21 Governance for Responsible Fisheries: an Ecosystem Approach

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Abstract

The term, 'responsible' can be interpreted in many ways. For fisheries, we believe responsible means sustainable production of human benefits, which are distributed 'fairly', without causing unacceptable changes in marine ecosystems. Governance is broader than fisheries management. It consists of formal and informal rules, and understandings or norms that influence behaviour. Responsible fisheries requires self-governance by the scientific community, the fishing industry and the public (including politicians), as well as responsible fisheries management. An ecosystem approach to fisheries management, also known as ecosystem-based fisheries management, is geographically specified fisheries management that takes account of knowledge and uncertainties about, and among, biotic, abiotic and human components of ecosystems, and strives to balance diverse societal objectives.

Much has been written about the principles that should underlie an ecosystem approach to fisheries management. The key elements of the approach should be: (i) goals and constraints that characterize the desired state of fisheries and undesirable ecosystem changes; (ii) conservation measures that are precautionary, take account of species interactions and are adaptive; (iii) allocation of rights to provide incentives for conservation; (iv) decision making that is participatory and transparent; (v) ecosystem protection for habitat and species of special concern; and (vi) management support, including scientific information, enforcement and performance evaluation. Fisheries ecosystem plans are a useful vehicle for designing and implementing fisheries management systems that capture these six elements. Such plans should highlight a hierarchy of management entities, from an ecosystem scale to the local scale of communities; ocean zoning, including marine protected areas (MPAs) and other geographically defined management measures; and specification of authorized fishing activities, with protocols required for future authorizations.

The scientific community needs to govern itself so that it produces scientific information that is relevant, responsive, respected and right. A multi-faceted approach is needed, including monitoring of fisheries and ecosystems, assessments and scientific advice tailored to management needs, and strategic research investments to improve monitoring and assessments in the future. One serious problem facing scientists is the controversial nature of assessments and scientific advice. This problem needs to be addressed with a three-pronged strategy that calls for: separation of scientific institutions from management; collaborative research with the fishing industry; and transparent quality assurance of scientific advice. The last-named requires peer review, which either can be integrated into the process of preparing the advice (referred to as integrated peer review) or can be conducted following the preparation of the advice (referred to as sequential peer review). The appearance of potential conflict of interest by peer reviewers is a factor in the credibility of the peer review process.

For an ecosystem approach for responsible fisheries, the fishing industry should govern itself to accept responsibility for providing fisheries information, embrace collaborative research, participate in the fishery management process and live with the outcome, comply with regulations, avoid waste and develop training to instil a responsible fishing ethic. Environmentalists and the public in general should also participate

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in the fisheries management process and live with the outcome. Politicians should produce legislation that is clear in intent and achievable within realistic funding levels. No one should make or condone 'end runs', which undermine fishery management decisions. All stakeholders should be respectful of other stakeholders.

Introduction

The title of a paper should inform the reader about its subject. However, the words used to discuss governance, fisheries and ecosystems often are ambiguous. This problem reflects the mixture of scientific information and personal values that relate to fisheries and ecosystem issues, and the differing perspectives of the people involved in governance. Thus, we begin this chapter with an elaboration on what the words in the title mean, at least to us.

From our perspective, a fishery has three dimensions: the people who catch fish, the capital and other inputs they use to fish, and the fish populations that produce the fish that are caught. A fishery may be defined narrowly (such as people from a specific port, using a specific gear, fishing a specific population of fish) or broadly (all of the people, gear and fished populations within a geographic area that encompasses all of their activities). The more narrowly a fishery is defined, the more likely it is that interactions with other fisheries will have an important influence on it. Ecosystems include fisheries (humans, fishing inputs and fish populations), but they also have many more dimensions, such as the physical and chemical environment, and unfished species. Ecosystems are usually defined by geographic area. The boundaries selected to define an ecosystem determine the degree to which it is influenced by other ecosystems. Ecosystems that are isolated from other ecosystems are referred to as 'closed'.

This chapter considers fisheries as components of marine ecosystems because fisheries are influenced by marine ecosystems, and fishing affects the non-fisheries components of marine ecosystems, either directly or indirectly. We define an ecosystem approach to fisheries management, also known as ecosystem-based fisheries management, as follows:

> An ecosystem approach to fisheries management (or ecosystem-based fisheries management) is geographically specified fisheries management that takes account of knowledge and uncertainties about, and among, biotic, abiotic and human components of ecosystems, and strives to balance diverse societal objectives.

An ecosystem approach uses knowledge about the relationship between fisheries and ecosystems and, where knowledge is lacking, makes robust decisions in the face of uncertainty (such that the outcome is likely to be ecologically benign, and unlikely to be irreversible).

Today, it is generally understood that to conduct responsible fisheries, one must also be responsible about the effects on the non-fishing components of ecosystems; but what does responsible mean? We think there are four criteria that must be met for a fishery to be considered responsible: it must be (i) sustainable; (ii) produce human benefits; (iii) have a 'fair' distribution of benefits; and (iv) not cause 'unacceptable change' in marine ecosystems. Our four criteria for responsible fisheries are consistent with the recommendations of the first US National Conference on Science, Policy and the Environment (NCSE, 2000), which called for sustainability that integrates economic security, ecological integrity and social equity.

Sustainability is virtually a universally accepted criterion. It means that a fishery potentially can continue forever into the future, which requires that the fishery resource population must continue to produce fish. This is not a very restrictive criterion, since even overfishing of a depleted resource often can be sustained indefinitely. However, the sustainability criterion is usually interpreted in association with the second criterion, that of producing human benefits. The second criterion is the reason for fisheries. It acknowledges that fisheries are beneficial and, indeed, necessary for the survival of a large number of people. Even where actual survival is not an issue, fisheries contribute much to human welfare (as food, livelihood, recreation and for cultural reasons). Thus, we believe that responsible fisheries should produce a high level of human benefits on a sustainable basis, which generally disqualifies overfishing. In fact, it implies that the concept of maximum sustainable yield (MSY), which has often been criticized (e.g. Larkin, 1977), is a useful foundation for responsible fisheries, as argued by Mace (2001).

A 'fair' distribution of benefits is hard to quantify because fairness is in the eye of the beholder (which is also true for quantifying 'responsible'). However, the fairness criterion acknowledges that people (both participants in fisheries and non-participants) care about the distribution of benefits. Caring about the distribution of benefits is a logical consequence of all people having a stake in marine ecosystems (ultimately, sustainability of the biosphere depends on the perception that everyone has a stake). The more closely associated people are with marine ecosystems (in terms of distance and activities), the greater their sense of ownership. A sense of ownership makes it natural that people care about who benefits. The criterion of a fair distribution of benefits will continue to increase in importance because the proportion of people who can benefit directly from fishing will continue to decrease due to human population growth and advances in fishing technology.

The unacceptable changes in marine ecosystems referred to in the fourth criterion are not necessarily restricted to changes that prevent fisheries from being sustainable (e.g. habitat destruction), or from producing a high level of benefits (e.g. stock depletion). There may also be other changes that people dislike, such that the intangible (non-market) value of marine ecosystems is unacceptably reduced.

The relative importance of the four criteria is subjective, and there may be little agreement on the meanings of 'fair' and 'unacceptable change'. However, it is our observation that individual perspectives with respect to all four criteria are important in shaping debates and decisions about fisheries. Ultimately, all four criteria determine whether or not people judge fisheries to be responsible.

The final key word in the title that needs to be defined is governance. Fisheries management and governance are commonly thought of as synonymous, but governance is broader. There are many definitions of governance in the literature (e.g. Juda and Hennessey, 2001). For the sake of simplicity, we think of governance as formal or informal rules, understandings or norms that influence behaviour. To sustain fisheries and ecosystems, fisheries managers govern some of the behaviour of the fishing industry. Sustainability also requires self-governance by the fishing industry. However, managers and the fishing industry are not the only human dimensions of fisheries systems. In addition, scientists, politicians and the public can either foster or undermine the responsibleness of fisheries, depending on how they govern their own behaviour.

