state of Pacific salmon (*Oncorhynchus* spp.) is also a consequence of the economic development and exploitation of Northwest Pacific ecosystems, including trapping (furs), mining, timber harvesting, grazing, irrigation, dams, municipal and industrial development, pollution and excessive harvest (Lichatowich *et al.*, 1999).

4.5 Competition Between Humans and Marine Mammals

Marine mammals are important predators located towards the apex of the oceanic food chain. They have been heavily depleted in the past and are still, in some cases, threatened with extinction. After decades of protection, many populations are again (or still) very abundant, and their feeding requirements place a very significant demand on ocean productivity. Some countries and stakeholder groups (see, for instance, http://www.nmfs.noaa.gov) are actively promoting the full protection of these species, questioning our capacity to establish a sustainable regime of exploitation. Other countries consider these species as essential resources and as competitors to humans, pointing to the very large quantities of fish consumed by them (Tamura, 2003).

4.6 Allocation Implications

Non-fishery impacts on resource abundance result in a reduction of the fishery resources available to humankind. While they may not be perceived as such by the fishery sector, they represent *de* *facto* a forced, non-negotiated, non-transparent, and potentially non-sustainable allocation of aquatic space and resources to non-fishing activities, often located far inshore (e.g. sources of pollution). One implication of the EAF is the need to deal with this problem in a more balanced and transparent way.

5. INSTITUTIONAL FOUNDATIONS

The EAF, as interpreted by FAO (2003) does not represent a revolution (in the sense of a rupture with the current fisheries management paradigm). It is rather an important new phase in a process of continuous evolution of fisheries-related institutions. While the specific terms *"ecosystem approach to fisheries (EAF)"* or *"ecosystem-based fisheries management (EBFM)"* may not yet be common in international instruments, regional conventions or arrangements and national legislation, the underlying principles and conceptual objectives examined above appear in many of them (Kimball, 2001; Aqorau, 2003).

The institutional foundations of EAF are to be found in the numerous instruments and events which, during at least the last three decades, reflected a growing societal concern for our degrading environment. Selecting the most significant ones among them is partly subjective. Annex 2 contains the list of international events and instruments that we have selected as most relevant in paving the way to the ecosystem approach to management of the environment as well as of fisheries. These events and instruments materialize the progressive building up of institutional strength in parallel with progress in the understanding of the ecosystem functioning and of human institutions created to conserve or use them in a sustainable manner.

The two main roots of EAF are the UN Conference on Human Environment in 1972 and the UN Convention of the Law of the Sea adopted in 1982, two historical institutional processes from which the concept of sustainable fisheries development emerged. A number of international events have preceded, accompanied and followed the adoption of the 1982 Convention and UNCED and have contributed to the progressive emergence of the EAF paradigm. They are briefly examined below (see also Annex 2).

The **FAO Technical Conference on Marine Pollution and its Effects on Living Resources and Fishing**, Rome, 1970, was an early expression of the concern for land-based sources of pollution and degradation.

The **UN Conference on Human Environment,** Stockholm, 1972, dealt with the environmental aspects of natural resources management, stressing *"the right of Man to modify the environment for its development and the dangers behind the huge capacity developed to do so"*. It stressed concepts central to the ecosystem management concept in general and to EAF in particular, such as people's participation, resource limitation, environmental degradation, demography, planning and management, institutions, role of science and technology, international collaboration and equity.

The **FAO Technical Conference on Fishery Management and Development,** Vancouver, 1972 (Stevenson, 1973), stressed both the problems of overfishing and of environmental degradation from non-fishery sources. It also called for new management approaches based on precaution and addressing multispecies problems. It proposed to design the new fisheries management into the broader framework of ocean management.

The 1980 **Convention on the Conservation of Antarctic Marine Living Resources**, which lead to the establishment of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), is usually considered a precursor of the ecosystem approach to fisheries. Its provisions require that any harvesting and associated activities must be conducted in accordance with the following principles of conservation (from Kimball, 2001):

1. A decrease in the size of any harvested population to levels below those which ensure its stable recruitment should be prevented. For this purposes its size should not be allowed to fall below a level close to that which ensures the greatest net annual increment.

2. The ecological relationships between harvested, dependent and related populations should be maintained, and depleted populations should be restored to the levels defined in 1 above.

3. Changes in the marine ecosystem which are not potentially reversible over two or three decades should be prevented or the risk of these changes should be minimized.

The evolution of the ecosystem approach in the CCAMLR context has been reviewed and analysed by Constable *et al.* (2000) in relation to the use of a precautionary approach, bycatch management, ecosystem impacts, etc. concluding that CCAMLR, which has not been able to conserve some of its most valuable resources, has still to face the real test in its ecosystem approach.

The 1982 **UN Convention of the Law of the Sea** formulated *inter alia* the basis for conventional fisheries management. It deals with maximum sustainable yield, the need for restoration of depleted populations, the interdependence of stocks (e.g. in Art. 61.3) and the issue of associated and dependent species (Art. 61.4 and 119.1.b). In addition, it stresses the obligation to protect and preserve the environment (Part XXII, Art. 192 and 193).

The **World Commission on Environment and Development** (WCED, 1984-1987) and the "Brundtland Report" (Our common future, WCED, 1987) further developed the concept of sustainable development. It stressed, *inter alia,* the concepts of intergenerational equity, sustainable use, prior environmental assessments, prior consultation, precaution and liability, cooperation on transboundary environmental problems and natural resources. The link between sustainable development and ecosystem-based management is illustrated by the definition of sustainable fishing adopted by the US Committee on Ecosystem Management for Sustainable Marine Fisheries, which defined it as *"fishing activities that do not cause or lead to undesirable changes in biological and economic productivity, biological diversity, or ecosystem structure and functioning from one human generation to the next. Fishing is sustainable when it can be conducted over the long term at an acceptable level of biological and economic productivity without leading to ecological changes that foreclose options for future generations."* (US National Research Council, 1998).

The related concept of "**Ecologically Sustainable Development (ESD)**" was adopted in the early 1990s in Australia in the wake of UNCED (Commonwealth of Australia, 1992) to emphasize the importance of the environment to long-term survival and to ensure that there was a balanced approach in dealing with environmental, social and economic issues. It was defined as *"Using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased"*. This definition emphasizes further the importance of the environment to long-term survival and the need for balance in dealing with environmental, social and economic issues. The ESD approach aims at three key objectives: *(1) to enhance individual and community well-being and welfare by following a path of economic development that safeguards the welfare of future generations; (2) to provide for equity within and between generations; and (3) to protect biological diversity and maintain essential ecological processes and life-support systems.*

The **UN Conference on Environment and Development** (UNCED, 1992) completed the work of the WCED, developing Agenda 21 as a basis for implementation. It led to the adoption of a number of conventions and agreements of relevance to EAF, such as the Framework Convention on Climate Change, the Biodiversity Convention and the UN Fish Stock Agreement. The Rio Declaration puts human beings "at the centre of concerns" (Principle 1) and recognizes the sovereign rights to exploit resources (Principle 2), as well as the responsibility to do so without damaging the environment beyond the EEZ (Principle 2). It recognizes, *inter alia*, the need to: cater for future generations (Principle 3); integrate environmental protection in development (Principle 4); eliminate unsustainable patterns of production and consumption (Principle 8); encourage public participation (Principle 10); widely apply the precautionary approach, internalize environmental costs (Principle 16); the need to apply the Polluter Pays principle and undertake environmental impact assessment (Principle 17); the role of women (Principle 20) and indigenous communities (Principle 22); and the need for peaceful conflict resolution (Principle 26).

The 1992 **UNCED Agenda 21** takes an ecosystem approach to ocean management. Its Chapter 17 calls for "*new approaches to marine and coastal area management and development which is … integrated in content… precautionary and anticipatory in ambit*". It recognizes that use of marine resources and environmental protection are inseparable, and that integrated management is necessary to protect both. It addresses in detail the integrated management and sustainable development of coastal areas (Programme A), marine environmental protection (Programme B), sustainable use and conservation of marine living resources in the high seas (Programme C) and in areas under national jurisdiction (Programme D). It also addresses uncertainties related to natural variability of the marine environment and climate change (Programme E). Programmes C and D are particularly relevant for fisheries. They provide for, *inter alia*, strengthening of conventional management (to eliminate overfishing) as well as multispecies management, associated and dependent species, relations between populations, restoration of depleted stocks, improvement of selectivity and reduction of discards, protection of endangered species and habitats, prohibition of destructive fishing, and the role of science.

The 1992 **Convention on Biological Diversity** (CBD) elaborates the core principles of multiple-use management of biodiversity. It emphasizes the conservation of biodiversity, the sustainable use of its components and the fair and equitable sharing of benefits. Under the Convention, parties have the right to exploit and use biological resources and have an obligation to manage activities that may threaten biodiversity, regardless of where those effects may occur, and to collaborate where these effects occur on the high seas. The CBD complements and reinforces the 1982 UN Convention on the Law of the Sea (Kimball, 2001). The CBD elaborates also on the 1982 Convention's content in relation to genetic resources and genetically-modified organisms (GMOs). Furthermore, the CBD identifies the establishment of a system of *marine protected areas* as a key measure for conservation of biodiversity. The CBD definition of Biodiversity (see Glossary in Annex 3) includes *ecosystem diversity* (the variety and frequency of occurrence of different ecosystems), *species diversity* (the frequency of occurrence of different species) and *genetic diversity* (the frequency of occurrence and diversity of different genes and/or genomes within species). Biodiversity is important from an EAF point of view because it is related to "resilience" or capacity to resist an impact or return to original conditions after the impact is removed. As a consequence, it is of interest to fisheries that the diversity of exploited habitats and the diversity of habitats and species in them is maintained and possibly enhanced as an "insurance" against negative consequences of future changes.

The 1995 **Jakarta Mandate on Marine and Coastal Biological Diversity** elaborated further on the "*ecosystem approach*" adopted by the CBD, further specifying it and basing it on: protected areas; the precautionary approach; scientific knowledge; indigenous knowledge and stakeholders' participation. It aims, *inter alia*, at integrated management; development of the ecosystem approach; valuation and effects of marine protected areas; assessment and minimization of mariculture impacts and the understanding of causes and impacts of the introduction of alien species (Pirot *et al.*, 2000; Kimball, 2001).

The 1995 **UN Fish Stock Agreement** (FSA) aims at long-term conservation and sustainable use of these marine living resources, recognizing from the onset "*the need to avoid adverse impacts on the marine environment, preserve biodiversity, maintain the integrity of marine ecosystems and* *minimize the risk of long-term or irreversible effects of fishing operations"*. The FSA deals with the precautionary approach, protection of biodiversity and sustainable use of fisheries resources. It calls on participating states to, *inter alia*: (1) protect biodiversity in the marine environment; (2) adopt measures to ensure the long-term sustainability of the fish stocks and promote their optimum utilization; (3) take account of environmental and economic factors; (4) adopt an ecosystems approach, whereby dependent or associated species are taken into account; and (5) take measures to prevent or eliminate overfishing and excess fishing capacity. It also provides for the precautionary approach, and the way of applying it is detailed for the first time, as through the specification of precautionary reference points and identification of management actions to be triggered in relation to them. It finally promotes a *principle of compatibility,* according to which management measures taken in different jurisdictional areas must be compatible across the entire area of distribution of the stocks.

The 1995 **FAO Code of Conduct for Responsible Fisheries** provided a voluntary framework to increase the sustainable contribution of fisheries to development. It combines the provisions of the 1982 Convention, the 1995 Fish Stock Agreement and the CBD and, as such, is the generally recognized global framework for capture fisheries and aquaculture, in marine or inland waters, in EEZs or the high seas. Its provisions are examined in detail further below.

The 1995 **Kyoto Declaration on the Sustainable Contribution of Fisheries to Food Security** emphasizes the importance of fisheries as a food source for the world's population. It sets out a number of principles that focus on sustainable development of fishery resources related to maintaining food security. It contains the agreement to undertake immediate action to, *inter alia*: "*conduct…. integrated assessments of fisheries in order to evaluate opportunities and strengthen the scientific basis for multispecies and ecosystem management…*" and to "*minimize post-harvest losses…*".

The 2001 **Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem** addressed directly and specifically the issue of introducing more ecosystem considerations into conventional fisheries management. Referring to the 1982 Convention, UNCED and the Code of Conduct, it recognized the need to "*take into account the impacts of fisheries on the marine ecosystem and the impacts of the marine ecosystem on fisheries*", and confirmed *"that the objective of including ecosystem considerations in fisheries management is to contribute to long-term food security and to human development and to assure the effective conservation and sustainable use of the ecosystem and its resources."* It recognized *"the complex interrelationship between fisheries and other components of the marine ecosystems"* but stressed that "*including ecosystem considerations in fisheries management…. would enhance management performance"*. It called for "*incorporation of ecosystem considerations such as predator-prey relationships"* and for a better "*understanding of the impact of human activities on the ecosystem"*. It emphasized *"the role of science and the impact of non-fishery (usually land-based) activities"*.

The Reykjavik Declaration called for, *inter alia*: (1) immediate introduction of management plans with incentives for sustainable use of ecosystems; (2) strengthening of governance; (3) prevention of adverse effects of non-fisheries activities on the marine ecosystems and fisheries; (4) advances in the scientific basis for incorporating ecosystem considerations in management (including the precautionary approach); (5) monitoring of interactions between fisheries and aquaculture; (6) strengthening of international collaboration; (7) technology transfer; (8) removal of trade distortions; (9) collection of information on management regimes, and (10) development of guidelines.

While calling generally for the continued implementation of Agenda 21 (in its Article 29b), the Plan of Implementation of the **World Summit on Sustainable Development** (WSSD, Johannesburg, South Africa, September 2002) in Paragraph 29d of the advance unedited Draft Plan of Implementation for the World Summit on Sustainable Development reinforced the conclusions of the Reykjavik Declaration by encouraging *"the application by 2010 of the ecosystem approach, noting the*

Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem ….". It also provides for *"the use of diverse approach and tools, including the ecosystem approach, the elimination of destructive fishing practices, the establishment of marine protected areas…".*

While it cannot easily be related to one particular international meeting, the recent and progressive development of **ecolabelling** in fisheries aims at establishing higher congruence between trade and sustainability objectives (Deere, 1999). Its application to fisheries has recently attracted a lot of international attention following UNCED. The potential usefulness of ecolabelling schemes to create market-based incentives for environmentally friendly products and production processes was internationally recognized at UNCED, where governments agreed to "*encourage expansion of environmental labelling and other environmentally related product information programmes designed to assist consumers to make informed choices*". The Marine Stewardship Council (MSC) has developed an ecolabelling system for capture fisheries, and the Global Aquaculture Alliance (GAA) is developing one for aquaculture products. Discussions are also ongoing regarding the possibility of applying to fisheries more generic systems such as ISO. While the future of the concept is still far from clear, fisheries managers are now aware that the future value of their fisheries might well be soon related to their management performance in terms of impact on the ecosystem.

6. RELEVANCE OF THE CODE OF CONDUCT

The Code being recognized by FAO members as the most complete and operational reference for management, any EAF guidelines produced under the aegis of FAO will need to be in line with its provisions. It is therefore important to examine the degree to which the Code already provides an appropriate basis for the development of EAF as an effective, scientifically sound and practical approach. The following section will show that the Code contains a significant number of ecosystem-related provisions (principles, axioms, conceptual objectives, constraints and conditions) which, when considered together, provide a good basis for EAF. These provisions could be grouped in various other ways than the one below. In particular, a finer grouping could be used to highlight the Code's relevance to more specific issues. This section should be sufficient, however, when cross-referred to the others (particularly Sections 2 and 3.1), to illustrate the fact that the Code, which does not mention EAF, does deal with practically all of its aspects.

6.1 Respect for the Ecosystem

The Code is generally elaborated "with due respect" for the ecosystem (Introduction). Recognizing the transboundary nature of the ecosystem (6.4), the Code provides that states should "conserve", "protect" and "safeguard" it (6.1; 6.6; 7.2.2d; 12.10), including from the impact of aquaculture (9.2), to keep its "integrity" (9.12). It promotes research (2.1), calling for an assessment of the impact of fishing, pollution, other habitat alterations and climate change (12.5). The Code provides for habitat protection (6.8; 7.2.2d) and "safeguard" (12.10) of critical habitats, requesting the rehabilitation of degraded ones (6.5; 7.6.10) and promoting research on the impact of their alteration on the ecosystem (12.5), as well as a prior assessment of the potential impact of new fisheries or introduction of new technologies (8.4.7; 12.11).

6.2 Account of the Environment

The Code states, in its Introduction, that it "takes account of" the environment. Its provisions promote its protection (2g; 6.5; 8.7). It promotes research on environmental factors (2j) and requires that such factors be taken into account in the "best scientific information available" (6.4), even when the scientific information available is inadequate (6.5). It provides that fishing be conducted "with due regard" for the environment (8.4.1), which should be monitored for impacts (10.2.4). It recognizes, in line with the 1982 Convention, the qualifying role of environmental factors on the Maximum Sustainable Yield (7.2.1).

6.3 Biodiversity and Endangered Species

The Code reflects "*due respect*" for biodiversity (Introduction). It promotes its maintenance (6.1), protection (7.2.2d), safeguarding (12.10) and conservation (9.2.1), mentioning genetic diversity (9.2.1; 9.1.2), the need to minimize fisheries impact on biodiversity (9.2.1) and to develop research about fishing gear impact. The Code also recognizes the existence of *endangered species* that need to be protected (7.2.2), and the need for measures to minimize fisheries impacts on them (7.6.9).

6.4 Species Interdependence

The Code distinguishes between exploited and non-exploited species belonging to the same ecosystem, the target species on the one hand and "non-target" species or "dependent or associated" species (in accordance with the 1982 Convention) on the other. Regarding the latter, the Code promotes the study of their behaviour (12.10), their conservation (6.2; 6.5) even in the absence of adequate scientific information (6.5, precautionary approach), the taking into account of accidental fishing mortality (7.2.5), the assessment (7.2.3) and the reduction/minimization of catches (7.2.2; 7.6.9; 6.6) or fisheries impacts (6.6; 7.2.2). The Code provides for conservation of populations structure (6.1), their rehabilitation in case of damage (6.3) and the analysis of the impacts of environmental factors on them (12). It also provides for the scientific study of the relations between populations (7.3.3).

6.5 General Impact from Fisheries

The Code provides that the impact of fisheries activities (including aquaculture and artificial reefs) should be minimized (6.7; 6.19; 8.9d; 9.1.5) and recommends the development of research on such impacts (8.11) for their assessment (9.15) and monitoring (9.15). It aims at "ecologically sustainable" activities (9.1.3). It promotes a reduction of pollution and use of chemicals (9.4), environmentally sound processing, transport or storage (11.1.7), and calls for regulation of environmental impacts of post-harvest practices (11.1.2). The Code provides also for the prior impact assessment and monitoring of gear impact (12.11), the prohibition of destructive practices (8.4.2) and the development of environmentally safe gear. The Code also considers, albeit very briefly, the problem of sound or optimal use of energy (8.6; 11.8c).

6.6 Selectivity, Ghost Fishing, Bycatch, Discards and Waste

Selectivity, or lack of it, is central to many biological issues affecting fisheries. Bycatch or incidental capture is responsible for endangering and contributing to extinction of a number of non-target species (such as dolphins or turtles) caught in driftnets or longline fisheries (Goñi, 1998). In addition, the discarding of unwanted catch, which is particularly important in unselective fisheries, is being considered by society not only as wasteful but as unethical. The Code dedicates a whole section to the issue (8.5). It promotes the use of more selective gear (7.6.9; 8.4.5) and calls for more international collaboration in better gear development (8.5.1; 8.5.4), as well as for the agreement on gear research standards. The Code calls for minimizing discards (12.10) and waste (6.6; 7.2.2; 7.6.9) including through reduction of dumping and loss of gear (7.2.2).

6.7 Impact from Other Activities

The Code also addresses itself to other (non-fishery) users (1.2; 10.1.5) and acknowledges the impact of other human activities on fisheries. It recommends avoiding or settling conflicts (10.1.4; 10.1.5). It also recognizes that their impacts should be assessed (7.2.3) and promotes the development of environmental research (8.4.8; 12.10). It provides that the negative effects of natural environmental factors should not be exacerbated by fisheries (7.5.5) and calls for restoration of resources affected by other uses (7.6.10). It calls specifically for consultation with fisheries authorities before making decisions regarding the abandonment of artificial structures (e.g. oil platforms) in the aquatic ecosystem. The Code contains also one Article entirely dedicated to the integration of fisheries into coastal area management (1.1; 1.3; 6.9; 8.11.3; 10.2.4). The Code calls for a reduction of pollution (7.2.2) through the development of waste disposal systems (e.g. for oil, garbage, decommissioned gear) in harbours and landing places (8.7.4; 8.9c). Dumping at sea from fishing vessels should follow the requirements of the MARPOL Convention (8.7.4) for onboard incineration (8.7.2). Emissions into the atmosphere should be reduced (8.8) including emissions of exhaust gas (8.8.1), ozone emissions, phasing out of conventional cooling agents such as chlorofluorocarbon (CFC) (8.8.3) and use of alternative refrigerants (8.8.4).

6.8 Improved Governance

The Code is recognized as a source of guidance for fisheries governance in line with all the main binding and non-binding agreements. The Code provisions related to regional fishery bodies (e.g. 6.5, 6.10, 6.12, 7.1.3, 7.6.10, 7.7.5, 10.3), legal instruments and norms (e.g. 6.13, 6.14, 6.17), national management systems (e.g. 7.1 to 7.8.1, 10.1, 10.2), participation (e.g. 6.13, 6.16), precaution (e.g. 7.5), research (e.g. 7.2.1, 7.2.3, 7.4, 12.1 to 12.20), monitoring, control and surveillance (e.g. 6.11, 7.1.7, 7.7.2), dispute resolution (e.g. 6.15, 7.6.5, 10.1.4), etc., provide guidance on the conventional governance of fisheries.[4] These are all relevant but not specific to EAF.

6.9 Uncertainty, Risk and Precaution

The Code, in line with the UNCED Rio Principle 15 and the 1995 Fish Stock Agreement, deals with uncertainty, risk and precaution (7.5) and recommends the wide application of the precautionary approach to "*preserve the aquatic environment*" (6.5; 7.5.1). It provides to do so taking into account various uncertainties (7.5.2; 10.2.3), using reference points (7.5.3), adopting cautious measures for new fisheries (7.5.4) and avoiding the addition of pressure on a stock naturally affected by a negative environmental impact (7.5.5). The Code also recommends a scientific Prior Impact Assessment (PIA) before a new fishery is developed or a new technology is deployed (8.4.7; 12.11).

6.10 Integrated Management

Coastal areas are one of the key geographical units for an ecosystem approach to coastal fisheries management. The Code provides that they should be protected (2g) and has a number of related articles (1.1; 1.3; 6.9; 8.11.3), as well as one article (10), entirely dedicated to the integration of fisheries into coastal areas management. A set of guidelines has been developed to assist in its implementation (FAO, 1996c; Scialabba, 1998).

7. EAF PRINCIPLES

The EAF amounts to introducing a series of modifications to conventional fisheries governance with the view to improving its poor performance (Sutinen and Soboil, 2003). As such, it is a fundamental contribution to sustainable development and is underpinned by all its principles. It follows that EAF is also a more comprehensive approach to the implementation of the Code of Conduct for

[4] The listing of Articles is not exhaustive but only indicative.

Responsible Fisheries in all its aspects, from assessment to management and from capture to processing and trade, and that the general principles of the Code are fully relevant to EAF.

The various forms of ecosystem management or ecosystem-based management described in the literature or adopted formally by states (e.g. under the Convention on Biological Diversity framework) refer to a number of interrelated guiding principles or conceptual objectives, many of which are fairly generally agreed to. Some of them were established formally in the 1982 Convention on the Law of the Sea. Others are derived or extended from that convention. They are reviewed in the following sections, the order of which does not imply priority.

7.1 Human and Ecosystem Well-being

- *Human well-being*: A condition in which all members of society are able to determine and meet their needs and have a large range of choices to meet their potential.

- *Ecosystem well-being*: A condition in which the ecosystem maintains its diversity and quality — and thus its capacity to support people and the rest of life — and its potential to adapt to change and provide a viable range of choices and opportunities for the future.

(Prescott-Allen, 2001).

The ecosystem approach to fisheries (EAF) is also a strengthened approach towards sustainable development of fisheries, recognizing more explicitly the interdependence between human well-being (HWB) and ecosystem well-being (EWB). It recognizes the need to maintain the productivity of ecosystems for present and future generations, conserving critical habitats, reducing pollution and degradation, minimizing waste and protecting endangered species. It also recognizes that this will not be achieved without the cooperation of people, i.e. unless the ecosystem contributes to human well-being, providing sustainable goods and services and sources of livelihood.

7.2 Resource Scarcity

The fact that a*quatic ecosystems' resources are finite and often in short supply* has now become an axiom. The resources are renewable but the quantities that can be extracted every year without jeopardizing the renewal capacity are limited and, in many cases, insufficient to satisfy the potential demand. The consequence is that many of them are depleted, leading to severe social and economic disruptions. A related objective is to assess the limits of the resources and the conditions for its maintenance (research), to regulate the extractive capacity of the fishery to match removals and to maintain critical ecosystem process and structures.

7.3 Maximum Acceptable Fishing Level

Article 61.2 of the 1982 Convention on the Law of the Sea provides that *"states should ensure that the maintenance of the living resources in the exclusive economic zone is not endangered by overexploitation"***.** This principle is reflected in the agreement establishing regional fishery management bodies and in most national fishery legislations. For instance, the Australian ESD charter provides *that "a fishery must be conducted in a manner that does not lead to overfishing"***.** While overfishing is not always precisely defined, the related objective is to allow catch levels (or fleet sizes) compatible with the maintenance of an ecologically viable stock at an agreed level, or range of levels, with acceptable probability that the set-up is viable. In this respect, the control of fishing activity, e.g. in terms of fishing capacity, gear and practices, is central to a responsible ecosystem approach to fisheries development and management.

7.4 Maximum Biological Productivity

"Exploited populations must not be allowed to fall below a level close to that which ensures their greatest net annual increase" (1980 Convention on the Conservation of Antarctic Marine Living Resources). This objective may be considered as an older formulation of the preceding one (on overexploitation) in which the maximum acceptable fishing level is that corresponding to the Maximum Sustainable Yield (MSY) at which the annual natural rate of increase is greatest. This principle has been central to conventional management as established in the 1982 Convention (Article 62.3), which provides that *"measures shall also be designed to maintain… populations of harvested species at levels which can produce the maximum sustainable yield, as qualified by relevant environmental and economic factors"*. As above, the related objective is to allow catch levels (or fleet sizes) compatible with the maintenance of a stock at or above the MSY level. Indeed the UN Fish Stock Agreement has established that, for precautionary purposes, MSY should be considered as a "limit" to be avoided and not as a target to be reached.

7.5 Impact Reversibility

The 1982 Convention (Article 62.3) requires States to *"restore populations of harvested species at levels which can produce the maximum sustainable yield"*. This principle is also reflected in the Australian ESD charter which provides that *"for those stocks that are accidentally overfished, the fishery must be conducted such that there is a high degree of probability that the stock(s) will recover"*. The same principle has also been adopted in relation to the ecosystem and provides that *"risks of changes to the marine ecosystem that are not potentially reversible over two or three decades must be minimized"*. The US National Marine Fisheries Service Panel on EBFM also noted as a principle that "*once (ecosystem's) thresholds and limits have been exceeded, changes can be irreversible*" (Fluharty and Cyr, 2001).

7.6 Impact Minimization

This objective complements the two above as keeping impacts at the lowest possible level may be an effective way to ensure the highest probability of reversibility. The principle provides that *"fishing operations should be managed to minimize their impact on the structure, productivity, function and biological diversity of the ecosystem"*. The principle is reflected in Article 5f of the UN Fish Stock Agreement. Related objectives are to conduct fisheries in a manner that (i) does not threaten bycatch species; (ii) avoids mortality of, or injuries to, endangered, threatened or protected species and (iii) minimizes the impact of fishing operations on the ecosystem generally. The latter is the most difficult to implement as it is open-ended, in the absence of clear socio-economic objectives to be met while "minimizing" the impact.

7.7 Rebuilding of Resources

When stocks are overfished, depleted populations must be restored to stable recruitment levels (1980 Convention on the Conservation of Antarctic Marine Living Resources). The principle is also reflected in the 1982 Convention on the Law of the Sea, Article 62.3, which requires that *"measures shall also be designed to …restore populations of harvested species at levels which can produce the maximum sustainable yield, as qualified by relevant environmental and economic factors"*. The related objective is to plan for and implement within mandatory time frames a rebuilding strategy for exploited stock(s) which are below the agreed (preferably precautionary) reference points.

7.8 Ecosystem Integrity

It is often stated that the "integrity" of the ecosystem should be maintained, preserved and in any case aimed at. While there is apparently no widely agreed definition of integrity, the application of the principle is taken, in the CBD, as implying or requiring: (i) maintenance of biodiversity at biological community, habitat, species and genetic levels and (ii) maintenance of the ecological processes that support both biodiversity and resource productivity.

7.9 Species Interdependence

The 1982 Convention refers to the need to *"take account of … the interdependence of stocks" (Article 62.3)* and provides that the *"coastal State shall take into consideration the effects on species associated with or dependent upon harvested species with a view to maintaining or restoring populations of such associated or dependent species above levels at which their reproduction may become seriously threatened"* (Article 62.4). The principle is reflected in Article 5b of the UN Fish Stock Agreement. The 1980 Convention on the Conservation of Antarctic Marine Living Resources provides that *"ecological relationships between harvested, dependent and related species must be maintained"*. This principle often refers specifically to endangered, threatened or protected species (see above). The related objective is to minimize bycatch and discards. As it is impossible to optimize the exploitation for all species at the same time, compromise solutions will need to be found, reflecting decisions on which species may be more negatively affected.

7.10 Institutional Integration

"*States should ensure that an appropriate policy, legal and institutional framework is adopted to achieve the sustainable and integrated use of the resources, taking into account the fragility of coastal ecosystems and the finite nature of their natural resources and the needs of coastal communities"* (The Code, Article 10.1). An expression of this principle can be found also in the WWF Guidelines (Ward *et al.*, 2002) which state that *"ecosystems are of value to society and can potentially be used in many ways, to satisfy various sectors' needs and strategic interests, now and in the future"*. The related objective would be to ensure that fisheries management takes account of interactions with other types of uses of the ecosystem. This implies a need to develop functional connections between fisheries management institutions, other sectoral institutions, and other institutions in charge of ecosystem maintenance.