In the following sections of this chapter, we offer our views on an ecosystem approach to governance for responsible fisheries. We do not pretend to be experts on governance. We base our opinions on decades of experiences at the interfaces of science, fisheries management, politics and public opinion. The second section focuses on key elements of fisheries management that are necessary for responsible fisheries in an ecosystem context. The third section discusses institutional arrangements for an ecosystem approach to fisheries management, including the concepts of fisheries ecosystem plans (FEPs) and ocean management areas (OMAs). The fourth section emphasizes the importance of a well-governed scientific enterprise as an underpinning of responsible fisheries, while the fifth section calls for self-governance by the fishing industry and the sixth calls for behaviour by politicians and the public that is conducive to responsible fisheries. We conclude in the last section with some thoughts on future governance challenges.

Elements of an Ecosystem Approach for Responsible Fisheries Management

There are many scientific papers and committee reports on exploitation of ecosystems that are applicable to fisheries management. Over two decades ago, Holt and Talbot (1978) stated seven principles that called for maintaining ecosystems at a desirable state, including safety factors in decisions, avoiding waste of non-target species, and resource assessments preceding resource use (see Box 21.1 for a more complete statement of the principles). Holt and Talbot's principles were revisited and revised by a meeting of more than 40 international scientists (Mangel *et al*., 1996) as indicated in Box 21.2. The Ecosystem Principles Advisory Panel (1999), established as a mandate of the USA Magnuson–Stevens Fishery Conservation and Management Act, recommended seven principles and six policies for achieving the overarching goal of ecosystem health and sustainability (Box 21.3). Some of the key principles acknowledged that predictability is limited, that diversity is important and that ecosystems have thresholds and limits which, if exceeded, can result

Box 21.1. Holt and Talbot's (1978) principles for conservation of wild living resources.

1. The ecosystem should be maintained in a desirable state such that
a. Consumptive and non-consumptive values could be maximized on a continuing basis;
b. Present and future options are ensured; and
c. The risk of irreversible change or long-term adverse effects as a result of use is minimized.
2. Management decisions should include a safety factor to allow for the fact that knowledge is limited and institutions are imperfect.
3. Measures to conserve a wild living resource should be formulated and applied so as to avoid wasteful use of other resources.
4. Survey or monitoring, analysis, and assessment should precede planned use and accompany actual use of wild living resources. The results should be made available promptly for critical public review.

Box 21.2. Holt and Talbot's (1978) principles, as revised by Mangel *et al*. (1996).

Principle I. Maintenance of healthy populations of wild living resources in perpetuity is inconsistent with unlimited growth of human consumption of and demand for those resources.
Principle II. The goal of conservation should be to secure present and future options by maintaining biological diversity at genetic, species, population and ecosystem levels; as a general rule, neither the resource nor other components of the ecosystem should be perturbed beyond natural boundaries of variation.
Principle III. Assessment of the possible ecological and sociological effects of resource use would precede both proposed use and proposed restriction or expansion of ongoing use of a resource.
Principle IV. Regulation of the use of living resources must be based on understanding the structure and dynamics of the ecosystem of which the resource is a part and must take into account the ecological and sociological influences that directly and indirectly affect resource use.
Principle V. The full range of knowledge and skills from the natural and social sciences must be brought to bear on conservation problems.
Principle VI. Effective conservation requires understanding and taking account of the motives, interests and values of all users and stakeholders, but not by simply averaging their positions.
Principle VII. Effective conservation requires communication that is interactive, reciprocal and continuous.

Box 21.3. Principles, goals and policies recommended by the Ecosystems Principles Advisory Panel (1999).

Principles

- The ability to predict ecosystem behaviour is limited.
- Ecosystems have real thresholds and limits which, when exceeded, can effect major system restructuring.
- Once thresholds and limits have been exceeded, changes can be irreversible.
- Diversity is important to ecosystem functioning.
- Multiple scales interact within and among ecosystems.
- Components of ecosystems are linked.
- Ecosystem boundaries are open.
- Ecosystems change with time.

Goals

- Maintain ecosystem health and sustainability.

Policies

- Change the burden of proof.
- Apply the precautionary approach.
- Purchase 'insurance' against unforeseen, adverse ecosystem impacts.
- Learn from management experiences.
- Make local incentives compatible with global goals.
- Promote participation, fairness and equity in policy and management.

in structural changes that may be irreversible. Some of the key policies called for applying the precautionary approach, making incentives compatible with goals and promoting participation and fairness.

Another set of recommendations was produced by the Committee on Ecosystem Management for Sustainable Marine Fisheries of the USA National Research Council (NRC, 1999). It recommended: (i) conservative single-species management; (ii) incorporating ecosystem considerations into management; (iii) dealing with uncertainty; (iv) reducing excess fishing capacity and assignment of rights; (v) using marine protected areas (MPAs) as part of a suite of tools for managing fisheries; (vi) taking account of by-catch and discards; (vii) effective institutions for fisheries management; and (viii) better information. These recommendations are noteworthy because they (i) do not call explicitly for ecosystem management (which might have been expected, given the name of the Committee) and (ii) do call for single-species management approaches, albeit conservative.

While our scientific understanding of fisheries and marine ecosystems has advanced tremendously, we now acknowledge that we cannot manage ecosystems. Even with perfect knowledge, humans can only control what humans do. We have only an indirect influence on other components of ecosystems. With limited knowledge relative to the complexity of ecosystems (e.g. as indicated in Fig. 21.1, from Link, 1999), which is likely to be the case for the foreseeable future, there will be a high degree of uncertainty about the magnitude of indirect influence. However, we have learned enough to predict often the directionality of perturbations, which is a valuable scientific foundation for an ecosystem approach.

There is another important aspect of the evolution in our thinking about fisheries within an ecosystem context. It often has been argued that we need an ecosystem approach because single-species fisheries management has failed to prevent undesirable outcomes, such as depleted fish stocks. It is now recognized that these undesirable outcomes usually result from the failure to apply the scientific advice being given based on single-species approaches. There is no inherent reason why the scientific advice for

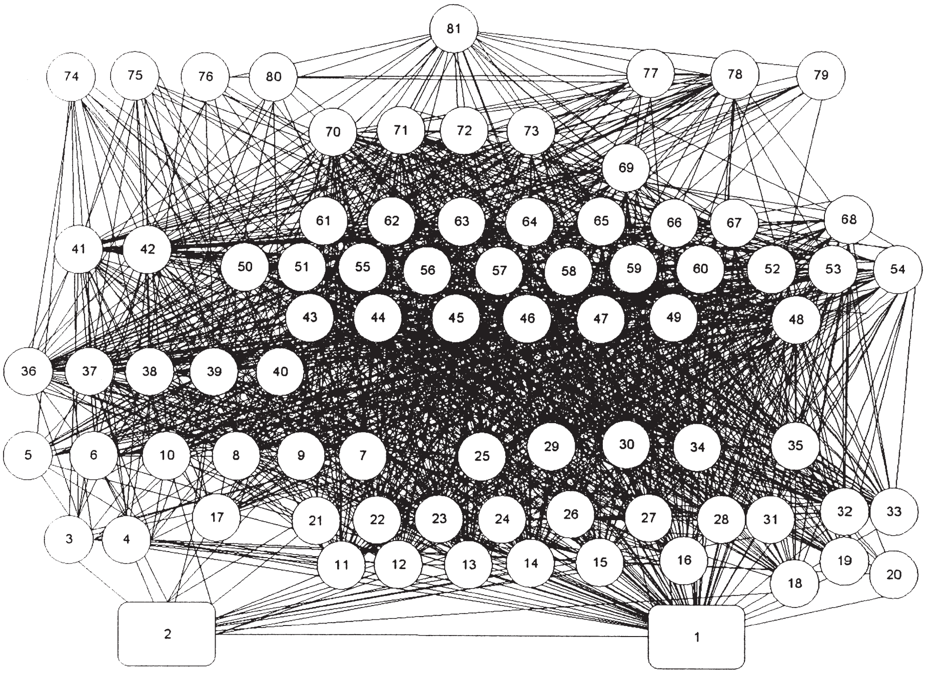

Fig. 21.1. Species and links for a northwest Atlantic food web. The boxes are (1) detritus and (2) phytoplankton, and the circles represent higher trophic levels, either species or species groups, with 81 being humans. The left side of the web generally contains pelagic organisms, and the right and middle represents more benthic or demersal organisms. Reproduced from Link (1999).

sustainable management of single-species fisheries should in general be inconsistent with an ecosystem approach (although it might be in specific situations).