7.11 Uncertainty, Risk and Precaution

Aquatic ecosystems are poorly known. They are complex, dynamic, changing seasonally and in the longer term and modified by fisheries, aquaculture and other activities. They are interconnected, potentially leading to significant transboundary effects. As a consequence, the resilience of ecosystems and the extent and reversibility of human impacts are difficult to forecast and hard to distinguish from natural changes. The related objectives are to: (1) improve research to better understand ecosystems; (2) take measures that account for complexity and dynamics and are robust to uncertainty, and (3) give attention to transboundary impacts. These objectives are encapsulated in the Precautionary Approach (see below).

7.12 Compatibility of Management Measures

Boundaries of ecosystems and of present jurisdictions are unlikely to be fully compatible.[5] In particular, many ecosystems will straddle political boundaries between EEZs or extend in the high seas. The implication is that management measures need to be coherent across the resource range.

[5] With the notable exceptions of the boundaries of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLAR) and the International Baltic Sea Fisheries Commission (IBSFC) which correspond to Large Marine Ecosystems (LME).

The UN Fish Stock Agreement is innovative in this regard and provides that *"conservation and management measures established for the high seas and those adopted for areas under national jurisdiction shall be compatible in order to ensure conservation and management of the straddling fish stocks and highly migratory fish stocks in their entirety"* (Article 6.2). The related objective is to promote collaboration between subnational or national authorities (as relevant) to ensure that measures taken under different jurisdictions converge towards common objectives. This also implies that objectives are indeed to be agreed on.

7.13 The Polluter Pays Principle (PPP)

The Polluter Pays Principle, which is well established in the literature related to pollution and sustainable development, provides that *"the polluter should bear the cost of the measures needed to ensure that the ecosystem is and remains in an acceptable state"* (Dommen, 1993). Such measures would include those aiming at prevention and control of pollution as well as mitigation of impacts and rehabilitation of affected areas. This principle is of direct relevance to fisheries where the sector is a source of significant pollution (e.g. fish processing) as well as dumping or involuntary loss of fishing gear. It could perhaps be extended to cover habitat damage. The principle can be implemented by various means, ranging from establishing process and products standards to application of taxes.

7.14 The User Pays Principle (UPP)

The User Pays Principle is also abundantly referred to in the literature about sustainable use and, as the Polluter Pays Principle, also aims at fuller internalization of production costs. It states that *"all resource users should pay for the full long-term marginal social cost of the use of a resources and related services including any associated treatment cost"* (Dommen, 1993, p.151). In other terms, authorized users should pay for the exclusive privilege granted to them to use a public resource. The principle can be implemented through payments for licences or quotas or though taxes.

7.15 The Precautionary Principle and Precautionary Approach

The Precautionary Principle and the way to implement it (the precautionary approach) are embedded in the UNCED Declaration (Principle 15) which provides that *"the precautionary approach should be widely applied and that, where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing cost-effective measures to prevent environmental degradation"*. The approach has been adopted for fisheries in the UN Fish Stock Agreement and the FAO Code of Conduct, and guidelines are available for its practical implementation (FAO, 1996a). Such implementation has already started in some areas, mainly in the developed world (Garcia, 2000), but the available experience is too limited yet to allow for an appraisal of its outcome.

7.16 Subsidiarity, Decentralization and Participation

Subsidiarity is a concept of governance in which *"decisions should be taken at the lowest possible level"* (Bothe, 1998). Together with decentralization and devolution, subsidiarity is more and more often invoked with the view to increasing direct involvement of stakeholders in decision-making. The concept is obviously attractive, considering the relative failure of central government systems, and is supported by the general trend towards reduced governmental power, characteristic of globalization. The process implies the creation of institutions at lower governance levels and the development of governance capacity at such levels. Such institutions and processes existed in traditional fisheries in all continents but have progressively disappeared, except in some areas, destabilized by modernization and intrusion of the market economy.

However, the concept which appears successful in developed countries (where it is seen as an extension of the regionalization process) may be difficult to implement in low-capacity areas and in freshly independent countries in which nationhood is a recent and still fragile concept.

Contributing to subsidiarity, decentralization is intended to increase participation of lower-level governance to decision-making. Participation may be implemented at many different degrees of involvement of the stakeholders in the management process in data collection, knowledge-building, option analysis, decision-making and even implementation, including enforcement. It calls for a decision-making framework that meaningfully includes and takes account of all sectoral and community interests. This is achieved by active participation from stakeholders, capacity building at appropriate level, widest possible distribution of information and dispute resolution mechanisms (e.g. at the lowest possible level, if the subsidiarity principle is applied).

7.17 Equity

Governance should endeavour to establish and preserve equity in all its forms: intergenerational, intragenerational, cross-sectoral, cross-boundary and cross-cultural, with special attention given to rights of minorities. Equity implies that similar options are available to all parties, a principle of stewardship by governments and the community. A number of sub-concepts have been referred to but may not meet with consensus. *Intergenerational equity,* for instance, is widely referred to and requires that future generations be given the same opportunity as the present ones to decide on how to use the resources. It can be sought through avoidance of actions that are not potentially reversible on some agreed time scale (e.g. a human generation), consideration of long-term consequences in decision-making and rehabilitation of degraded physical and biological environments. Lack of *intragenerational equity* (i.e equity among sections of the present generation) is recognized as one major source of conflict and source of non-compliance. *Intersectoral equity* would seem very hard to define and operationalize but would imply, for instance, that the fishery sector be fairly treated when its interests conflict with those of other sectors. *Cross-boundary equity* may be a condition to successful shared stocks agreements. *Intercultural equity* is relevant when allocating resources to different cultures or defining rights of minorities (e.g. between indigenous and other populations).

8. OPERATIONAL OBJECTIVES AND MEASURES

Looking at the perspectives of implementing EAF, one might wonder how to ensure that an ecosystem approach to fisheries is more successful than conventional management has been over the past 50 years. A number of changes have been proposed to improve conventional management (Garcia and Grainger, 1997; Mace, 1997; Sutinen and Soboil, 2003; Cochrane, 2000; Sissenwine and Mace, 2003). They are also needed to successfully implement EAF. Among them, features stressing prominently the need to better set and clarify the operational objectives and their relation with management structure, process, and measures, rationalizing and bringing transparency in the implementation path between high-level policies and on-the- ground fishing operations.

This section elaborates briefly on a number of operational objectives stemming from the set of conceptual objectives and principles (given in Section 7) as well as the policy guidance available in existing international instruments and the Code (Sections 5 and 6). In relation to each of these objectives, it considers some of the measures available to implement them. Looking at some key aspects of the practical implementation of EAF, this section does not pretend to be comprehensive and was developed to provide a checklist for consideration by the FAO Expert Consultation in charge of developing the FAO Guidelines on the ecosystem approach to marine capture fisheries (FAO, 2003) which the reader is advised to look at for a more complete treatment of the matter.

The set of principles and conceptual objectives reviewed in Section 7 reflect high-level policy agreements (albeit not always binding) to be used as a basis to develop national or regional policies. They need, however, to be translated into more operational objectives before specific targets, limits and measures can be elaborated. As seen in Section 6, the Code provides more detailed objectives and some practical measures. However, additional specifications will be required in most cases, adapting the Code's guidance to local conditions, developing consensus among stakeholders on their relative priority (ranking) and resolving possible conflicts between them before designing an EAF implementation strategy and management plan for a specific subsector or fishery.

Many of the measures needed in principle will be examined below. It is important to stress, however, that not all of these are immediately needed in all fisheries. The implementation challenge can only be faced, in many areas, if a stepwise approach is adopted, dealing with more vulnerable fisheries first and, in these, with the most urgent issues in an effort which can only be commensurate with the resources available.

8.1 Targets, Constraints, Indicators and Reference Points

Operational objectives usually relate to specific development targets expressed in terms of physical or economic output the system intends to produce. They can be set, for instance, as an average amount or a range of catches, revenues or employment. They can also be set as limits reflecting ecological or socio-economic constraints (e.g. minimum spawning biomass, minimum viable revenues) within which the system is bound to remain. The use of the terms "objectives" and "constraints" is not entirely innocent. In conventional use of the terms in fisheries, the fishery system aims at the objectives while simultaneously attempting to comply with the constraints. However, what may be considered an ecological "constraint" in conventional fisheries management (e.g. conserving critical habitats) may be considered a conservation objective in the context of ecosystem management. Similarly, what may be considered an objective in fisheries management (e.g. maintaining people's livelihood) might be considered a constraint from the point of view of ecosystem management. The spirit of EAF would require that both targets and constraints be formally considered as "objectives" and be used as the basis for performance assessment.

It has been argued that, because ecosystems are complex, dynamic and unpredictable, and as they do not maximize their functions but tend to optimize them, management strategies aiming at maximizing some aspect of the ecosystem will fail (Kay and Schneider, 1994). It follows that, in order to improve their probability to be implemented, strategies would need to adopt, in relation to their operational objectives, reasonable targets and constraints as well as time frames for producing the expected outcome.

The history of fisheries management has shown that "objectives" have often remained rhetorical, with little real linkage with practical management measures and fishing operations. In order to improve on this aspect of management failure, it will be necessary to develop a strong link between the selected objectives and a formal and continuous assessment of the performance achieved (Sainsbury and Sumaila, 2003). In practice, this will require that objectives are formally organized in a system of sustainability indicators or sustainable development reference system (SDRS) (FAO, 1999a; Garcia and Staples, 2000) in which objectives and constraints are respectively used as target and limit (or threshold) reference values as required by the precautionary approach (Garcia, 1996b; FAO, 1996a). Improving performance assessment requires that national policies and related management strategies be documented, publicly available, transparent and developed through a consultative process. Policies should be established with a long-term horizon and determine the appropriate pathway for the adaptation trajectory, defining intermediate steps and milestones.

8.2 Priority Setting

The difficulty in identifying, selecting and ranking objectives, already substantial in conventional management systems, increases in an EAF context because of the exponential increase in possible options provoked by the additional number of parameters and stakeholders and the lack of general agreement on definitions and concepts. In the USA, for instance, the NMFS panel on ecosystem-based management agreed that the goal was to *"maintain ecosystem health and sustainability"*, recognizing, however, that neither "health" nor "sustainability" could meet with an agreed definition[6]. The issue has been extensively discussed and is more comprehensively treated in FAO, 2003. Obtaining consensus when selecting and ranking objectives, however, is not easy; it seems to be easier to obtain consensus among stakeholders on what is not acceptable to most (i.e. on limits) than on what is collectively desired (i.e. objectives) (Cury *et al.*, 2002).

In setting priorities in EAF, just as in conventional fisheries management, careful attention will need to be given, *inter alia*, to:

- transjurisdictional stocks (shared, transboundary, straddling, highly migratory) and pollution, which require effective forms of cooperation;
- small-scale fisheries, which are both socio-economically important and fragile;
- coastal areas, from where most of the production comes and where most conflicts and degradations occur.

The general aim of introducing EAF is to improve the performance of fisheries management in relation to both human and ecological well-being. In order to do so, the best practices of conventional fisheries management (e.g. on control of fishing capacity) need to be more effectively implemented and new ecosystem-based considerations need to be introduced. These two aspects will be addressed successively below.

8.3 Improving Conventional Management

There is no shortage of prescriptions to improve conventional fisheries management (see for instance Cochrane, 2000 and 2002; Sutinen and Soboil, 2003). This form of management covers a wide range of management strategies, structures and measures used with variable success. In general, however, conventional approaches need basic improvements without which no EAF could be successful. These adjustments include: better identification and ranking of objectives; improved priority for the long-term social and economic benefits; control and, where appropriate, reduction of fishing capacity; suppression of "bad subsidies", generating overcapacity; introduction of market incentives such as allocation of user rights; improving compliance through decentralization, participation, improved transparency and more deterrent enforcement; more attention to uncertainty and its consequences through implementation of the precautionary approach; adopting a system of sustainability indicators and, using indicators, the undertaking of performance assessments as a routine procedure.

Control of fishing capacity requires better harmonization between development and management programmes and between electoral and fishery management targets. It also requires the reduction or suppression of subsidies. The precautionary approach has been adopted at the highest level at UNCED, as well as in the UN Fish Stock Agreement and the Code. It needs to be formally adopted

[6] Both, however, are understood in relation to satisfaction of human needs and health requirements.

by fishery authorities and implemented at sectoral and subsectoral level, with the active participation of industries. It needs to be actively promoted at central level and within the fishery associations. Market-driven incentives intend to modify industry's behaviour. Marketable forms of property or use rights could be established. This may not be possible for fisheries in isolation and may require a change in national policies regarding use rights across the whole range of natural renewable resources. The reduction or suppression of subsidies seems to be the main measure required against overcapacity in many FAO member countries and by most environmental NGOs. A number of countries (and most developing ones) argue that "good subsidies" are still needed to steer fisheries development in the appropriate direction (including towards capacity reductions) and to protect small-scale industries and coastal communities' livelihood in the process.

Improving compliance requires that fishers adhere to other relevant national fisheries laws, regulations and strategies but also to relevant, perhaps more stringent, international or regional management regimes. This is particularly important, considering the large number of relevant agreements criss-crossing the development of a modern fisheries policy. In addition, the policy should aim at ensuring that the means to enforce the management regulations are available and this may imply interministerial agreements, e.g. between the Navy and the fisheries ministries.

EAF adds complexity to management but brings additional tools for the task. Some of its "specificities" have already been proposed as part of conventional management in the past but are briefly referred to in the following subsection because of their particular "ecosystem" nature.

8.4 Improving Ecosystem Well-being

We have not been able to find a straight definition of human and/or ecosystem well-being. In the sustainable development literature, where the term is often used, human well-being is taken as an aggregate conceptual indicator reflecting the state of individual and population health, household and national wealth, knowledge and culture, community functioning (freedom, peace, order, governance) and equity. Ecosystem well-being reflects the state of water and habitat, species and genetic diversity, resource use, etc.

Operational objectives related to ecosystem well-being must therefore be set in relation to the elements that, jointly, will contribute to maintain the ecosystem function and productivity. While the objective of achieving ecosystem well-being (together with human well-being) may not be very operational in itself, its explicit expression in fisheries policies will signal the willingness and commitment of the country to the objectives of EAF. Much work is in progress (see for instance http://www.ecosystemindicators.org/) even though there is still a shortage of operational indicators of ecosystem well-being, as well as a shortage of related operational targets and limit reference values.

For instance, the maintenance of the trophodynamic balance (i.e. of a balance between predators and preys) is not very operational, as it is not easily translated into a measurable objective or represented by a useful indicator. The average trophic level or Fish-in-Balance index (Pauly and Palomares, 2000) calculated on landings may reflect the long-term trends of the ecosystem trophic structure, but the trends and eventual changes in either direction cannot yet be safely interpreted.[7]

[7] A decrease in the index may reflect a change in the ecosystem as well as in the catch only, and result from a climate oscillation (e.g. temporarily favouring small pelagics' abundance) or a change in fishing strategy (to target a particular group of fish). For example, a total trawl ban, a powerful measure in an overfished area, would decrease the index (a change normally perceived as negative). On the opposite, a decision to develop intensive fisheries for, say, manatees and small cetaceans in an already overfished area would increase the index (a change normally considered as positive). An extension of the fished area or a change in discarding practices would move the index in any direction, depending on the gear and target species.

A large number of objectives can contribute to ecosystem well-being either directly or indirectly. Some of them are examined below in more detail.

8.5 Rebuilding Ecosystems

Rebuilding strategies are requested for depleted stocks under conventional management and indispensable under EAF**.** Depleted stocks must be rebuilt at least to their MSY level of abundance and preferably even higher (e.g. according to the UN Fish Stock Agreement). It should be obvious that rebuilding the various target stocks of an ecosystem would contribute greatly to improvement of the state of the exploited ecosystem. It is not obvious, however, that rebuilding target stocks, if successful, will also rebuild depleted populations of associated and dependent species. Indeed, successful rebuilding of a target stock of predators may very well lead to decline in its prey populations. In addition, particular measures might be needed for endangered species.

Considering the present state of fishery resources, their recovery and that of the ecosystem in which they normally live should be a strong priority objective. In practice, "recovery" may imply a suite of complex interventions to, *inter alia*:

- reduce fishing harvest (if only in the short term) and capacity;
- stop habitat degradation and rehabilitate macrohabitats (such as seagrass beds or mangroves);
- reestablish freshwater flows and regimes;
- reestablish the original species composition;
- reduce pollution and depollute bottoms from accumulated contaminants (if appropriate);
- enhance productivity (e.g. through artificial reefs and/or restocking).

Twenty years ago, Regier (1982) called for the development of "*ecological engineering*" to correct major ecological deficiencies and deformities and "*therapeutic ecology*" to aid natural recovery processes. Little progress in that direction seems to have been made, at least in the marine environment. Because of the need to experiment and the costs implied, realistic milestones and targets for recovery are needed. Improvement of the state of the resources and of their critical habitats can only be a gradual process, compatible with ecosystem processes as well as changed social and economic conditions.

In implementing a policy of ecosystem rebuilding (as suggested, for instance by Pitcher and Pauly, 1998), it would be unrealistic, for instance, to expect to return to preindustrial conditions, sometimes referred to as "ghost" or "pristine ecosystems", because of the irreversibility of many interconnected impacts (particularly coastal or land-based ones) and their link to existing and often already stressed livelihoods (Ward *et al.*, 2002)**.** Return to "pristine" conditions would require not only measures to reduce or indeed eliminate fishing (e.g. from protected areas) and replant seagrass or mangroves, but also eliminate major public works such as dams, weirs and reservoirs, reestablishing some tidal inlets but closing others leading to ports. It would imply reintroducing original species but also eliminating accidentally introduced ones. Pushing the concept to its limits, this would require downsizing major megacities (sources of sewage) and, in the end, reverting the human migration processes from the rural areas to cities and from the hinterland to the coastal zone. Many of these actions are technically and socio-economically impossible.

The broad objective of ecosystem "rebuilding" (taken in a pragmatic sense) can also be approached through other sub-objectives related to reduction of capacity, protection of habitats, endangered species, elimination of deleterious fishing techniques, such as: reduction of waste and discards, improving selectivity and finding an acceptable destination for the bycatch (e.g. human food); elimination of destructive fishing techniques (e.g. using poisons or explosives) and practices (such as catching fish larvae or juveniles); elimination of illegal fishing, a factor of overfishing and risk for endangered species, reinforcing the deterrence of the enforcement; control and reduction of fishing pressure; last but not least, this objective remains the cornerstone of any form of fisheries management and is central to the success of any ecosystem approach to fisheries. It has also been shown that highly adaptive management (e.g. based on harvest control laws and other preagreed courses of action and not on constant fishing effort policies)[8] was more likely to avoid ecosystem-related crises and facilitate recovery (Nowlis and Bollermann, 2002).

8.6 Maintaining Reproductive Capacity of Target Resources

This subsection tends to overlap with the preceding one as the target resources are part of the ecosystem and their rebuilding contributes to ecosystem rebuilding. However, as this is one of the main concerns of fisheries management and one for which the action needed is well known, we decided to treat the subject separately.

EAF, just as conventional fisheries management, will aim at preserving and, where appropriate, rebuilding the reproductive capacity of the target resources and their recruitment, preserving simultaneously ecosystem nurseries, feeding and spawning grounds in optimal state. Reproductive biomass of the target species needs to be maintained at a sufficient level by:

- limiting fishing pressure to ensure sufficient survival until spawning age;
- directly protecting spawners' concentrations from targeted fishing;
- controlling fishing regimes (i.e. mortality-at-age) through effective enforcement of mesh-size regulations, bycatch limitations, minimum size at landing, market controls prohibiting trade of larval or juvenile fish, including in restaurants, zoning (to protect growing areas);
- ensuring availability of food for growth to adulthood, protecting stocks of preys;
- prohibiting destructive practices (e.g. dynamite or cyanides);
- adopting highly reactive (adaptive) management schemes (e.g. with harvest control rules) (Nowlis and Bollerman, 2002);
- actively campaigning against land-based pollution, e.g in the context of integrated coastal areas management;
- combating habitat degradation, e.g. though preventive or corrective measures which may include: biodiversity reserves (e.g. in marine protected areas), artificial habitats and zoning of fishing gear and practices. Examples can be found in Amanieu and Lasserre (1982), for littoral ecosystems and lagoons, or Blanc (2000), for an overall synthesis covering the broad ecological and climatic aspects of environmental management.

It should be noted that protecting recruitment in a given fishing regime is also an excellent way of improving spawning stock.

[8] "Reactive management" is not taken here as describing management which only reacts to problems once they occur (i.e. the contrary to preventive management). It refers to management schemes such as those based on harvest control laws which attempt to tailor fishing pressure to changes in the resources based on pre-agreed courses of action. The concept comes closer to "adaptive management".

8.7 Maintaining Biological Diversity

EAF aims at the maintenance of diversity in terms of the variety of ecosystems, species and genetic variability within species. Management will need to focus primarily on the habitats or species directly impacted by fishing, but significant attention must be given to non-fishing impacts, promoting a more effective role of fisheries departments in the environmental (and integrated) management of the coastal areas and watersheds. The difficulty in distinguishing the effects of fishing from other anthropogenic influences (e.g. pollution and habitat modification), as well as from natural environmental variability, is a significant impediment in determining the most useful measures to take. Relevant management objectives or strategies may include:

- reduction of fishing pressure to lower and biologically compatible levels is one of the best ways to reduce stress on biodiversity. This may have significant costs in the short term and requires specific approaches well described in the conventional management literature, including rights-based approaches to fisheries management.
- rebuilding of depleted populations, which assumes reduction of overcapacity (see preceding point) and rehabilitation of critical habitats.
- reduction of bycatch (and improvement of its survival) through gear and other regulations;
- protection of endangered species (see below);
- maintenance of the connection with and quality of river flows, where relevant;
- introduction of artificial habitats, restocking and other enhancements;
- integration of fisheries in coastal area management plans;
- implementation of the precautionary approach;
- effective habitat management/rehabilitation (see below).

The above should apply both to target and non-target species and will require partnership with fishers, fish traders, the gear development industry, the tourism industry (in relation to coastal development); the land-based chemical industry (for land-based pollution), the urban development managers (for sewage treatment and control), etc., possibly within some sort of integrated basin/coastal area management framework.

Alien species, introduced voluntarily or accidentally, can be a particularly serious threat to an ecosystem. They may be introduced with the solid or liquid ballast used by tankers, as well as through fouling of boat hulls. While the regulations regarding ballast are improving, fouling is difficult to control in practice, as antifouling treatments tend to be damaging for the environment. Aquaculture is also a growing source of alien species. The existing Code of Conduct for species introduction (FAO, 1996a) should be implemented.

Endangered species have always been a concern, but the question of their survival or reestablishment (as dealt with, for instance, by CITES) has tended to be at least partly disconnected from their harvest operational management. The trend is now for a closer integration of this issue in fisheries management. This is illustrated, at global level, by the growing collaboration between FAO and CITES and should be reflected at national level by improved coordination between the ministers of environment and fisheries. A systematic identification and characterization of endangered species is needed, as well as specific considerations of the relative impact of fisheries and other activities (e.g. coastal development versus fishing mortality in the case of turtles).

8.8 Protecting and Enhancing Habitats

It is necessary to protect functional habitats from fishing and land-based pollution and degradation, maintaining connections between interdependent habitats, accessibility of fishery resources to critical habitats and overall productivity. It may be necessary also to restore damaged habitats (if possible) or to create new ones, with the view to reestablishing the original biological functionality or establishing an alternative and to increase the diversity of habitats[9] on which the biodiversity of exploited populations depends. This will be easier inland than in the coastal oceans or the high seas. The task can be arduous (e.g. to restore eroded grass beds in polluted, turbid waters) or even impossible. The diversity of habitat conditions the biological diversity of the aquatic ecosystems and the variety and stability of the flow of goods and services it can provide.

Fishing, other economic activities and unexpected climatic events (hurricanes, climate change), may lead to a loss of habitat diversity or a reduction of their accessibility to species. Habitat management is therefore needed to take preventive, corrective or mitigating action (Kaiser *et al.*, 2003). For example, the access of fish to their spawning grounds must be protected and facilitated, e.g. through control of vegetation growth, maintenance of tidal passes, construction of fish passes in dams, elimination of some fishing techniques across migration routes or of other obstacles. Similarly, physical connections between habitats might need to be reestablished, e.g. through a network of MPAs or "corridors" to maintain their interconnection and facilitate free and safe flow of species and life stages between them.

In **riverine habitats**, management techniques include: monitoring and maintenance of the natural characteristics; maintenance of the banks; vegetation control; safeguarding or restoration of fast-flowing zones; safeguarding or restoration of calm shallow zones, favourable for the development of aquatic vegetation such as mangroves and easily flooded marshes, generally used as spawning grounds and nurseries; creation of thresholds to eliminate suspended matter and thus the turbidity which limits the light penetration and primary productivity. A biological knowledge of the periods and duration of reproduction of fish and of larval ecological requirements is necessary to understand the impact of natural modifications of the physical environment. Any physical installation which supports the diversity of the habitat and the mineralization of the nutritive substances trapped in the mud must be encouraged.

In **lakes and lagoons,** restoration of the physical environment includes control of vegetation, which must be sufficient (but contained) to provide shelter, spawning grounds, support for food, etc. It may need to be limited to certain areas, to reduce risks of dystrophy, using mechanical or biological means. The latter include introduction of herbivorous fish or planting of trees along the banks to dim the light and thus reduce photosynthesis while still contributing organic matter (dead leaves).

In **coastal marine areas** the vegetation (e.g. seagrass or algal beds) should not be destroyed by the fishing gear. The necessary protection can be provided through proper zoning of fishing practices, excluding mobile bottom gear (trawls) from the coastal areas, supplemented, as appropriate, by artificial reefs and other antitrawl devices. The concept of marine protected areas could apply (see below for more details). Conventional measures aiming at reducing gear impact on the bottom or biological habitat (e.g. seagrass beds) should receive particular attention (through gear development, the creation of protected areas and effective prohibition of destructive fishing techniques and practices).

In all habitats, an inventory of the sources of degradation, including chronic pollution and physical installations altering the ecosystem, is necessary. It is useful to predict the modifications physical installations can produce on the overall ecosystem. Hydrological basins (with their forestry, agricultural, aquaculture and other development activities), water streams and trophic levels are interconnected, and any modification of one of them is reflected on the whole functioning of the ecosystem. For example, modifying a river profile can affect some of its parameters such as slope,

[9] e.g. in terms of hydraulic conditions or types of substrate in spawning, nursery and feeding areas.

current velocity and sediment coarseness. This may in turn induce qualitative and quantitative transformations affecting energy and matter cycling, the river output and the physical and chemical properties of the water.

Enhancement methods have been applied for more than a century throughout the natural range of the Atlantic salmon (*Salmo salar* L.). Hatcheries, the cornerstone of enhancement programmes, are used to facilitate colonization of new habitats; restore and rehabilitate stocks; supplement wild stock production; compensate for major environmental disturbances or problems such as hydroelectric development and acid rain and support fisheries entirely dependent upon restocking. Enhancement methods may also foster research and technology development. However, enhancement is one of a series of management measures that require careful planning and should be fully integrated with the management of stocks, resources and the ecosystem.

Man-made structures (artificial habitats) can be placed in the aquatic environment to improve its productivity or protect it (e.g. from trawling). They often tend to imitate natural reefs or rocky zones which seem to support more diversified and productive ecosystems than featureless sandy plains. Artificial habitats are used on flat substrates to diversify the physical habitat available to fishery resources by adding volume and structure. The creation of an artificial reef leads to a modification of fishing techniques usable in the area, making it possible to protect or reconstitute biotic habitats previously degraded by fishing, maintaining or increasing the diversity of the habitats and of the organisms depending on it. Man-made structures may also reduce temporal variability and optimize the biogenic capacity of the ecosystem. The brush park technology ("acadjas" in Benin or "vovomora" in Madagascar) increase the primary production (filamentous algae) and the abundance of Tilapia and shrimps. In the Thau Lagoon (in France), the introduction of immersed concrete blocks allowed the settlement and production of mussels and oysters, which, under shellfish farming conditions, reach a biomass of 30 000 tonnes. In the last two examples, the man-made structures improve the production of the ecosystem without reducing its diversity. The physical installation of habitats is more effective where space is indeed the limiting factor. Artificial habitats are used in Spain to restore seagrass beds and in Monaco to restore populations of precious red coral for economic exploitation (Jensens *et al.*, 2000).

The following measures would facilitate habitat management:

- A research capacity sufficient to: (1) identify critical habitats and design habitat management strategies; (2) carry out *ex-post* environmental impact assessments (EIA) for activities already ongoing (*ex-post* assessments) as well as *ex-ante* assessments for new proposed development, possibly related to Prior Informed Consent procedures (see below); (3) improve gear design and operations to reduce impact.

- Maintenance of freshwater inflows in conflict with agriculture and energy production.

- Adoption of some sort of Prior Informed Consent procedures (PIC) or any other form of prior authorization before any new ecosystem-impacting development is put in place. This is in line with the precautionary approach and may require the establishment of pilot-scale projects before granting authorization for full-scale deployment.

- Effective enforcement of bans on destructive fishing methods such as dynamiting, poisoning, and Muro Ami fishing[10].

[10] A fishing technique used in Southeast Asia implying outright destruction of reef areas through pounding of the habitat to scare fish into entangling nets.

- Effective enforcement of zoning of gear types to avoid destructive practices resulting from use of gear on inadequate habitats. Use of artificial reefs, "gear-excluder devices" could be a solution in some cases and might also be useful as enhancements as well as a basis for resources allocation (territorial use rights).

- Delimitation of specially designated areas (e.g. particularly sensitive areas, marine protected areas) the use of which is regulated through seasonal or total closure, exclusion of some gear types, etc. To be really effective, such closures should also protect the areas from other degrading activities (such as mining or dumping) and accompanied by measures to limit or eliminate transboundary pollution from land or neighbouring sea areas.

Environmental Impact Assessment (EIA) is likely to become mandatory for all fisheries development activities as it already is in many countries for all activities with impacts on the environment and public health. While such assessments may be retroactively requested for established fisheries, they should be part of the documentation required when requesting permission to start a new fishery.