Thus, the NRC (1999) Committee on Ecosystem Management for Sustainable Marine Fisheries emphasized conservative single-species management as a key element of an ecosystem approach. It stated that

> . . . a significant overall reduction in fishing mortality is the most comprehensive and immediate ecosystem-based approach to rebuilding and sustaining fisheries and marine ecosystems.

In a similar vein, Hall's (1999) book on *The Effects of Fishing on Marine Ecosystems and Communities* emphasized this point with a section in the concluding remarks of the book entitled 'Reduce effort, reduce effort, reduce effort'. The Commission on Fisheries Resources of the World Humanity Action Trust (WHAT, 2000) makes the same point. It states that applying

> . . . less complex single-species models and reversing the tendency towards risk-prone decisions could make a substantial difference to effectiveness of the management effort. This is likely to be much more cost effective than the information-hungry, and therefore costly, ecosystem models that would be needed.

All of the groups cited above (the NRC Committee, WHAT and the Ecosystems Principles Advisory Panel) highlighted the problem caused by the tradition of open access to fisheries (i.e. where anyone can fish) and risk-prone fisheries management decisions (i.e. to err toward overfishing rather than conservation) in the face of uncertainty. The problem is illustrated in Fig. 21.2 from Sissenwine and Rosenberg (1993). It is the reason that rights-based allocation of access to fisheries and the precautionary approach are important elements of responsible fisheries (see the discussion below).

There are numerous other published statements of goals, principles, indicators

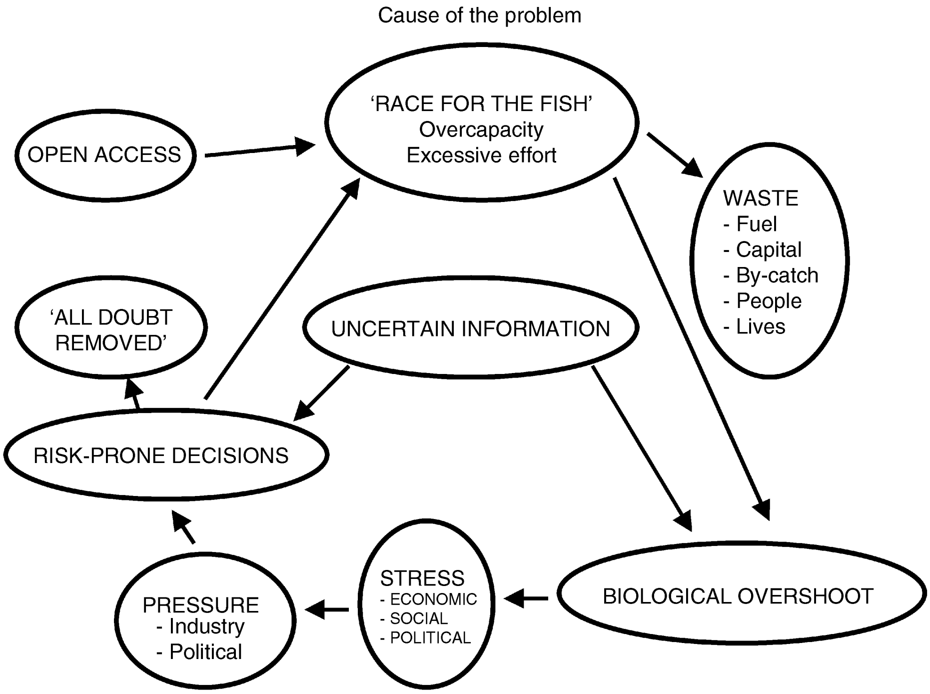

Fig. 21.2. The causes and consequences of the 'race for the fish'. Re-drawn from Sissenwine and Rosenberg (1993).

and approaches for an ecosystem approach to fisheries management (e.g. Gislason *et al.*, 2000; Murawski, 2000; Pajak, 2000; Pitcher, 2000; Mace, 2001). Based on the scientific literature, and our own experiences, we believe an ecosystem approach to a responsible fisheries management system should include:

- *Goals and constraints* that characterize the desired state of a fishery, and undesirable changes in ecosystems (including the human dimension) that fisheries should not be allowed to cause.
- *Conservation of fisheries resources* that is precautionary, takes account of species interactions, and is adaptive.
- *Allocation of fishing rights* in a manner that provides incentives for conservation and efficient use of living resources.
- *Decision making* that is participatory and transparent.
- *Ecosystem protection* for habitat, and for species vulnerable to extinction or deemed by society to warrant special protection.
- *Management support* that provides scientific information, enforcement and performance evaluation.

The matrix in Table 21.1 indicates the relationship between the above elements of a system for responsible fisheries management and the four criteria for responsible fisheries specified in the Introduction. Note that five of the six elements of the fisheries management system (i.e. other than ecosystem protection) are necessary for single-species fisheries management. However, they are implemented differently for an ecosystem approach. The similarity between single-species fisheries management and an ecosystem approach should not be a surprise. As noted above, more rigorous (usually more cautious) application of single-species methods is an important step toward an ecosystem approach, and realistically we can only move to an ecosystem approach

Table 21.1. Matrix showing the relationship between elements of a fisheries management system (rows) and criteria for responsible fisheries management (columns). The elements of fisheries management may all help to fulfil the criteria for responsible fisheries management, but only the most important relationships are indicated in the matrix.

	Sustainable	Human benefits	Fair	No unacceptable changes to ecosystems
Goals and constraints	X	X	X	X
Conservation of fisheries resources	X	X		X
Allocation of fishing rights	X	X	X	
Decision making			X	X
Ecosystem protection	X			X
Management support	X	X	X	X

incrementally. Next, we discuss each of the elements.

Goals and constraints

The purpose of fisheries management is to achieve societal goals. There are many ways to state goals, such as in terms of net economic benefits, food production, recreation or employment, or a combination. The goal may be to provide a livelihood for a specific segment of society, such as coastal communities, or to provide subsistence to people who lack other options. Some goals may mean forgoing a large proportion of the potential total economic benefits, but this is legitimate in the context of responsible fisheries that recognize the need for a fair distribution of benefits (assuming there is societal agreement on what is fair).

Goals are not useful to guide fisheries management unless they are accompanied by constraints that specify the 'price', in terms of ecosystem or social change, that is unacceptable. Some constraints are almost universally agreed, such as the premises that species should not be driven to extinction, and that ecosystems should not be changed irreversibly. Society may also agree on other constraints, such as the premise that marine mammals should be protected (as required by law in some countries, but not others), or that traditional participants in fisheries should not be displaced.

There is great flexibility in the goals and constraints for responsible fisheries since responsibility is subjective. However, goals and constraints must be stated clearly for the other components of the fisheries management system to be effective.

Conservation of fisheries resources

The direct effect of fisheries on fisheries resources is through fishing mortality, which can be expressed as the annual fraction of a population removed by fishing (the exploitation rate). There are many examples of fisheries removing more than half of the exploitable fish in a population annually (sometimes much more). With today's demand for fish, and modern technology for catching fish, responsible fisheries usually require measures to control fishing mortality. The main issues are: what should the fishing mortality rate be? and how should it be controlled?

Fishing mortality rates

Biological reference points are used by fisheries scientists to guide fisheries management in terms of the fishing mortality rate and the future size of fisheries resources that fisheries management measures are intended to achieve. There is a vast scientific literature on biological reference points (e.g. Mace, 1994) to achieve a high sustainable yield (such as the MSY), including recent work that suggests precautionary reference points and control rules to make the precautionary approach operational (e.g. Restrepo *et al*., 1998). The precautionary approach is a key element of the United Nations Agreement for Straddling Fish Stocks and Highly Migratory Fish Stocks (United Nations, 1996) and the FAO Code of Conduct for Responsible Fisheries (FAO, 1995a). FAO (1996) described the precautionary approach as the application of prudent foresight, taking account of the uncertainties in fisheries systems, and the need to take action with incomplete knowledge. A more complete description is given in Box 21.4.