8.9 Protecting Selected Marine Areas

Marine protected areas (MPAs) are regularly proposed as central to biodiversity and ecosystem management and, by extension, are often considered in the context of fisheries management (Sutinen and Soboil, 2003; Sainsbury and Sumaila, 2003). The 1982 Convention proposes to protect areas from pollution, referring to measures *"necessary to protect and preserve rare or fragile ecosystems as well as the habitat of depleted, threatened or endangered species and other forms of marine life."* (Article 194.5). Protected areas are called for in the CBD which calls on states to establish a network of protected areas at the national level where special conservation measures are needed. Marine and coastal protected areas (MCPAs) are one of the five programme elements established by the 1995 Jakarta Mandate, which sees protected areas as instruments integrated into wider environmental conservation strategies. Because of their central role in ecosystem protection, marine protected areas deserve a particular treatment under an EAF approach.

Protected areas are of widespread use in ecosystem protection. The protected area conventions take two forms, which identify the values to be protected. Some identify areas in which all potential activities are regulated, restricted or prohibited, depending on their degree of harm. Others identify specific areas particularly vulnerable to an activity (e.g. oil spill) and narrowly prohibit or regulate that activity (particularly sensitive areas). MPAs cannot directly address all threats to an area and its populations. They can do little to insulate essential habitats against negative effects, e.g. of pollution from adjacent areas. Surreptitious risks arise from modified sediment or nutrient flows by rivers into coastal habitats or the withdrawal and diversion of freshwater for upstream development.

MPAs are considered effective for conservation purposes but pressures for more lucrative economic activities in coastal areas may compete with this objective. *"Several of the regional instruments recognize the limitations of area designation if the application of other specialized instruments is not strengthened at the same time"* (Kimball, 2001). The effectiveness of buffer zones around the MPA perimeter to shield them from external influences may also be eroded if the ambient social pressure is too high. This has led to strategies embedding protected areas within a larger bioregional approach to conservation and targeting directly the sources undermining conservation on an activity-by-activity basis.

The debate about the exact role and effectiveness of MPAs is still open (Hilborn *et al.*, in press). The consequence of Kimball's analysis for fisheries is that they will not operate properly in terms of enhancing and sustaining yields without improving conventional management and, specifically, without reduction and control of fishing capacity. On the other hand, if capacity could be adequately controlled, it is not obvious that MPAs would be necessary. However, there is general agreement that MPAs are useful for biodiversity conservation, and partisans and opponents of this management measure may often be talking at cross purposes.

8.10 Reducing Bycatch and Discards

Bycatch of vulnerable non-target species and endangered species, as well as juveniles of target and non-target species, can have very significant impact on the ecosystem. In addition, discarding resources accidentally killed (bycatch) is often considered as socially unacceptable. Accidental capture and discards can be reduced by:

- improving selectivity of fishing gear and practices to minimize bycatch. Modification of the gear to scare away or release (alive) the unwanted species (bycatch reduction devices);
- establishing seasonal closures of the areas when they are regularly and seasonally used by the living resources to be protected and when fishing has no long-term physical impact on the area;
- real-time closures as soon as the proportion of the protected resource appears to be higher than an agreed precautionary maximum;
- improving use of bycatch to reduce discards (e.g. in the case of sharks or non-commercial species), developing new markets and products;
- mandatory landing of discards, possibly combined with bycatch quotas.

8.11 Reducing Ghost Fishing

To address the specific risk of ghost fishing, where it exists, it is necessary to:

- enforce a prohibition on gear dumping at sea;
- elaborate gear disposal systems in landing places;
- establish procedures to recuperate lost gear systematically, particularly when losses may occur on a large scale as in some driftnet fisheries (e.g. by dragging hooks on the bottom) or after exceptional events such as hurricanes, during which important quantities of gear can be lost.

8.12 Reducing Uncertainty and Risk

In the context of conventional fisheries management, it has already been agreed that the adoption of objectives, policies and implementation strategies (including management strategies) need to take account of uncertainty, risk and their implications in the framework of the precautionary approach. Scientists will need to track more systematically the uncertainty related to the knowledge accumulated and its consequences for policy options and decision-making. The evolving understanding should be integrated into adaptive management strategies. The FAO Guidelines on the precautionary approach to marine capture fisheries (FAO, 1996a) elaborate on the problem of prior consent and pilot projects. The EIA should ideally include an assessment of the impact of non-fishing activities.

The EAF broadens significantly the field of considerations to be made, increasing the amount of scientific uncertainty and related risk for the resources and the people depending on them. This is the reason why the precautionary approach, already adopted as a necessary complement to conventional fisheries management, is also systematically and *a fortiori* seen as an integral part of EAF. The related FAO guidelines (FAO, 1996a) and scientific documentation (FAO, 1996b) contain substantial guidance for an effective implementation of this complicated approach, which requires, *inter alia*:

- the formal adoption of a precautionary, participatory, adaptive and science-based approach to fisheries management;
- an uncertainty-conscious research capacity to formulate appropriate advice, taking account of the limitations in knowledge and its implications;
- a responsible fishing technology, stabilizing fishing capacity at a level commensurable with the sustainability of the resources available, limiting environmental damage and waste.

The FAO Guidelines on EAF (FAO, 2003) focused heavily on these aspects and should be examined for more details.

8.13 Improving the Institutional Set-up

The failure of conventional fisheries management is largely the result of inadequate institutions, weak organizations, insufficient participation and coordination, poor enforcement and unclear rights of use. We will not review all of them and only stress a few of particular importance for an EAF.

Laws and regulations for fisheries need to be modernized to take the ecosystem requirements more clearly into account. They should clarify rights, responsibilities and liability. Fisheries and environmental legislation need to be harmonized. National fisheries authorities need to be strengthened. Their mandate should be redefined and expanded to cover the ecosystem management. Links with the research capacity should be strengthened (where appropriate). Their "litigation power" should be increased to improve their effectiveness. At present, fishery management authorities have only relatively weak power in this respect. To become really deterrent, monitoring, control and surveillance systems need to be more effective and result more frequently in penalties of significance for the enterprise.

The EAF cannot be implemented effectively without formal adoption of the EAF approach and its framework, signalling the political will and commitment of the country or the regional commission towards ecosystem-based management. The 1982 Convention on the Conservation of Antarctic Marine Living Resources is the first and only convention explicitly taking an ecosystem stand. Australia has already adopted a framework for Ecologically Sustainable Development (ESD) and its large-scale marine planning. Section 5 of this paper has shown that the UN Fish Stock Agreement and the Code contain already a substantial EAF framework, and it should be possible to adopt formally the EAF, referring to them. The framework should be completed, at national level, by dispositions improving the interaction between the line ministries in charge of the various uses of the ecosystem (environment, tourism, transports, defence, etc.).

EAF national or subsectoral guidelines, possibly based on international templates such as those prepared by FAO (2003), could be developed and promoted as a means to mobilize industry and the stakeholders' collaboration and develop ownership among them.

Intersectoral planning and coordination must be improved, on an ecosystem basis, particularly when resources are shared (e.g. space shared among aquaculture, transportation and fisheries) or nuisances are transboundary. This requires developing collaboration between institutions in charge of the different economic sectors as well as of research, environment, etc. Such collaboration will not be very effective without explicit allocation of natural resources and space and improved coherence between sectoral legislative frameworks. A requirement in this respect is to improve coordination between regional fishery and environmental commissions. The ultimate objective would be to integrate fisheries into coastal areas management, as provided by the Code.

The Code (Art. 10; FAO, 1996a) recognizes the need to integrate fisheries management with the management of coastal areas in order to manage fisheries as one of the interacting uses of the coastal area, under some suprasectoral authority, such as a Coastal Area Management Agency, charged with the responsibility to:

- coordinate the development planning of the area;
- allocate or facilitate the allocation of resource use rights;
- monitor the evolution of the sector and the performance of its management.

The **Fisheries Departments are only partially responsible** for this matter and are generally not the most important sector or ministry in the area. Nonetheless, fisheries departments can actively promote the establishment of a coastal area management (CAM) framework, where negative interactions from other sectors are significantly affecting the productivity and the future of the fisheries or are threatening to do so. In general, earlier establishment of these institutions will be preferable, as dismantling competing industries is usually difficult. Action required includes:

- establishment of a framework with consultation and conflict-resolution mechanisms;
- establishment of an adequate system of use rights;
- assessment of the value of fisheries for the coastal area and the country;
- establishment of multidisciplinary research and indicators monitoring system;
- mapping of uses, resources, jurisdictions, conflicts, etc.;
- implementation of the precautionary approach;
- development of local capacity to play an active role in the framework.

8.14 Matching Jurisdictional and EAF Boundaries

Current jurisdictional areas, at national or regional levels, have rarely been designed on the basis of ecosystem considerations.[11] As a consequence, rights and responsibilities are often presently defined within jurisdictional boundaries which do not match ecological boundaries (Garcia and Hayashi, 2000). A significantly large number of stocks[12] straddle the boundaries of established EEZs as well as of the areas under jurisdiction of regional fishery bodies. The problem is worse in areas where EEZs have not yet been established (as in the Mediterranean) or are still disputed (as in the South China Sea). If fisheries management is defined at the broader ecosystem level, a significantly larger number of the resource complexes will be found to be "transboundary".

As a result, existing institutional boundaries would often need to be adjusted to better match ecosystem ones. This need is already reflected in conventional management, in the pressure for extension of the coastal State rights and responsibilities beyond the 200 miles zone, where large straddling stocks exist, e.g. in the Northeast Atlantic and Southwest Pacific. The 1995 UN Fish Stock Agreement (and the principle of compatibility between management measures that it provides) as well as the Code are attempts to deal with the problem within the Law of the Sea context. In inland ecosystems the relevant spatial units (lakes, rivers) need to take account of the broader watershed in which development takes place and from which impacts are received. In coastal areas the sea-use and land-use planning administrations need to cooperate, developing integrated systems of information and a governance capable of allocating resources and enforcing use rights. Zoning activities can be a way to allocate immobile resources. In most cases, the boundaries of the exclusive economic zones and the coastal ecosystems will not match, requiring bilateral (or

[11] The FAO statistical divisions, for instance, which correspond also to areas of jurisdiction of many regional fishery organizations, are a compromise between ecological considerations (biogeography) and political boundaries.

[12] More than 1 500 according to Caddy, 1996.

multilateral) negotiations. At subnational level, the decentralization of management responsibility to coastal communities will need to account for ecosystem boundaries promoting intercommunities coordination. In the open ocean, the jurisdictional boundaries of the fishery organizations may not properly match the ecosystem boundaries (e.g. in the case of Large Marine Ecosystems).

In practice, the difficulty in defining ecosystem boundaries and the potentially high costs of political interaction will lead to pragmatism. The relevant boundaries for EAF will account as much as possible for the scale of the ecosystem interactions, processes and externalities but will ultimately be determined by the policy questions and management problem at hand. This, in turn, implies that societal goals and preferences (values) are established and agreed, against which the management "problem" can be determined. Watersheds, for instance, are ecosystems with fairly discrete physical boundaries. On the contrary, coastal zones tend to be artificial constructions with weak ecosystem and strong jurisdictional bases. Because aquatic ecosystems are interconnected, it is tempting to define as large a geographical scale as possible. However, for scientific, policy decision-making and management purposes, "reductionism" is necessary. When modelling ecosystem processes for the purpose of fisheries management, there is a trade-off between holism (for the sake of ecosystem realism) and pragmatism (for the sake of institutional effectiveness).

EAF boundaries definition implies therefore an identification of the main interactions with neighbouring ecosystems, adjacent jurisdictions and management institutions. An important task for research will be to identify and redraw the boundaries of the ecosystems, the fishing grounds of the various components of the different fisheries, the critical habitats and specially sensitive areas to be protected, the areas under the various local, national and international jurisdictions, the areas occupied by competing activities, etc. Fisheries mapping and Geographical Information Systems (GIS) will need to be finally recognized (Caddy and Garcia, 1986).

8.15 Improving the Decision-making Framework

The conventional decision-making framework for fisheries management is deficient (Garcia and Grainger, 1997; Cochrane, 2000; Sutinen and Soboil, 2003). In general, the governance (institutional) component of an EAF needs to include such things as:

- Decentralization of decision-making and management responsibility to lower-than-central national level (e.g. to coastal communities), building the necessary capacity at that level.

- Higher participation of stakeholders in decision-making through opening of institutions, broader public debates, development of representation of the sector, etc. Various forms of partnership management (co-management, community-based management, etc.) are available.

- Improved transparency, diffusing more information and instating oversight mechanisms.

- Establishment (or confirmation) of user rights, communal or individual, free or against payment, exchangeable or not, depending on the circumstances.

- Bilateral and international agreements are required to optimize management of shared and straddling fish stocks. This implies agreeing on resource allocation and, in the ambit of regional fisheries commissions, with the issue of new entrants and illegal fishing. Agreements may also be needed to deal with transboundary pollution.

- Cooperation between regional fishery bodies and environmental commissions (e.g. the UNEP Regional Seas Programme) need to be significantly upgraded in many areas (FAO-UNEP, 2001).

- Oversight mechanisms by institutions and individuals independent from sectoral interested pressures would help build objectivity and public confidence in fisheries governance.

New institutional structures that involve municipalities, government departments and Non-Governmental Organizations (NGOs), as well as representatives of commercial interests, need to be developed in a cost-effective manner (Gislason *et al.*, 2000). The application of the Code thus implies the creation of an institution and mechanism to consult, inform and involve in a democratic and representative way all those using the ecosystem. The economic or financial interests in all the activities significantly affecting the use of the ecosystem must be taken into account, and the major difficulty in that respect is to find the way to involve those responsible for land-based pollution. The amount of information needed to support the implementation of a management plan may require the creation of specialized databases, central information systems (GIS), services of consultants, engineering and design departments, both in the public and private sectors, to develop the capacity to provide information and studies most relevant to the social demand.

8.16 Improving Statistics and Inventories

Any fishery management system would be "blind" without a mechanism to collect reliable data on the fishery sector and resources to be analysed by scientists in order to provide a basis for decision-making. EAF requires a more comprehensive data collection system and analytical capacity than conventional management to monitor, understand and forecast the behaviour of the fishery, additional components of the fished ecosystem and the other uses of such ecosystem. Areas in which more data are needed include:

- **Improvement of conventional statistics.** Catch and effort data are a standard element of a fisheries management and monitoring system. They are of insufficient, if not dubious, quality for a large number of fisheries. Despite decades of effort, conventional catch statistics are frequently still way below the required level of detail and, often, of accuracy needed. The quality of catch data are recurrently questioned, particularly in small-scale fisheries or for vessels flying flags of convenience, but also in relation to illegal fishing and discarding. In a small number of cases, FAO has still to confront member countries on reported figures which appear to be increasing according to national plans, out of proportion with local ocean productivity. Species breakdown of catches is dismal for many countries, even among the largest producers, and does not allow proper monitoring of key biological components of the ecosystem. Fishing capacity and precise effort data are almost lacking. The geographic resolution of the globally available data is usually much too coarse, and the activity of the fishing fleets in space and time is not recorded with sufficient detail. The access to the finer resolution data sometimes available is often restricted because of confidentiality.

- **Identification of exploited ecosystems.** An inventory of exploited ecosystems and of their components needs to be established for: (1) the main species (main targets, associated ones, endangered ones, etc.) and stocks; (2) the exploited ecosystems in the EEZ and in the high seas (with their biological, chemical, and physical structure, their dynamics and boundaries); (3) fisheries and their fleets components, with their dynamics and relationships. Inventories are also needed for sources of pollution (from agriculture, forestry, coastal development, industrial or urban settlements, etc.); (4) critical habitats (e.g. feeding, spawning and nursery areas, areas of passage and concentration); (5) competing uses (see below).