Simply stated, the precautionary approach means that, when in doubt, err on the side of conservation. The bottom line from the scientific literature on fishing mortality rates and international policies on the precautionary approach is that: (i) the fishing mortality rate should be limited to the rate that could produce the MSY (i.e. F_{MSY}) if the resource population size is large enough; (ii) the target fishing mortality should be lower than the limit to take account of scientific uncertainty; and (iii) the target might be reduced further when the resource population size is smaller than the size required to produce the MSY. We refer to this approach as a precautionary fishing mortality rate strategy. At this point, our description of the strategy is only based on single-species considerations, not an ecosystem approach. However, as emphasized by Mace (2001), reducing fishing mortality rates below single-species F_{MSY} levels for most, if not all, harvested species would be a substantial first step towards satisfying many of the commonly stated ecosystem objectives, such as maintaining ecosystem integrity and biodiversity.

There is also a vast literature that addresses trophic (e.g. predator–prey) interactions between species (e.g. Daan and Sissenwine, 1991; Sissenwine and Daan, 1991; Link, 1999; Hollowed *et al.*, 2000). It is clear that trophic interactions have a great deal of influence on the dynamics of fisheries resources, but we usually lack predictive models that can be used quantitatively to adjust fishing mortality rates to take account of these interactions. Ecosystems may be so complex (for example, see Fig. 21.1), that it is unrealistic to expect models to be capable of generating realistic predictions. However, this is not an excuse to ignore species interactions.

We believe that an ecosystem approach for responsible fisheries management requires taking account of trophic interactions in a precautionary fishing mortality rate strategy. One way of taking account of interactions is to keep fishing mortality rates low so that perturbation of the trophic web is small.

Box 21.4. Description of the precautionary approach according to the technical consultations of the Food and Agriculture Organization (FAO, 1996).

The precautionary approach involves the application of prudent foresight. Taking account of the uncertainties in fisheries systems and the need to take action with incomplete knowledge, it requires, *inter alia*:

- consideration of the needs of future generations and avoidance of changes that are not potentially reversible;
- prior identification of undesirable outcomes and of measures that will avoid them or correct them promptly;
- that any necessary corrective measures are initiated without delay, and that they should achieve their purpose promptly, on a time scale not exceeding two or three decades;
- that where the likely impact of resource use is uncertain, priority should be given to conserving the productive capacity of the resource;
- that harvesting and processing capacity should be commensurate with estimated sustainable levels of resource, and that increases in capacity should be contained further when resource productivity is highly uncertain;
- all fishing activities must have prior management authorization and be subject to periodic review;
- an established legal and institutional framework for fishery management, within which management plans that implement the above points are instituted for each fishery; and
- appropriate placement of the burden of proof by adhering to the requirements above.

Pauly *et al*. (1998) highlight the problem of perturbing ecosystems by fishing down the trophic food webs. Given our current state of understanding of ecosystems, it seems prudent to avoid disproportionate impact on any trophic level.

In order to take account of trophic interactions, trophic information should be summarized, and used to identify the most important interactions. Which species have the greatest influence on other species through predation? Which species are the most important prey species? For important prey species, it may make sense to consider modifying the precautionary fishing mortality rate strategy so that a high prey species abundance is maintained. For important predators, it is less clear how to adjust the precautionary fishing mortality rate strategy. Predatory species play an important role in stabilizing ecosystems (Pace *et al*., 1999), but they may also reduce the production of species lower in the trophic web. Thus, the advice that no trophic level should be impacted disproportionately is probably appropriate for important predators.

After considering information on trophic interactions, it may be concluded that for some species the precautionary fishing mortality rate strategy should be adjusted, or the conclusion may be that given our current state of understanding, no changes are justified. We believe that either outcome may be justifiable, depending on the specific situation, so long as all of the fishing mortality rates are low, to ensure that the food web is not seriously perturbed (thus making the approach robust).

An ecosystem approach also needs to take into account environmental variability that affects the productivity of fisheries resources (Steele, 1996; Mantua *et al*., 1997). It is now known that there can be extended periods (decades or more) where environmental conditions either favour, or do not favour, production by certain fish populations. Favourable periods for some populations often will be unfavourable for others. Thus, a fishing mortality rate strategy that is precautionary during favourable periods may not be sustainable when the environment is unfavourable. Also, efforts to rebuild a population to the size that is required to produce the MSY with a favourable environment may be unrealistic when the environment is unfavourable. Thus, the precautionary fishing mortality rate strategy must be flexible so that management can adapt to changes in productivity of fisheries resources, even if the linkage to environmental change is unclear or unknown.

There is another aspect of the precautionary approach that needs to be reflected in responsible fisheries management. Some refer to it as a change in the burden of proof (Sissenwine, 1987; Dayton, 1998; Ecosystem Principles Advisory Panel, 1999). Holt and Talbot (1978) captured it in one of their principles, which called for resource assessments to precede resource use. Traditionally, fisheries have been permitted without restriction until there is evidence that they cause unacceptable impacts. A responsible approach to fisheries management would require all fishing activity to be authorized. An analysis of the risk of a fishery having an unacceptable impact should be conducted prior to authorization. This will usually require research, which could include a scientifically designed experimental fishery, prior to authorization of a full-scale fishery. The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) has adopted a protocol for collecting information in an experimental or exploratory mode, prior to authorizing a fishery.

The standard of evidence that a fishery will not cause an unacceptable impact should be commensurate with the severity of the risk of making a mistake. Making the standard too rigid (such as 'beyond any shadow of doubt') would virtually always prohibit human benefits from fishing, which would not constitute responsible fisheries management, according to our definition.

Control measures

Many types of control measures are available, such as setting a total allowable catch (TAC), limiting the amount of fishing effort (e.g. days of fishing), controlling the size of fish that are caught, applying time and area closures, and restrictions on fishing gear type. There are advantages and disadvantages of each method (some are discussed by Sissenwine and Kirkley, 1982). In general, the control measures do not matter with respect to the responsibleness of fisheries management, so long as there is adherence to the following criteria. They must:

- result in the precautionary fishing mortality rate strategy being fulfilled;
- not cause unnecessary or unacceptable harm to the ecosystem (such as allowing destructive fishing practices); and
- not cause an 'unfair' distribution of benefits.

There is one type of control measure that has been highlighted as particularly well suited to an ecosystem approach to responsible fishing. MPAs (Agardy, 1994; Bohnsack and Ault, 1996; Roberts, 1997) are a form of the time-area closures that have been used as fisheries control measures for decades. However, MPAs are usually thought of as permanent, year-round closures. Advocates point out that MPAs protect biodiversity, as well as the resource species that are the targets of fisheries. They may also provide some degree of robustness to uncertainty about fish populations and the effectiveness of other types of fisheries management control measures.

There are many examples of the application of MPAs in fisheries management, although the closures rarely have been labelled MPAs. Year-round closures of large areas on Georges Bank off the northeast coast of the USA (Fig. 21.3) have been an important part of fisheries management plans to rebuild once severely overfished groundfish populations, and the results are very promising (Murawski *et al*., 2000). However, these large closed areas or MPAs are only part of the control measures that have been necessary to prevent overfishing and begin rebuilding the depleted populations. Limits were also placed on the days per year that vessels could fish, such that the total fishing effort was cut in half. Lauck *et al*. (1998) and Hannesson (1998) showed that for MPAs to be relied on entirely as a management control measure, they would have to be unrealistically large (perhaps 70–80% of the total fishing grounds).