- **Identification of competitive uses.** A complete inventory of competitive uses of the fishery resources and environment, including sources of land-based pollution and degradation, need to be developed. Such an inventory should record the characteristics of these activities, particularly their geographical location, purpose, type of use of the resources or environment, and their impacts. This will require access to data collected by agencies other than the fisheries management authority.

8.17 Monitoring and Indicators

The data collected on the fishery activities (including the catching, processing and trade subsectors) need to be used for monitoring the status and trends of the fisheries, their resources, associated and dependent species, and their environment. As stressed by the FAO Advisory Committee on Fisheries Research (FAO-ACFR, 2001; 2002), accurate knowledge about status and trends of fisheries is essential but generally insufficient or totally lacking. EAF requires that conventional monitoring systems (at best using standard fishery statistics) be complemented or strengthened to follow trends of key environmental factors, habitat, endangered species, associated and dependent species, etc.

- **Environmental monitoring** is needed to detect changes in water quality or the habitat. It would assist in detecting and analysing medium-term natural variability (e.g. El Niño and other similar oscillations). It could also help in detecting and avoiding or mitigating environmental crises (anoxia, contamination).

- **Biological monitoring** would help detect spatio-temporal changes in the organization of communities as measured for instance by species richness and the presence/absence of a particular population which, by its life strategy, happens to be sensitive to particular disturbances (e.g. pollution). The disappearance of a sensitive population can be preceded by a reduction in its abundance (lower survival). As a consequence, species richness and abundance of key species together give a relevant measurement of the integrity of the ecosystem and an indication of the cumulated effect of the disturbances. The disappearance of one of the populations could lead to a demographic explosion of a more resistant population (e.g. algae or macrophytes) with all the corresponding harmful effects such as dystrophic crises, "red tides" and other toxic algal blooms.

- **Fisheries monitoring** is essential to conventional management and we will not dwell on it here. Data on catch and effort but also on costs, revenues, prices, employment, etc., are essential to the achievement of human well-being objectives (FAO, 1999b; FAO-ACFR, 2002).

Monitoring can be undertaken as an automatic continuous process (e.g. through buoys measuring sea temperature, salinity or other chemical properties). It can be spatially comprehensive if based on satellite remote sensing (e.g. as for waves, wind, sea surface temperature or chlorophyll and some types of habitats such as mangroves, coral reefs, etc.). It can also be quasi-continuous if undertaken with the sector's cooperation during normal fishery activities (e.g. through fishing log books or satellite-based vessel monitoring systems). Some of the data most difficult to obtain through the conventional quasi-census processes of the classical fishery data collection systems could be obtained at regular intervals using statistical sampling of space and time. While these procedures are gaining momentum and can be cost-effective, they sometimes meet with lack of confidence by policy-makers and the sector not used to deal with statistical estimates. They can, in some cases, still be overexpensive for some developing countries or low-value fisheries.

Monitoring the state and trends in coastal environments is in most countries beyond the responsibility of the fisheries departments. Some of the data useful for an EAF, such as land-based contamination or abundance of pathogens, are not within the competence of the fishery management authority. As a consequence, EAF implies the development of improved interagency collaboration by strengthening institutional links through which the data needs and concerns of fisheries can be made more visible at higher governance levels. Strategic alliances of fisheries authorities with environmental ministries and institutions could be of assistance.

To be fully useful and to ensure their long-term funding, monitoring systems need to be used in policy development for objective setting and performance assessment. This is best ensured by nesting data collection and monitoring systems as part of a sectoral (or national) system of indicators of sustainability. The debate on the extension to EAF of the conventional (but still unused) concept of sustainability indicators has only started (Hall, 1999; Witherell, 2002; Witherell *et al.*, 2000). FAO guidelines are available for the development of Sustainable Development Reference Systems (SDRS) (FAO, 1999a) but implementation remains limited to a few advanced countries. Some ecosystem indicators are available in these guidelines as well as in the EAF Guidelines (FAO, 2003). Additional work is being undertaken by the SCOR-IOC Working Group 119 on Quantitative Ecosystem Indicators for Fisheries Management.[13]

8.18 Improving Research Capacity

The data collected as indicated above have value only if analysed and transformed into strategic information, understanding and scientific advice usable by decision-makers. Similarly, monitoring is worth its cost only if fully integrated into decision-making, feedback and performance assessment. More specific research is needed to understand, *inter alia*, the behaviour of the sector and the ecosystem and their interrelationships; to measure the resilience of the resource to fishing or environmental degradation; to elaborate policy options for decision-making which account for natural variability, market trends, climate change and other uncertainties; to detect responses to management action and, ultimately, assess governance performance. The present chronic shortage of understanding is related to insufficient research capacity and inadequate processes of communication between research and policy or management.

Research means are commonly insufficient. In most developing countries, the scientific capacity available for the required recurrent assessments has decreased during the last decade because of low salaries and poor working conditions. The trend will not be easily reversed. In the developed world, the broadening of the research spectrum, within largely stagnating if not decreasing budgets, has reduced critical mass in the ecological disciplines. This is a problem because of the higher requirements of the EAF in terms of ecological data, basic understanding and scientific advice. More research is needed to develop management approaches (e.g. adaptive management, co-management, habitat rehabilitation, risk management), to test specific tools (such as protected areas), to develop more ecological fishing gear and practices (Valdemarsen and Suuronen, 2003), and to reduce post-capture losses, genetic impact or spreading of pests and diseases.

As a consequence, the **"best scientific information"** available required by the 1982 Convention as a foundation for management is often poor. This increases uncertainty, leads to poor scientific advice, impedes performance assessment, reduces transparency of decision-making, opens the way to misinformation and unwarranted interpretations potentially hampering the needed public debate, impedes the analysis of natural variability and of human impacts, reducing forecasting capacity. Simple improvements required include: (a) an inventory of the most important habitats, in terms of extension or of species or fishery supported, with their characteristics and location; (b) some understanding of the specific role of these habitats for the productivity and resilience of the resources and ecosystem health and sector well-being; (c) explicit societal value judgements and preferences regarding ecosystem states and uses that could also be used in systems of sustainability indicators.

Research objectives need to be reviewed, focusing on understanding and forecasting of ecosystem variability and reaction to exploitation by fisheries and other industries. Impact assessment and rebuilding strategies need particular attention.

The **research scope** needs to be broadened to cover the range of ecosystem components. In particular, environmental economics and social sciences should increase their contribution. It is also

[13] See at http//:www.ecosystemindicators.org

necessary to identify alternative or competing uses of these systems and establish contact with their respective authorities. Overall, more means need to be allocated for research.

Formal and systematic ***ex-ante* and *ex-post* impact assessments** need to be undertaken.[14] The impact on the target resource is usually studied as part of the stock-assessment routine but assessments of other impacts (e.g. on the bottom and habitats) and impacts of non-fishery activities (e.g. changes to river drainage, habitat alteration, injection of nutrients and contaminants, introduced species, pests and diseases, etc.) are rare or non-existent and in any case not routinely conducted. The absence of requirements for an Environmental Impact Assessment (EIA) in most countries, for fisheries but also for other industries, explains the poor efforts in this direction. In the absence of specific information, generalizations tend to be made. These can be dangerous because impacts tend to be site-specific and resource-specific. The impact of a management strategy depends greatly on the species and the socio-cultural context (e.g. the community history, level of education, local governance, well-being, alternative opportunities, etc.). As a consequence of scarce impact assessments, risks may be poorly perceived. In addition, impacts may interact with each other, leading to unpredictable cumulative effects and they can be transboundary, potentially leading to difficulties with the neighbouring countries.

More specifically, the EAF requires an assessment or characterization of the **sensitivity** or **vulnerability** of the species of importance to fisheries and ecosystem processes in terms of their resilience to disturbances such as fishing, habitat degradation, pollution, etc. Sensitivity can be described and assessed based on the biological and life-cycle characteristics of the species. The **risk of extinction** is becoming very relevant considering the levels of overfishing measured on many important resources. This concept is illustrated by the increase in the number of proposals for listing fishery species under Appendices I and II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) during the last few years. This risk has been analysed by FAO (2000) and can be related to (i) the life cycle of the species; (ii) its market value related to its availability relative to the demand, and (iii) the effective level of deterrence of protection measures.

More importantly perhaps, **ecosystem modelling** and **option analysis** are not yet widely used in management-oriented fishery science. Considering the significant broadening of the options available for policies and management in an EAF, the critical analysis of such options, with their pros and cons, and consideration of the consequences of uncertainty, would be essential. The shortage stems in part from the lack of data mentioned above but also from a lack of quantitative models and human capacity to use them. This is often aggravated by the lack of measurable policy or management objectives. Progress must be made to improve the relevance of ecosystem models to decision-making and management. Conceptual models of the food webs, such as ECOSIM and its developments (Pauly *et al.*, 2000), are very useful as exploratory tools. However, most of the ecosystem models available are useful as concepts or for the exploration of possible behaviour in an ecosystem but cannot be used for operational management purposes. Because of the costs of data collection and the uncertainties attached to the responses obtained by highly parameterized models, advances will be needed in simpler and more reliable models. The challenge is particularly high in data-poor areas.

8.19 Management Planning

As already stated above, the main difficulty met by countries and fishery authorities in implementing instruments that have been agreed and adopted, even at the highest political level, resides in the

[14] *Ex-ante* assessments are part of the precautionary approach and aim at predicting the potential impacts of new gears and practices, increases or reductions in fishing capacity, etc., and are used to develop management strategies. *Ex-post* assessments are useful to assess the performance of the latter.

design of the operational management strategy and plan as well as in their implementation. An EAF management plan is a central requirement to formalize the approach and send to stakeholders a clear expression of the Government's willingness to act.

A management plan usually includes: (i) the issues covered; (ii) the setting of agreed targets and limits (related to constraints); (iii) details of the management actions that will be taken to meet targets and stay within limits; and (iv) procedures to measure performance in achieving the above. Objectives and constraints will be reflected in the agreed target and limit reference points. The plan will also specify pertinent time frames, identify stakeholders, ensure transparency and establish oversight processes and identify socio-economic externalities as well as jurisdictional issues. It is also best developed with a high degree of stakeholders' participation. Issues, problems and solutions related to the development of a fisheries management plan in an EAF context are not specific to it and are indeed relevant for conventional fisheries management. We will not dwell on these conventional aspects which have been properly addressed elsewhere (FAO, 1997a; Cochrane, 2002; FAO, 2003) and limit the treatment to a few selected aspects of central relevance to EAF.

8.20 Certification

Certification of management systems[15] could be an effective measure as well as a condition for improved international trade. The development of norms, such as the ISO 14000 standard, may provide a useful base for such systems. In order to be useful, an ecosystem-approach to fisheries does not have to be ISO-accredited. Moreover, as the ISO accreditation systems only audit the management process, they cannot guarantee that the expected environmental outcomes will be generated.

The EAF should normally have a broader scope than certification as it would encompass all aspects and issues of the activities related to the overall sustainability of the resources and the fishery as covered within a management plan, administered by a regulatory body. However, a certification system may be developed to only address a single issue. For example, within a fishery, some operators may wish to certify the origin of the catch (catch certification) or the quality of fish handling to achieve improved quality of fish products reaching the market. The use of certification may be more appropriate for those aspects that are not covered by fisheries legislation. As such, certification could be an important mechanism to foster the objectives of the EAF, and the Marine Stewardship Council (MSC) has elaborated and is implementing a system of ecolabelling specific to capture fisheries. While there are still resistances from industry as well as governments to ecolabelling in general, the concept seems to be progressing and might be part of the general landscape of fisheries management within a decade (FAO, 1999c).

9. IMPLEMENTATION ISSUES

For detailed guidance on implementation, the reader is advised to refer to the FAO Guidelines (FAO, 2003). This section will address only a few selected issues related to implementation.

9.1 EAF: Hurdle or Opportunity?

The intention behind implementing an EAF is to improve fisheries management. One of the conclusions stemming from the scientific symposium organized during the Reykjavik Conference

[15] This section is modified from: Commonwealth of Australia, 2002. (http://www.fisheries-esd.com/c/what/what0300.cfm).

was that there was largely enough knowledge available to start implementing an EAF without delay. It was stressed that the existing imperfections in the knowledge should not be used as an excuse for not acting (a statement which recalls the formulation of the Precautionary Approach in the UNCED Declaration). As the paper has abundantly shown, there is pressure from many leading countries and NGOs to start implementing EAF as soon as possible and the WSSD Plan of Implementation asks for its implementation by 2010 (Paragraph 29d).

It has been argued, however, that EAF will be a more complicated endeavour than conventional fisheries management and even suggested that *"the attempts to implement ecosystem-based management programmes may actually slow progress towards … sustainable fisheries"* (Sutinen and Soboil, 2003). This pessimism is based on the fact that the chronic and generalized absence of fishing and other property and use rights in the oceans promotes institutional and political shortsightedness strongly biasing governance towards short-term interests against conservation objectives and the interests of future generations. It is also based on the assumption that the "ecological angle", with its emblematic species and simplistic approaches, would detract from the strict and priority attention to be given to the interwoven issues of overcapacity, allocation and user rights. Ensuring the success of EAF requires therefore deep changes in governance (reviewed above) with the key introduction of user rights.

9.2 Rhetoric Versus Commitment

The international instruments already adopted by coastal and fishing nations, either specific to fisheries or of relevance to them, already include a wealth of agreements at the highest level, as well as provisions and guidance constituting a sound basis for implementation of the Ecosystem Approach to Fisheries. Many, if not all, of the principles of EAF have already been adopted in theory, albeit not yet widely applied in practice, and are very intricately meshed into the Code. This conclusion is reinforced by the fact that a number of principles described as part of the ecosystem approach in general are also advocated (if not generally applied) principles of good practice in conventional fisheries management (e.g. those related to participation, decentralization, subsidiarity, transparency, precaution, flexibility and adaptation).

However, despite the availability of this global consensual framework, a major drawback is that many States are not party to the agreements (when ratification is required) or merely pay lip service to the concept in large international fora while demonstrating limited political will to implement the approach effectively at national or regional levels (Aqorau, 2003). The main reasons behind such behaviour tend to be (1) the lack of capacity to implement, particularly in developing countries, and (2) the perceived or real political, social and economic costs of the transition required. The shift from rhetorics to commitment and implementation is needed urgently, if a major negative reaction from consumers and the society at large is to be avoided.

9.3 Capacity, Pragmatism and Stepwise Implementation

Even if political will and resources were available, any fishery manager, contemplating the actions needed to bring fisheries under an EAF framework, would be overwhelmed by the potential task. It must be recognized that, while most conceptual objectives and principles proposed are generally acceptable, it is unlikely that all the possible implications will be agreed to by all parties. A complex debate can be expected about them in a participatory, bottom-up implementation process. In addition, all the actions listed under Section 8 (in a list that is probably not exhaustive) may not be absolutely needed from the onset. Their practical implementation raises scientific and managerial challenges often incompatible with the available human and financial resources and, in many cases, with the economic value of the fisheries themselves. To illustrate this point, it is sufficient to remember that the fundamental principles of sustainable development adopted at UNCED and formulated in Agenda 21 a decade ago have proven to be very difficult to implement, despite the political will and the high scientific and technical capacity available. The situation of countries confronted with the implementation of the EAF ten years later has not really improved in most cases.