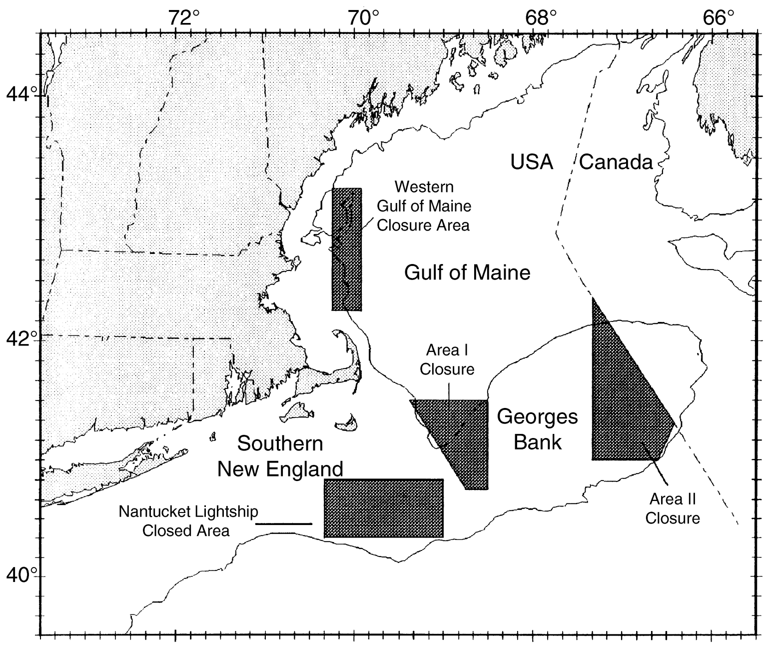

Fig. 21.3. Large closed areas on Georges Bank and surrounding areas off the northeast coast of the USA.

Allocation of fishing rights

One reason that MPAs may not be effective on their own is that many of today's fisheries are characterized by such high levels of overcapacity (in terms of inputs such as capital and labour) that area closures may simply result in displacement of fishing effort, not an overall reduction in fishing effort. In fact, overcapacity frequently has been highlighted as one of the key factors threatening the long-term viability of exploited fish stocks and the fisheries that depend upon them (e.g. Mace, 1997). If the overcapacity problem could be solved, overfishing would probably be a non-issue or, at worst, a spatially or temporally local issue. However, overcapacity has proved extremely difficult to control in the absence of systems that allocate fishing rights.

There are many reports (some of them are cited in the previous section of this chapter) that emphasize the importance of allocating fishing rights. WHAT (2000) gives a useful overview, which is the basis of the discussion that follows.

The amount of fish that a fishery can catch on a sustainable basis is shared by the participants in the fishery. The traditional manner in which their share is determined is by competition. Individual fishing boats (in small-scale fisheries it may be individual people without boats) compete to catch as large a share of the available fisheries resources as possible. This situation is often referred to as 'the race for the fish'. Total costs increase (due, for example, to people competing by buying more expensive boats and fishing gear) but, since the total amount of fish available to be caught does not increase, profits decline. This behaviour of spending more in the race is rational from the perspective of an individual, but it does not make sense for the fishery overall.

The race for the fish also encourages overfishing. Since the amount of catch that fisheries resources can sustain varies as a result of environmental fluctuations, eventually, a fishery that is marginal under most environmental conditions will face economic losses when the catch needs to be reduced (regardless of the cause – whether it was overfishing or natural environmental variability). The fishing industry usually resists regulations that decrease catch because this will increase their losses in the short term, even though it will be beneficial in the long term. From the industry's perspective, there will be no future in the fishery if they cannot pay their bills in the short term. Also, even if they remain in the fishery, they risk having to compete with even more fishing capacity in the future and therefore they may not benefit from cutting their catch now. When pressured by the fishing industry to give more consideration to short-term financial losses, rather than sustaining fisheries resources and long-term economic benefits, fisheries managers often yield to the pressure, particularly when faced with uncertain scientific information (i.e. perhaps a cut is not really necessary?). Making risk-prone decisions (relative to the condition of a fisheries resource) in the face of scientific uncertainty and pressure from the fishing industry becomes a vicious cycle that ultimately makes matters worse for the resource and the fishing industry (Fig. 21.2).

The solution to this problem is to assign rights to shares of the fishery. With rights, participants in the fishery have an incentive to use their right efficiently (i.e. to produce the greatest value at the lowest cost), and to conserve its value for the future.

Governance systems that assign rights to shares of a fishery can take many forms. The systems are characterized by the nature of the shares in the fishery, the types of entities that hold rights and rules about transferability of rights. Shares can be in the form of an amount of catch, units of fishing effort (e.g. days of fishing or numbers of traps), or an exclusive geographic area and time period where fishing is allowed. The sum of all of the shares must not result in overfishing. Shares that are specified as effort units or fishing areas and time periods where fishing is allowed are not as effective at eliminating the race for the fish as shares specified as an amount of catch, but they may have other advantages (e.g. greater acceptance by the fishing industry, and greater ease of enforcement). There may be additional rules, such as size limits, gear restrictions or closed areas, that apply to all shareholders in the fishery.

Rights may be assigned to individuals, corporations, communities or other groups of people. The type of entities assigned rights is also important in ending the race for the fish. In an ideal system, individuals should have no incentive to race. Corporations have internal governance rules such that they use their shares for the common good of the corporation (i.e. they use their shares as if they were an individual). Communities (or other groups of people) may be cohesive enough, or have sufficient internal governance mechanisms, to use their shares for the common good of the community, although this is not necessarily the case.

Options for the transferability of rights to shares in a fishery range from totally prohibiting rights to be transferred, to allowing transfers without restrictions. Allowing transferability tends to increase economic benefits, but it might also accelerate social changes that could be deemed undesirable.

One form of rights-based fisheries management that is increasing in popularity is known as individual transferable quota (ITQs). There is little doubt that ITQs effectively eliminate or alleviate the incentives for the race for the fish. They are now applied in several countries, including Iceland, New Zealand, and parts of the USA and Canada, Australia, Namibia and Chile. ITQs probably are not a practical option for most small-scale fisheries in developing countries, and also in many fisheries in developed countries, because of the complexity of multispecies fisheries, limitations of the scientific information needed to set catch quotas, difficulties with enforcement, and the large number of people dependent on fisheries. While ITQs have some theoretical advantages over other rights-based approaches, we believe that even imperfect rights-based approaches are better than the systems promoting the race for the fish that still exist in most fisheries throughout the world.

Decision making

Responsible fisheries management requires many decisions about goals and objectives, a precautionary fishing mortality rate strategy, a rights-based allocation method that is deemed to be fair, and avoidance of unacceptable changes in ecosystems. As noted above, many of these decisions are subjective. Therefore, stakeholders need to have the opportunity to participate in the decision-making process and they need to be able to understand the basis for decisions. Stakeholders include the fishing industries (there are usually several segments of the industry with different perspectives, including those involved with recreational fishing), environmentalists with concerns about the effects of fishing on ecosystems, and anyone who is interested in the distribution of benefits. There are many papers that highlight the importance of participatory fisheries management decision making (e.g. Pinkerton, 1992; Jentoft and McCay, 1995; Sen and Nielsen, 1996).

There are also many different types of arrangements for stakeholders to participate in decision making, ranging from having the opportunity to comment before final decisions are made, to having input into the initial stages of decision making where options are being formulated, to delegation of management authority to some stakeholders to make some of their own decisions. We believe that responsible fisheries management requires as much participation in decision making as is practical, recognizing that, ultimately, a management authority (e.g. government officials or a council of stakeholders) must be charged with weighing the options and making a decision.

Some authors (e.g. Jentoft, 1989; Pinkerton, 1989) advocate almost totally delegating decision-making authority to the local level of communities. This approach makes direct use of local knowledge, with management decisions that are made locally being more likely to be accepted (and adhered to) than rules imposed from a distant (impersonal) decision-making authority. However, there is an inherent limit to the type of decision-making authority that can be delegated to communities, particularly from an ecosystem perspective.

Ecosystems and fisheries resource populations usually cover large geographic areas. Conservation measures and ecosystem protection needs to be effective over the entire range of resource populations and the area of ecosystems. They usually are impacted by the activities of many local communities. Therefore, the authority delegated locally must be constrained by management measures and ecosystem protection that applies over entire ecosystems. Local decision-making authority is likely to be limited to community decisions about implementation of higher level decisions. Communities may also be allocated rights to shares of a fishery, which they can then manage.

One purpose of participatory and transparent decision making is to garner the broadest possible support for decisions. However, there will usually be some participants in the process who are unhappy with the outcome. Responsible fisheries management requires that even those who dislike decisions are nevertheless bound by them.

Unfortunately, there are situations where unhappy participants gather the political strength to over-rule the duly constituted decision-making process, often with disastrous consequences. The USA National Research Council (NRC, 1997) concluded that this phenomenon, which it referred to as an 'end run', was a cause of the collapse of the New England groundfish fisheries. More recently, the 'end run' has taken another form. It has become common in the USA for participants in the fisheries management decision-making process to seek to overturn decisions using litigation, sometimes over trivial matters or legal technicalities, in our opinion (as non-lawyers). At present, the US National Marine Fisheries Service is coping with more than 100 legal actions attempting to overturn fisheries management decisions. In almost all cases, the litigating parties actively participated in the debates leading up to the decision, but they disagreed with the outcome.

Ecosystem protection

This element of the fisheries management system goes beyond the conservation measures that are applied to conserve the fisheries resource populations that are the targets of fishing. Fisheries also depend on habitat. Habitat is the place where fish live. Its physical, chemical and biological character determines how favourable it is for production. From a fisheries perspective, our immediate concern is the habitat of the fisheries resources. There are also other aspects of ecosystems that society wants to protect from unacceptable effects of fishing; in particular, species of special concern that are not targets of fishing. We discuss protection of habitat and species of special concern below.

Protection of habitat

Fish may occupy habitat as an option (i.e. it is suitable for them, but they can be productive in other habitats) or because it is essential for them to be productive. We refer to the latter as essential fish habitat (which is also a term used in the USA Magnuson–Stevens Fishery Conservation and Management Act). It is rare that we know definitively which habitat is optional and which is essential, but we think there are some common-sense approaches to identifying the habitat that is most likely to be essential.

In some cases, there is research to demonstrate preference for a specific type of habitat with a reasonable scientific explanation for why that habitat is preferred. For example, the coarse bottom area with high vertical relief on the northern edge of Georges Bank has been identified as preferred habitat for juvenile cod, because it provides protection from predators. There are also situations where a particular life stage of a species is known to concentrate in a particular type of habitat that is uncommon compared with other types of habitats. We think information like this (i.e. a scientific rationale for why one type of habitat is likely to be more important than another, or empirical evidence that a particular type of relatively uncommon habitat is heavily used by a species) is a useful basis for identifying the places and habitat types that are most likely to be essential. An important part of an ecosystem approach to responsible fisheries management is to identify essential fish habitat so that it can be protected from threats.

There are many potential threats to habitat, including fishing (Hall, 1999 provides a comprehensive overview of the topic; the USA National Research Council currently is reviewing the topic and will issue its report soon). Mobile bottom-fishing gear clearly impacts some habitat types. Particular habitat types may be more vulnerable to the effects of fishing than others. Coral reef habitat is particularly fragile. Certain habitat changes may not matter to most species (the suitability of the habitat may not be changed), but it seems likely that other changes caused by fishing will be harmful to many species. Therefore, we think that responsible fisheries management requires that essential fish habitat be protected from fishing activity that has the potential to make the habitat less suitable. This may mean changing the fishing activity so it is more benign, or it may mean prohibiting the activity from areas identified as essential fish habitat.

There are many other threats to habitat. Boesch *et al*. (2001) give an overview of the problem of marine pollution in the USA. They identify toxins, bio-stimulants, oil, radioactive isotopes, sediments (including bottom alterations by dredging, and sand and gravel extraction), plastics and other debris, noise, human pathogens and alien species as forms of pollution. All of these can cause habitat degradation. Management of the human activities that are responsible for these forms of pollution is not within the scope of fisheries management, but is within the scope of governance of marine ecosystems overall. The fisheries management system can identify the threats for particular ecosystems, and participate as stakeholders in the decision-making processes for regulating the activities that threaten ecosystems from a fisheries perspective.

Protection of species of special concern

There are some species in marine ecosystems that society does not want to be harmed by fisheries. Here we are referring to species that fisheries do not intend to catch, but that may be taken incidentally (as by-catch). Fisheries may also harm them by adversely affecting their habitat or reducing the abundance of their prey. The rationale for protecting them varies. In some cases, they are vulnerable to extinction, which is almost universally accepted as a reason for protection (note that there are 180 parties to the Convention on Biological Diversity). Other species may be deemed by society (for whatever reason) to merit special protection (e.g. marine mammals in the USA and some other countries), regardless of their population status.

An ecosystem approach to responsible fisheries management requires information on the fishing activities that have the potential to harm species of special concern so that they can be protected. To protect them, there may need to be area–time restrictions on fishing, or prohibitions on certain types of fishing activities. The precautionary fishing mortality rate strategy may need to be adjusted to ensure that the prey of a species of special concern remains abundant (or that other predators are not too abundant). The abundance of the prey may only be important in the vicinity of the species of special concern, such as within the foraging range of land-based predators (e.g. seals and penguins in the Antarctic).

Management support

Fisheries management depends on scientific information. It is ineffective unless there is compliance with fisheries management rules (conservation measures, allocation rules and restrictions for ecosystem protection). Fisheries management needs to evaluate its own performance in order to be responsible.

Scientific information on which management depends needs to be:

- *relevant* by providing the type of information that is needed in a form that fisheries managers can use, and that stakeholders can understand;
- *responsive* by being timely;
- *respected* (i.e. credible), which means that it must be perceived to be unbiased, and based on science conducted according

to high scientific standards, including quality assurance; and

- *right*, which requires an investment in research and appropriate data, in addition to high scientific standards and quality assurance.

We discuss the governance of the scientific activity that is necessary to fulfil management needs later in this chapter. There are also aspects of scientific information that depend on the fishing industry, and these are discussed in a later section on their self-governance.

Compliance with fisheries management rules requires either rules that the fishing industry believes in, such that most of the industry willingly comply and they do not tolerate non-compliance by others in the industry; or enforcement capability and sufficiently severe penalties to force compliance. Obviously, the former is preferable. We also consider compliance and enforcement further in the section on self-governance by the fishing industry.

Performance evaluation is a valuable element of a fisheries management system because it is a way of learning from experience, so that management can be improved. FAO (1999) discusses indicators of sustainability for fisheries. Such indicators can serve as the basis for performance evaluation.

Institutional Arrangements for an Ecosystem Approach to Fisheries Management

Most countries have legislation that authorizes management of the fisheries within their jurisdiction. The Magnuson–Stevens Fishery Conservation and Management Act is the primary fisheries management legislation in the USA. It established eight regional Fishery Management Councils (FMCs) to prepare fishery management plans (FMPs) consistent with broad policy requirements. The Act is noteworthy because it captures two important elements of an ecosystem approach. It institutionalizes participatory fisheries management since the members of the FMCs are drawn from stakeholders in the fisheries (i.e. from commercial and recreational industries, state and federal government officials, environmental interests and other members of the public). The FMCs also have responsibility for all fisheries within geographic areas that are of reasonable size to define ecosystems, and to manage most fisheries as a whole.

The historical and legal basis of international fisheries management was reviewed by Juda (1996). The foundation of international fisheries management is the Convention of the United Nations Conference on the Law of the Sea (Law of the Sea Convention – LOSC), which has now been ratified or acceded to by 132 countries. An important provision of LOSC is recognition of national jurisdiction over the waters within 200 miles of their coasts (know as exclusive economic zones; EEZs). This makes most fisheries subject to national jurisdiction, although there are important fisheries that operate on the high seas, and there are many transboundary resources with geographic distributions in more than one EEZ, or straddling an EEZ and the high seas.

In 1995, the application of the LOSC to fisheries was strengthened by the United Nations Agreement on the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks. The Agreement proclaims the right of all countries to fish on the high seas, but it also establishes a general obligation to cooperate in the conservation and management of straddling fish stocks and highly migratory fish stocks. It highlights the role of Regional Fishery Management Organizations (RFMOs) as vehicles for cooperation in conservation and management. The Agreement also adopts the precautionary approach.

Another important international agreement for responsible fisheries management is the FAO Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas, adopted in 1993 (FAO, 1995b). The agreement specifies the responsibilities of countries for high seas fishing vessels flying that country's flag. The agreement makes it harder for fishing vessels to avoid complying with international fisheries management measures by 're-flagging' to a country that does not require its vessels to comply.