Considering the rigidities in most administrations and institutions, and the limited resources usually available, the implementation of EAF can only be through a stepwise process, the speed and priorities of which will depend on local conditions (history, emergencies, capacity). The difficulty will reside in allocating between areas and steps the resources available for the process, selecting the priorities so as to maximize effectiveness (e.g. in terms of stock or environment rehabilitation) while reducing human impacts and conflicts to the minimum possible.

9.4 The Need for Subsectoral Approaches

The difficulties met during implementation may be partly different in small-scale and industrial fisheries but generalizations are dangerous. Small-scale fisheries are often considered as less threatening to the ecosystem (Mathew, 2003) but are also affected by overcapacity, overfishing and destructive practices in many areas. Industrial fisheries may represent a threat to sustainability (e.g. through illegal fishing or use of flags of convenience) but they have also shown to be strong supporters of EAF in some contexts (Bodal, 2003).

Difficulties may be particularly acute with small-scale fisheries because of their size (in number of people concerned), diversity of gear and practices, geographical dispersion, low level of education, low political influence, etc. On the other hand, however, these fisheries, which are essentially coastal area-based, with traditional management structures and rules often still operational, flexible and multispecies, and which often draw additional resources from other natural resources (e.g. through small-scale agriculture, aquaculture and forestry), should be particularly adapted and receptive to an ecosystem approach to their livelihood. For these fisheries, Mathew (2003) proposes to use a progressive implementation, starting from the easier steps and proceeding to more complicated ones as the stakeholders' response improves.

9.5 Role of NGOs

The role of environmental and sectoral NGOs cannot be understated. They can play a role as interface between the fishers and the government, as well as with society at large. They can also help improve the coherence and coupling between the action taken in the environmental and fishery ministries, an area in need of significant progress. A difficulty in the process is that there is not always common understanding within environmental or sectoral NGOs or between them (Agardy, 2003).

It is impossible to date accurately the process of development of an ecosystem approach to fisheries. It probably started unconsciously when the first groups of fishers, most likely in inland waters, realized they had depleted a small stream and had to do something to deal with the problem. In its more formalized, modern form, it is a product of the 20th century (Couper, 1992) and has developed inland before spreading into oceans as their exploitation increased together with the environmental risk resulting from it. The process was fuelled by concerns about pollution, principally from the oil industry, and it progressively extended to fisheries impacts in the late 1990s. From an environmental angle, the process is one of inclusion of fisheries as an additional source of impact in the ecosystem governance. From a fisheries point of view, it is one of extension of the conventional concern about the fishers and the resources to other essential elements of the exploited ecosystem. In addressing this extension, its principles and institutional basis, as well as its aims and means, this paper does not dwell on EAF implementation *stricto sensu*. The matter is addressed in more detail by the FAO Technical Consultation (FAO, 2003) which undertook to develop preliminary guidelines for the approach. The reader is therefore advised to look at these guidelines for a better appreciation of ways and means and implications of implementing EAF.

EAF is an attempt to graft additional ecosystem considerations to conventional fisheries management, giving to the former more weight in decision-making than they historically had. It is certainly an institutional "evolution" (and not a "revolution") looking at ecosystem-related outcomes but with significant social and economic consequences in both the short and long terms. It is obvious that the fisheries sector cannot avoid it, and some parts of the sector will even intend to "ride the wave" with the hope to attract consumers (e.g. through ecolabelling). It is more obvious that, following the high-level support expressed in FAO and at WSSD (Johannesburg, 2002) governments will have no other choice than to foster its implementation. Two issues require attention: (1) the implementation challenge and (2) the potential collision between ecosystem and fisheries management paradigms and requirements.

DISCUSSION: FUSION OR COLLISION?[16]

Evolution Versus Revolution

EAF is an evolution of the fisheries management paradigm which borrows some central principles of ecosystem management and gives to them a practical operational meaning. However, both paradigms are evolving and the interaction between their respective trajectories is not immediately obvious. While this paper could not address the evolution of ecosystem management (*sensu lato*), it underlines the fact that ecosystem management and fisheries management have become two related but fairly distinct paradigms, with their independent schools of thought, scientific guilds, line ministries, international instruments and regional institutions. It also underlines the fact that they are evolving and converging, exchanging principles and elements of action. Their decades-long evolution, on parallel if not diverging routes, is now inflected towards a closer encounter or violent collision, depending on areas, governance systems and types of fisheries. We argue that a violent collision would be detrimental to society, environment and fisheries.

Co-evolution of Science and Governance

The process is one of co-evolution of governance and science, a symbiosis through which, supporting and criticizing each other, they were both forced to evolve (Garcia, 1996a) and become more conscious of: (1) the long-term costs of short-term "fixes"; (2) natural variability, uncertainty and need for precaution; (3) the need for more democratic, participative and transparent processes, as well as more powerful oversight mechanisms; (4) the importance of cooperation, coordination and integration. However, the fundamental perceptions remain still at some angle. While the long-term goals of the two processes are converging, there are sources of friction, e.g. in the attention to be given to social and economic stress in decision-making and in selecting options, as well as in the expectations about the acceptable time horizon for implementation.

Parallel Evolution of Paradigms

Ecosystem management, on the one hand, has developed and maintained a body of (largely qualitative) knowledge on ecosystem structure and functioning. It is developing sets of sustainability indicators. It has tested management organizations, processes and instruments (e.g. protected areas) and rediscovered that people, their aspirations, costs and benefits, allocation and equity — with the potential conflicts they can generate — have to be taken into account.

[16] This section contains elaborations and modifications of earlier elaborations on the issue by Garcia (2002; 2003)

Fisheries management, on the other hand, has developed a body of (more quantitative) knowledge on population dynamics, interactions between fisheries and target resources, consideration of uncertainties in assessment and management and sustainability indicators. It has tested management institutions at all levels, has experienced 20 years of space allocation following the adoption of the 1982 Convention and rediscovered that maintaining associated and dependent species, as well as critical habitats and ecosystem processes, is necessary.

In **both processes**, the players have discovered that conflicts must be tackled and resolved equitably, that enforcement capacity must be improved and both are testing the assumption according to which increased participation, decentralization and transparency will improve management performance. With time, through scientific progress, recurrent failures and growing pressure from developing environmental ethics, both paradigms are evolving towards a more balanced approach to ecosystem and human well-being. It is recognized that both needs are intricately interconnected and that conflicts between users' requirements need to be addressed and resolved.

The shift to new terminology reflects this evolution. Fisheries management has started to take on more environmental and biodiversity considerations, as shown by the evolution of ecosystem-related provisions from the 1982 Convention to the UN Fish Stock Agreement and the FAO Code of Conduct in 1995. In parallel, ecosystem management has started to take on more socio-economic and cultural considerations, progressively accepting humans as a necessary part of the ecosystem and the satisfaction of their needs as a condition for sustainability and conservation. The examination of both trajectories indicates that, while probably starting from a common concern and set of principles far in human history, the two management paradigms have developed different (albeit convergent) focus and objectives, based on different perspectives, processes and institutions. They both met with dismal performance and rediscovered that the needs and constraints of both the people and the environment must be satisfied.

Obstacles to the "Fusion"?

It would seem obvious that there is a need to join the paradigms as they probably were centuries ago in more primitive civilizations and as attempted in the concept of sustainable development, but there are some difficulties on the way:

- The two paradigms are underpinned by two separate families of institutions, organizations and legal instruments and two types of scientists similar by their academic background but often different by the institutional system in which they operate. This creates the costly need for coordination and collaboration but also the political incentives to maintain separate identities with related fights for power and budgets. In other words, the institutions created as part of the solution may well become part of the problem across the way towards a joint (fused) paradigm.

- The two processes are somewhat different. **Fisheries management** decisions are based on evolving science (at least in theory), the outcome of which is considered (and sometimes applied) through an administrative process that has shown strong inertia, reinforced by the inherent resistance to change of the sector, struggling with the direct practical, social, economic and political consequences of the change. Fisheries management has been intensively tested in all contexts. It has been used for decades and its strong points and weaknesses are well known. **Ecosystem management** is also supported by science but decision processes (particularly at international level) seem to operate under higher public pressure often organized by NGOs through an efficient use of the media. It is evolving rapidly, supported by a large number of citizens, most of them with limited or no understanding of the costs of change to the sector and who often assume a zero cost to themselves. It has had a much more limited time for operational application and has accumulated little experience in accounting for social and economic issues. The difference in history and processes makes it more difficult for the two paradigms to "merge".

Both paradigms, however, must confront the difficult and recurrent question of allocation of resources and wealth at societal, cross-sectoral and even individual levels, the complexity of the "equity" question and the potential for conflict among a large and diversified group of stakeholders.

Outlook

It is not easy to forecast how the evolution of the two paradigms will proceed. Such evolution will probably depend partly on the evolution in other sectors than fisheries (e.g. water, forestry, waste, etc.). In any case, fisheries will most probably be considered from now on as one "environmentally degrading" industry among many others, a fact that the sector must take seriously into account. During the next two decades, the process could evolve as:

(1) A "violent" collision between radicalized paradigms, thrown out of balance by globalization, conflicts between stakeholders, and no reversal in overfishing and pollution trends.[17] In this scenario, public pressure increases on a sector perceived as adapting too slowly and unwillingly to new societal requirements. Considering the respective political and electoral weights of the two stakeholder groups, the perspective is that fishermen could lose the conflict in many countries, particularly in the developed world, with very significant political, financial and cultural losses. While the sector itself may survive because alternative ways of producing 150 million tonnes of food are simply impractical, many fisheries may be closed, starting from the most environmentally "aggressive" ones and in areas where the contribution to food is not essential. Whether this scenario would be favourable to small-scale (more ecological?) or large-scale (more politically effective?) industries is not clear.

(2) A smooth confluence between the two paradigms through improved collaboration between existing institutions or the creation of new, integrated ones. The fisheries stakeholders are put in the position of effectively adopting and implementing a more ecosystem and precautionary approach to development and management. The ecosystem stakeholders realize that in many areas fishing is needed and the fisherman is an "endangered species", essential for the functioning of the coastal communities. Both groups of stakeholders realize that future long-term benefits can operate as incentives today only if the issue of resources allocation is resolved. Both realize and accept that, in the short term, a major problem is in the fact that the cost of change can easily be overwhelming. Both agree that the solution is neither in *status quo* (fishing as usual) nor in systematic exclusion of fishers through bans or moratoria, and that the challenge is to work out a transition at a pace that is effective enough in reaching the goal and socio-economically acceptable.

Predictions and generalizations as to which scenario will prevail would be risky. While a range of positions exist in both paradigms and both include extremists, option 2 seems to be the one generally favoured by national governance but often looked at reluctantly by a defying sector. It is also the one implicit in most scientific papers with some statement about the future.

It seems indeed that an outright elimination of fisheries as a main use of the aquatic ecosystems is highly unlikely. The ecological footprint of an alternative solution to production of the needed 150

[17] After drafting this paper, the authors discovered that the concept of "collision" had already been used referring to "policy train wrecks", collisions of economic enterprise and environmental preservation (Fitzsimmons, 1994).

million tonnes of food now coming from the sea would probably be worse and the socio-economic earthquake resulting from the demise of world fisheries unacceptable to society.

A global disappearance of fisheries is unlikely and, as a consequence, a progressive change towards more ecological fisheries will probably happen. Based on the past 50 years' experience, however, the change will happen at different paces in different places and fisheries. Further degradation can therefore be expected in some places while in others the situation will markedly improve. More stocks will collapse. Others will be closed down by management, under public pressure, before this happens. In both cases socio-economic disruption will be very damaging, most often to poor people for which fishing is the only livelihood.

Capture fisheries have sometimes been considered a sunset industry, spiralling down through plummeting resources and profitability as conventional management failed to maintain target stocks at the appropriate level. Will EAF be able to reverse the image? Will EAF succeed in maintaining target stocks and, in addition, the biochemical environment and the habitat? The reply to this question will depend on the circumstances, the political will, the capacity, etc. In any case, EAF appears as a necessary if not sufficient condition to the maintenance of fisheries in the long term.

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Annex 1

MALAWI PRINCIPLES FOR THE ECOSYSTEM APPROACH

In a Workshop on the Ecosystem Approach (Lilongwe, Malawi, 26-28 January 1998), whose report was presented at the Fourth Meeting of the Conference of the Parties to the Convention on Biological Diversity (Bratislava, Slovakia, 4-15 May 1998, UNEP/CBD/ COP/4/Inf.9), twelve principles/characteristics of the ecosystem approach to biodiversity management were identified:

(1) Management objectives are a matter of societal choice.

(2) Management should be decentralized to the lowest appropriate level.

(3) Ecosystem managers should consider the effects of their activities on adjacent and other ecosystems.

(4) Recognizing potential gains from management there is a need to understand the ecosystem in an economic context, considering e.g. mitigating market distortions, aligning incentives to promote sustainable use, and internalizing costs and benefits.

(5) A key feature of the ecosystem approach includes conservation of ecosystem structure and functioning.

(6) Ecosystems must be managed within the limits to their functioning.

(7) The ecosystem approach should be undertaken at the appropriate scale.

(8) Recognizing the varying temporal scales and lag effects which characterize ecosystem processes, objectives for ecosystem management should be set for the long term.

(9) Management must recognize that change is inevitable.

(10) The ecosystem approach should seek the appropriate balance between conservation and use of biodiversity.

(11) The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices.

(12) The ecosystem approach should involve all relevant sectors of society and scientific disciplines.

Annex 2

KEY EVENTS IN THE EVOLUTION OF FISHERIES AND ECOSYSTEM MANAGEMENT[18]

1902	Charter of the International Council for the Exploration of the Sea. Revised 1964, 1970.
1910	International Commission for the Scientific Exploration of the Mediterranean (ICSEM)
1969	Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP)
1971	Convention on Wetlands of International Importance, Especially for Waterfowl (Wetlands or Ramsar Convention). Its "wise use" principle anticipates the concept of sustainable development. Led to the development of the protected areas concept.
1971	Man and Biosphere Programme (MAB), launched as a program of UNESCO. Contributed to the development of protected areas.
1972	Stockholm Conference on Human Environment. Defined the right of mankind to a healthy environment.
1972	Convention Concerning the Protection of the World Cultural and Natural Heritage (World Heritage Convention). Covers both natural and cultural areas of outstanding value.
1972	Convention for the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention)
1973	Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Embodies an ecosystem-based approach.
1973	FAO Technical Conference on Fisheries Management and Development: stressed overfishing, overcapitalization, environmental degradation (as a risk higher than fishing!) and the need for precautionary, anticipatory and experimental fisheries management. Proposed to frame fisheries management into ocean management (Garcia, 1992).
1979	Convention on the Conservation of Migratory Species of Wild Animals (CMS or Bonn Convention). Priority work on marine turtles and small cetaceans.
1979	Indian Ocean whale sanctuary
1980	Commission on the Conservation of Antarctic Marine Living Resources (CCAMLR)

18 Information selected mainly from Kimball (2001)

1981	Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region
1981	Convention for the Protection of the Marine Environment and Coastal Areas of the South East Pacific
1982	UN Convention on the Law of the Sea. The comprehensive framework for marine environmental protection and resources conservation.
1982	Protocol on Specially Protected Areas
1983	Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region
1984	Action Plan for Biosphere Reserves (MAB Programme of IOC)
1984-87	World Commission on Environment and Development
1985	International Wildlife Coalition moratorium on whaling
1985	Regional Convention for the Conservation of the Marine Environment of the Red Sea and the Gulf of Aden Environment
1985	Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern African Region
1986	Convention for the Protection and Development of Natural Resources and Environment of the South Pacific Region
1987	Publication of the Brundlandt Report (Our Common Future). A report of the World Commission on Environment and Development.
1989-91	UN General Assembly Resolutions on Large-Scale Pelagic Driftnet Fishing and its Impacts on the Living Marine Resources of the World's Oceans and Seas
1989	Exxon Valdez oil spill
1990	Regional Seas Caribbean Protocol on Specially Protected Areas and Species
1990	Convention for a North Pacific Marine Science Organization (PISCES)
1991	MARPOL Guidelines for the Designation of *Particularly Sensitive Sea Areas (PSSAs)*
1992	UNCED Declaration and Agenda 21
1992	Convention on Biological Diversity
1992	Convention for the Protection of the Marine Environment of the North East Atlantic
1992	Convention on the Protection of the Marine Environment of the Baltic Sea Area
1992	Convention on the Protection of the Black Sea Against Pollution. Followed by the Black Sea Environment Programme (BSEP) in 1994.