In addition to these binding legal agreements for international fisheries management, there are several non-binding agreements that establish expectations about responsible conduct in fisheries. The most significant of the non-binding agreements is the Code of Conduct for Responsible Fisheries (FAO, 1995a). The Code establishes 19 general principles (an abbreviated version from Edeson, 1999, is given in Box 21.5) which include prevention of overfishing and excess fishing capacity, conservation of ecosystems, application of the precautionary approach, transparency in decision making, and decisions based on the best scientific evidence available. Several non-binding International Plans of Action (IPOAs) have also been adopted by the FAO to promote implementation of the Code, including an IPOA for the Management of Fishing Capacity, and one to prevent illegal, unreported and unregulated (IUU) fishing. These non-binding agreements are referred to as 'soft governance', and Edeson (1999) concludes they are a useful instrument for achieving responsible governance of fisheries. An important aspect of the Code and the IPOAs is that they apply to fisheries within national jurisdictions, in addition to fisheries on the high seas.

There are numerous additional international treaties, agreements and other arrangements that are part of the governance framework for fisheries and ecosystems. Weiskel *et al*. (2000) catalogue and summarize 123 arrangements that involve the USA, which is only a fraction of the total number of arrangements that exist worldwide. Of

Box 21.5. Abbreviated version of the General Principles (Article 6) of the Code of Conduct for Responsible Fisheries (from Edeson, 1999).

- Conserve aquatic ecosystems, recognizing that the right to fish carries with it an obligation to act in a responsible manner.
- Promote the interests of food security, taking into account both present and future generations.
- Prevent overfishing and excess capacity.
- Base conservation and management decisions on the best scientific evidence available, taking into account traditional knowledge of the resources and their habitat.
- Apply the precautionary approach.
- Develop further selective and environmentally safe fishing gear, in order to maintain biodiversity, minimize waste, minimize catch of non-target species, etc.
- Maintain the nutritional value, quality and safety in fish and fish products.
- Protect and rehabilitate critical fisheries habitats.
- Ensure fisheries interests are accommodated in the multiple uses of the coastal zone and are integrated into coastal area management.
- Ensure compliance with and enforcement of conservation and management measures and establish effective mechanisms to monitor and control activities of fishing vessels and fishing support vessels.
- Exercise effective flag state control in order to ensure the proper application of the Code.
- Cooperate through subregional, regional and global fisheries management organizations.
- Ensure transparent and timely decision-making processes.
- Conduct fish trade in accordance with the principles, rights and obligations established in the World Trade Organization Agreement.
- Cooperate to prevent disputes, and resolve them in a timely, peaceful and cooperative manner, including entering into provisional arrangements.
- Promote awareness of responsible fisheries through education and training, as well as involving fisheries and fish farmers in the policy formulation and implementation process.
- Ensure that fish facilities and equipment are safe and healthy and that internationally agreed standards are met.
- Protect the rights of fishers and fish workers, especially those engaged in subsistence, small-scale and artisanal fisheries.
- Promote the diversification of income and diet through aquaculture.

particular importance for implementing an ecosystem approach to responsible governance are 34 organizations with responsibility for providing scientific information on fisheries and/or for managing fisheries (referred to as regional fisheries bodies, RFBs), and 13 Regional Seas Conventions (RSCs). These organizations have geographic responsibility as indicated in Fig. 21.4. The RSCs are broad framework agreements that could serve as an umbrella for an ecosystem approach to fisheries within their geographic jurisdictions but, in general, they have not been considered fisheries management organizations.

Since ecosystems are defined geographically, an ecosystem approach to responsible governance of fisheries requires management institutions or arrangements that are defined geographically. Accordingly, Sherman (1994, and in several other papers and books) and Sherman and Alexander (1993) proposed 49 large marine ecosystems (LMEs), covering coastal waters that account for most fisheries production, as logical units for research and governance. Juda (1998) and Juda and Hennessey (2001) discuss aspects of the governance of LMEs.

However the geographic areas used for management are labelled, they must be sufficiently large to encompass reasonably self-contained ecosystems and fisheries throughout their range. Following the proposal of the Ecosystem Principles Advisory Panel (1999), we believe that fisheries ecosystem plans (FEPs) are useful vehicles for designing and implementing an ecosystem approach to responsible fisheries management. Our vision of an FEP would address the elements of the fisheries management system described earlier in this chapter (thus, it would differ from the outline given by the Ecosystem Principles Advisory Panel).

Three key elements of an FEP that we want to emphasize are:

- *Decision-making processes*. We propose that a hierarchy of management entities should be formed from the ecosystem scale to more local scales, such as communities. The primary role of the local-scale entities should be to implement the FEPs locally. Local entities can also be useful to represent the views of people within their local jurisdiction during the development of the FEPs.
- *Ocean zoning*. An ecosystem approach should make use of several geographically defined management measures.

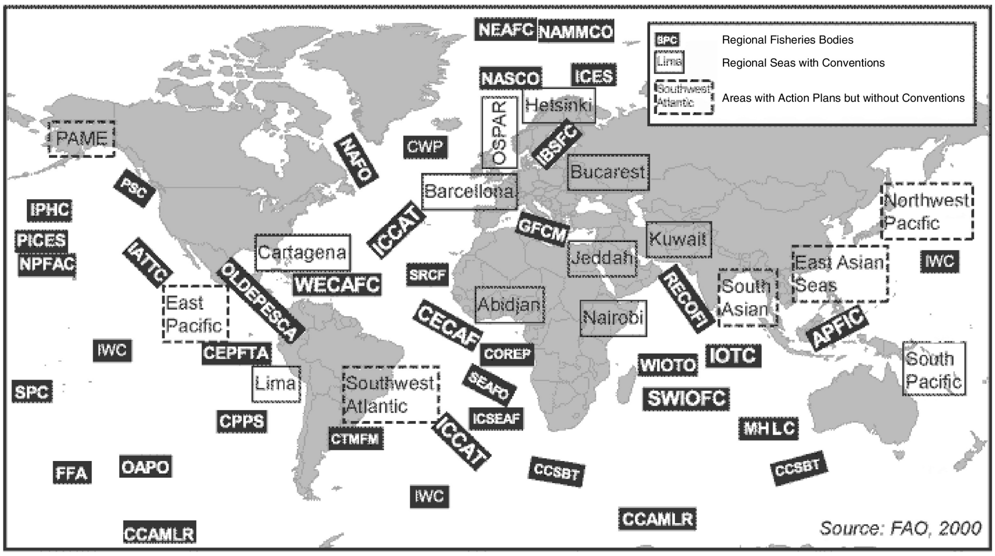

Fig. 21.4. Jurisdictions of Regional Marine Fisheries Bodies (see Appendix for definitions of acronyms). Reproduced from FAO (2001).

MPAs could be one part of an ocean zoning plan. There may also be geographically defined management measures to protect habitat or species of special concern, or to separate competing segments of the fishing industry (including recreationalists). Certain areas might be set aside for aquaculture or research. Ocean zoning should also take into account alternative, non-fisheries-related uses of the oceans, such as aquaculture, research, oil and gas exploration, ocean mining, dredging, ocean dumping, energy generation, ecotourism, marine transportation and marine defence.

- *Authorized fishing activities*. The plan should state specifically what type of fishing activities are allowed, and the protocols (e.g. data collection requirements, qualifying criteria and application procedures) for getting a new type of fishing activity authorized.

The geographic areas covered by FEPs may be embedded within even larger areas (i.e. they may be part of an even larger hierarchy). Such an arrangement generally will be useful for dealing with interactions between ecosystems (which are never entirely closed). However, it will also mean that FEPs must adhere to policies established higher-up in the hierarchy, which will generally be the case. In the USA, FEPs developed by Fishery Management Councils will have to adhere to the National Standards of the Magnuson–Stevens Fishery Conservation and Management Act, and international FEPs will have to adhere to LOSC and other international agreements, such as the Convention on Biological Diversity (CBD).

Gislason *et al*. (2000) considered ocean management areas (OMAs) as potentially useful management units. They also proposed a hierarchical approach. We interpret the concept of OMAs as broader than FEPs. The former addresses the management of all human activities that affect ecosystems within the area of an OMA. FEPs apply only to the management of fisheries, although they should describe threats from other human activities and how fisheries stakeholders ought to try to influence management of these other activities.