1994	Code of Practice on the Introductions and Transfers of Marine Organisms. Supersedes earlier versions of 1973, 1979 and 1990.
1994	Establishment of the Antarctic whale sanctuary
1995	Global Programme of Action on Protection of the Marine Environment from Land-Based Activities (GPA)
1995	Agreement Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (Fish Stocks Agreement or FSA)
1995	FAO Code of Conduct for Responsible Fisheries
1995	UNESCO Seville Strategy and the Statutory Framework for the World Network of Biosphere Reserves
1995	Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean. Call for protected areas. Supersedes the 1976 Convention.
1997	International Guidelines for the Control and Management of Ships' Ballast Water to Minimize the Transfer of Harmful Aquatic Organisms and Pathogens
1999	ITLOS decision regarding Pacific Southern Bluefin Tuna
1999	FAO International Plans of Action (IPOAs) : (1) To reduce the incidental catch of seabirds in long-line fisheries; (2) For the conservation and management of sharks; (3) For the management of fishing capacity.
2001	*Draft* legally-binding instrument to prevent the harmful effects of the use of anti-fouling systems on ships.
2001	FAO International Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing

Annex 3

GLOSSARY

Adaptive management — A management strategy that can be readily adapted to take account of new knowledge obtained during implementation, including performance assessments.

Alien species — A species occurring in an area outside its historically known natural range as a result of intentional or accidental dispersal by human activities. Also known as **Introduced species**.

Anoxia — Absence of oxygen. A pathological deficiency of oxygen. (*The American Heritage Dictionary of the English Language, 2000).*

Assemblage — See: **Population assemblage**.

Associated species — Species that occur with the target species in a given area and may be caught as bycatch during the fishing process.

Benthic — Living on or in the bottom.

Biodiversity — The variability among living organisms from all sources, including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part *(Convention on Biological Diversity, 1992.* http://www.biodiv.org/convention/articles.asp). The variety and variability of living organisms. It takes into account intraspecific genetic variability, the variety of species and their way of life, the diversity of species communities and their interactions, as well as the ecological processes that they influence or realize, the diversity of adaptive strategies and the number of interactions between the organisms and the variables of the environment (Lévèque 1997; FAO 1997).

Biogenic — Produced by living organisms or biological processes. Necessary for the maintenance of life processes. (*The American Heritage Dictionary of the English Language, 2000).*

Biological potential — A characteristic capacity of all populations, from bacteria to fish, to expand population size, more or less rapidly up to some naturally variable maximum. The expansion capacity of a population is limited by the **biogenic** capacity of the ecosystem. In fisheries, the term "potential" of a stock refers to its Maximum Sustainable Yield (MSY).

Community — An integrated group of species inhabiting a given area; the organisms within a community influence one another's distribution, abundance and evolution. (A Human Community is a social group of any size whose members reside in a specific locality.) (*WRI Biodiversity glossary of terms*).
See also: **Population assemblage.**

Competition The interaction among organisms for a necessary resource that is in short supply (Nybakken, 1982). Happens between individuals of a given population or between different populations of the same species which occupy the same ecological niche (**intraspecific competition)**. May happen also between different species with the same or overlapping ecological niches (**interspecific competition**). It is being argued that, as apical predators, human beings are in competition with marine mammals (Tamura, 2003). Organisms and populations are able to exclude competitors by altering their surroundings through excretion of chemical substances that modify the interactions. In a fished ecosystem, fishers compete for resources with other predators they may exploit (e.g. tunas, sharks) or not (e.g. piscivorous birds and marine mammals).

Conservation The management of human use of the biosphere so that it may yield the greatest sustainable benefit to current generations while maintaining its potential to meet the needs and aspirations of future generations; thus, conservation is positive, embracing preservation, maintenance, sustainable utilization, restoration and enhancement of the natural environment (*WRI Biodiversity glossary of terms*).

Coral bleaching Anomalous phenomenon occurring in coral reefs through which corals lose their natural colouration and take a whitish color. The discolouration is due to the loss of the microscopic algae living inside their colonies and leads to the loss of photosynthetic capacity of the coral reefs and, eventually, to their death.

Dependent species A non-target species depending on the target species (e.g. a predator fish depending on a prey).

Diadromous Regularly migrating between freshwater and seawater. This category includes anadromous and catadromous fishes (e.g. sea lampreys, *Anguilla*, *Alosa*, etc. (*FishBase Glossary, 2000;* http://www.fishbase.org/search.html).

Diversity Diversity is a measure of the complexity of an ecosystem and often an indication of its relative age. It is measured in terms of the number of different plant and animal species (Scialabba, 1998). A numerical measure combining the number of species in an area with their relative abundance (Nybakken, 1982). Often called **species richness**, the diversity of a community is represented by a mathematical expression relating species richness to the relative abundance of a species. For a fixed species richness, the diversity is maximum when the abundance of each species is the same.

Ecolabel A seal of approval (or certification) of a product, process or service complying with a particular set of agreed environmental criteria usually awarded by an impartial third party (certification company). In fisheries, the label informs on the quality of the product itself as well as on the production and management processes.

Ecolabelling A voluntary method of certification of environmental quality (of a product) and/or environmental performance of a process based on lifecycle considerations and agreed sets of criteria and standards.

Ecological niche

The function of a species in the ecosystem. For example, the niche of herbivores or the niche of carnivores. The connections between organisms and the ecosystem. Should not be confused with the **habitat** (Odum, 1975). The ecological niche of an organism depends not only on where it lives (habitat) but also on what it does. By analogy, it may be said that the habitat is the organism's "address", and the niche is its "profession", biologically speaking (Odum, 1959).

Ecological valence

Represents the extent of the variations of the environmental factors which a species can survive in the long run. Thus, a species is an indication of a particular ecological situation. Certain species endure great variations (thermal, eurythermic, saltwater, euryhaline) or no variation (stenothermal).

Endangered species

Species threatened by extinction as a direct or indirect result of human activities, e.g. through habitat degradation, overexploitation, competition with introduced species.

Environment

Group of biotic and abiotic variables and their interactions.

Eutrophication

The slow aging process of a lake, estuary or bay evolving into a marsh and eventually disappearing. During the later stages of eutrophication, the water body is loaded with excessive concentrations of plant nutrients such as nitrogen and phosphorus, causing excessive algal or plant production. As organic matter accumulates in the water and on the bottom, eutrophication may lead to oxygen depletion, anoxia and massive mortalities. While eutrophication can be a natural process, it can also be provoked or accelerated by human activities adding nutrients (e.g. agriculture fertilizers, manure, urban sewage) to a water body.

Fish-in-Balance index

FiB. A composite indicator of an exploited ecosystem based on the average trophic level and weight of the total catch (see equation below). In the absence of long-term, environmentally-induced changes in species or size composition, changes in FiB may be related to fishing. An increasing trend could indicate, *inter alia*, a broadening of the resource base through fisheries expansion (e.g. to new and bigger species, farther offshore, at greater depth, etc.). A decreasing trend would indicate overfishing. A stable value would indicate an overall stable (and possibly sustainable) fishery but it may hide trends, including overfishing, in some of the catch components.

$$FiB = \log\{Y_i \cdot (\frac{1}{TE_i})^{TL_i} / \left(Y_0 \cdot (\frac{1}{TE_0})^{TL_0}\right)\}$$

where Y_i is the catch in year i, TL_i the mean trophic level in that catch, Y_0 the catch at the start of the series, TL_0 the mean trophic level in the catch at the start of the series and *TE* the mean transfer efficiency between trophic levels. *TE* has been estimated as 10% in various marine ecosystems (Pauly and Christensen, 1995). Assuming that this estimate applies through the time series the equation simplifies to:

$$FIB = \log\{\frac{Y_i \cdot 10^{TL_i}}{Y_0 \cdot 10^{TL_0}}\}$$

<u>Compiled from</u>: Pauly *et al.* (2000).

Ghost fishing The continued killing of fish by a fishing gear, e.g. through gilling or entanglement (by a gillnet) or trapping (by a fish trap or pot) after the gear has been lost or voluntarily dumped in the water body.

Governance In general, the activity or process of governing; a condition of ordered rule; those people charged with the duty of governing or the manner/method/ system by which a particular society is governed. In a particular sector (e.g. fisheries), a continuing process through which governments, institutions and stakeholders of the sector and of other interacting sectors, elaborate and adopt appropriate policies, plans and management strategies to ensure sustainable and responsible resource utilization. In the process, conflicting or diverse interests may be accommodated and co-operative action may be taken. The modern use of the term implies change in the meaning (and mode) of government, with: reform of the civil service; greater use of non-governmental organizations (civil society); reduction of public intervention; privatization of public enterprises; encouragement of competition; greater use of markets and quasi-markets to deliver public services; openness of information (transparency), integrity and accountability (auditing); decentralization of responsibilities (local governance) (*FAO Glossary, 2002,* http://www.fao.org/fi/glossary/default.asp)**.**

Guild Group of organisms that exploit the same resources (share the same food resources) in an ecosystem.

Habitat The biological place or position of a population in an ecosystem (Nybakken, 1982). The place where an organism is found (Odum, 1975). The place or type of site where species and communities normally live or grow, usually characterized by relatively uniform physical features or by consistent plant forms (Scialabba, 1998).

Homeostasis The speed at which a population — or group of populations — regains the state in which they were prior to a disturbance (Pearson *et al.*, 1992) or return to the original equilibrium (Barbault, 1997). See also**: Resilience.**

Introduced species See: **Alien species.**

Lentic Of or relating to or living in still waters (as lakes or ponds).

Lotic Of or relating to or living in moving water (as brooks, rivers, etc.).

Overfishing Exerting a fishing pressure (fishing intensity) beyond agreed optimum level. (*FAO Glossary, 2002;* http://www.fao.org/fi/glossary/default.asp)**.** The symptoms of ecosystem overfishing include: reduction in diversity, reduction in aggregate production of exploitable resources, decline in mean trophic level, increase in bycatch, greater variability in abundance of species, greater anthropogenic habitat modification (Hall, 1999). According to Murawski (2000), an ecosystem can be considered to be overfished when cumulative impacts of catches (landings plus discards), non-harvest mortality and habitat degradation result in one or more of the following conditions: (1) Biomasses of one or more of the most important species assemblages fall below minimum biological acceptable levels, such that recruitment is impaired or rebuilding times to MSY are extended; (2) Diversity of communities declines significantly as a result of sequential

Overfishing (continued) "fishing down" of stocks; (3) Species selection and harvest rate lead to greater year-to-year variations in populations than would result from lower cumulative harvest rates ; (4) Changes in species composition as a result of fishing significantly decrease the resilience or resistance of the ecosystem to perturbations arising from non-biological factors; (5) The harvest rates result in lower cumulative net economical or social benefits than would result from a less intense overall fishing pattern; (6) Harvest of prey species or direct mortalities resulting from operations impair the long-term viability of ecologically important non-resource species (e.g. marine mammals, turtles, sea birds).

Persistence Characteristic of a group of stable populations that conserve the same number of species in time (Pimm, 1984; Pimm and Hyman, 1987).

Population All the individuals of a given species that occupy a given area or ecosystem (from Barbault, 1992). A population is therefore the basic biological functional unit of an ecosystem. The exploitation and eventual overexploitation concerns a **population** or a group of **populations.** The unit directly targeted by fishing is the **stock**, which is not necessarily representative of a population**.**

Population assemblage A group of populations living in a given ecosystem, also called **community** or **species assemblage** (Lévêque, 1997; Amanieu and Lasserre, 1982). The term **community** is sometimes considered as more restrictive, referring to a given taxonomic group taken with a given sampling technique.

Protected areas Designated areas of the ecosystem which are protected by law and regulations with the view to conserving/rehabilitating them and the biodiversity they contain. Protection includes regulation or outright prohibition of human uses.

Regularity Relationship between the observed diversity and maximum diversity for a given species richness (Odum, 1975). The distribution of the total number of individuals among the species (Nybakken, 1982).

Resilience See: **Homeostasis**.

Resistance The degree of modification of the species composition or a species assemblage after a disturbance. The capacity of species assemblages to resist during a disturbance (Pearson *et al.*, 1992).

Richness See: **Species richness**.

Species diversity See: **Diversity**.

Species richness The number of species (taxons) occurring inside an ecosystem. A simple listing of the total number of species in a community or trophic level (Nybakken, 1982). SR reflect the capacity of the environment to sustain species, because it is a function of the number of ecological niches and of the habitats' diversity. This concept is important in restocking programmes. See also: **Species diversity**.

Stability An assemblage of species is stable when it conserves the same number of individuals of each species in the course of time (modified from Connell and Sousa, 1983). A population is stable when it conserves the same number of individuals in the course of time.

Stewardship The conducting, supervising or managing of something. The careful and responsible management of something entrusted to one's care: stewardship of our natural resources (*Webster Dictionary*).

Top predators Predators (carnivores) located at the top of the food chain, feeding on preys located at lower levels in the chain and with no or few predators able to feed on them. Large marine mammals, sharks, tuna, are top predators. Top predators may have a role in top-down control of ecosystem structure and functioning.

Trophic chain The complex architecture of living creatures interconnected through feeding (predator-prey relationships) from the lower levels of primary productivity (microscopic algae in the plankton) to top predators.

Trophic level The level of a living creature in the food chain. The phytoplankton is found at the lower levels (bacteria and other microorganisms are at an even lower level). Top predators occupy the highest levels.

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Fisheries development, management, research and operations (including marketing) need to be conducted, taking account of the nature and characteristics of the ecosystems in which they operate in order to minimize negative impacts. Many of the principles and conceptual objectives have already been proposed and agreed upon, particularly the FAO Code of Conduct for Responsible Fisheries, constituting a solid institutional foundation for the ecosystem approach to fisheries (EAF). The challenge is to progress towards operational objectives and guidelines for implementation. This technical paper, prepared as a basis for the development of the FAO EAF guidelines, presents a thorough review of the field.

ISBN 92-5-104960-2 ISSN 0429-9345

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TC/M/Y4773E/1/7.03/1800