Ideally, there should be integrated management of all human activities that affect ecosystems for entire OMAs. This will be hard to achieve since the responsible government agencies and legal authority for different activities (e.g. fishing, oil and gas exploration, and dredging) are almost always independent. Nevertheless, all entities responsible for managing the activities that affect an OMA should make arrangements to plan and coordinate their management together, in the form of an OMA ecosystem plan (OMAEP). Even if the plans are non-binding, they could be a useful form of soft governance. This would be consistent with the ecosystem protection element of an FEP, which deals with threats from human activities other than fishing.

Governance of the Scientific Community

It is the responsibility of the scientific community to govern itself so that it produces scientific information that is relevant, responsive, respected and right (we refer to these characteristics as the 'four Rs'). What is needed is a multifaceted approach that includes scientific institutions that are designed to: (i) collect the scientific data that underpin fisheries management, especially long time series monitoring fisheries resources and ecosystems and the performance of fisheries; (ii) conduct assessments and provide scientific advice tailored to the needs of management; and (iii) strategically invest in research to improve (i) and (ii). All three elements are critically important. Today's fisheries management advice depends on time series of scientific data that were begun years or decades ago. Progress toward a more comprehensive ecosystem approach in the future depends on strategic research investments today, in order to advance understanding of trophic interactions, fish habitat and other relevant concerns. Assessments tailored to the needs of managers are required to be relevant and responsive.

We believe that responsible governance of science requires 'firewalls' between the funds for monitoring, for strategic research and for assessments, so that pressure to do more of one activity (usually assessments) does not jeopardize the others. However, we do not believe in isolating the scientists involved in these three activities. To do so would mean that: (i) the scientists conducting strategic research would lose touch with what is needed to be relevant; (ii) the scientists who conduct assessments would be less likely to have the cutting-edge scientific skills required for research; and (iii) neither group of scientists would appreciate the strengths and weaknesses of the monitoring data they use, nor would the scientists collecting the data understand the requirements for the data to be useful. Therefore, we believe that governance of science for responsible fisheries requires scientific institutions that are to perform all three elements. We liken these scientific institutions to combined teaching–research hospitals that conduct research, maintain health care infrastructure and treat patients.

One of the most serious issues facing the scientific community, and governance of fisheries, is controversies over assessments and scientific advice. These controversies should come as no surprise. Thompson (1919) expressed the problem well when he said 'proof that seeks to modify the way of commerce and sport must be overwhelming'. More recent calls for a precautionary approach shift the burden of proof, but they do not eliminate the tendency for those who disagree with management decisions to challenge scientific advice. In fact, the tendency for today's managers to make tough decisions in the face of uncertain scientific information may intensify some of the controversies.

Today, it is routine for scientific advice on fisheries management to be challenged (by environmentalists, the commercial fishing industry, recreational anglers and subgroups of any of these). In some cases, these controversies have led to accusations about the objectivity of scientific advice, as exemplified when Hutchings *et al.* (1997) asked the question 'Is scientific enquiry incompatible with government information control?' Sissenwine *et al.* (1998) described similar challenges to the objectivity of scientific advice for management of western Atlantic bluefin tuna.

We believe that a three-pronged strategy is necessary to deal with the all too common lack of respect for scientific advice. Our strategy calls for: (i) separating scientific institutions from management; (ii) collaborative research with the fishing industry; and (iii) transparent quality assurance of scientific advice. Each element of this strategy is discussed below. We also warn about a looming crisis regarding controversies over scientific advice.

Separating scientific institutions from management

The rationale for this element of the strategy is that it is common for opponents of fisheries management decisions to call for 'independent' science. The opponents are implying that managers have a management agenda with which they disagree, and that the managers are influencing the scientific advice to get their way. In our experience, these perceptions are not valid, but separating scientific institutions from management will help to eliminate them as a basis for undermining fisheries management decisions.

There is usually some degree of both integration and separation between scientific institutions and management. At some organizational level, they are integrated because they are part of the same government or depend on funds that the government controls. At a lower organizational level, they are independent, because scientists are usually supervised by other scientists, not managers. In order for scientific advice to be more credible, we envisage that scientific institutions should be separate from management at least at the organizational level where management decisions initially are made (usually they will require approval at a higher level).

Of course, separating scientific institutions from the managers could make the scientific institutions less responsive to management needs. To avoid this problem, managers will need to influence scientific priorities through budget and funding mechanisms. Budget control clearly influences priorities, but it is less likely to lead to the perception of an influence over results (i.e. the advice) than from supervisory control. Budget control, rather than supervisory control, is consistent with the trend toward quasi-independent businesses or privatization of scientific institutions, such as that which has occurred in some countries (e.g. New Zealand, Australia, the UK and Spain). However, care must be taken not to allow this trend to go so far that it creates excessive competition between organizations bidding on contracts to provide scientific advice, to the extent that cooperation and communication are inhibited. Also, in many circumstances (e.g. small countries), it is not economical for there to be more than one organization large enough (e.g. with a research vessel) to serve as the backbone for providing scientific advice. Thus, there may be an important advantage to having a 'preferred provider' for scientific advice.

Collaborative research with the fishing industry

Lack of respect for scientific advice often reflects a lack of understanding of scientific methods by the fishing industry, and the fishing industry's belief that it has useful knowledge that is ignored by scientists. Collaborative research between scientists and the fishing industry can help to address both problems. To realize its full potential, we believe that the collaboration must:

- be collaborative throughout (i.e. with respect to defining objectives, planning studies, implementing studies and analysis);
- foster open-mindedness and a willingness to compromise between scientists and the fishing industry (i.e. participants should not expect to do business as usual);
- ensure that scientists and the fishing industry are both willing to accept that the other may be 'right', e.g. scientists may have to accept that there may really be more fish than they had estimated;
- ensure that the fishing industry has realistic expectations, e.g. it must understand that an assessment that depends on a time series of relative abundance data cannot be replaced by a single collaborative survey; and
- acknowledge that there must be sufficient financial and personnel resources to conduct collaborative research, in addition to ongoing research conducted by scientists, not as a substitute. Much necessary research cannot be done within a collaborative mode.

Many collaborative research projects have been undertaken recently. The approach has become common off the northeastern USA and in Atlantic Canada. The New Zealand experience with collaborative research is examined by Harte (2001).

Transparent quality assurance of scientific advice

There are three primary approaches to improving the quality and credibility of scientific information. They are: (i) certification of scientists; (ii) use of standard practices; and (iii) peer review. Licensing of medical doctors and engineers are examples of certification. There are many examples of using standard practices, such as material standards for building a bridge, procedures for calibrating scientific instruments and criteria for prescribing diagnostic medical tests. Certification and standard practices usually are applied when scientific methods are applied routinely (i.e. the operational end product of research). In situations where research has not 'matured' to the stage where there is a consensus on criteria for certification and/or standard practices, peer review is the most common option for quality assurance. In some cases where the scientific problem is difficult or the cost of making a mistake is high, peer review is applied even when practitioners are certified and there are standard practices, such as when a 'second opinion' is sought for a difficult medical diagnosis of a potentially grave illness.

Peer review generally is expensive and time consuming relative to the other two approaches. However, it is the primary quality assurance mechanism used to govern the preparation of scientific advice for fisheries management.

Peer review is a process where the work of scientists is reviewed by other scientists, who are themselves qualified to have performed the work (i.e. they are peers). The most well known form of peer review is the process used by scientific journals to determine whether papers merit publication. However, this approach is not practical for most scientific advice for fisheries management. It also lacks the transparency that we think is needed to increase the credibility of scientific advice. However, there is a high price to be paid for transparency, as is discussed below.

There are two common forms of peer review of scientific advice for fisheries management. We refer to them as either integrated or sequential. Integrated peer review is carried out while the scientific work is being conducted. The peer reviewers work with the scientists who take the lead in conducting a scientific study. The reviewers have input into numerous decisions that are made as intermediate steps in conducting the study. In general, peer reviewers are not formally identified, but they are the individuals whose job description does not include the subject of the scientific study being conducted. Sequential peer review is conducted by peer reviewers after the initial assessment and scientific advice has been prepared. Its primary purpose is to either accept or reject the assessment and scientific advice. Often the sequential peer review is able to refine the initial assessment and scientific advice. The sequential reviewers or the review panel adopt the assessment and scientific advice as their own (thus taking responsibility for it). This is clearly a different role from the sequential peer reviews conducted for journal publications.

There are advantages and disadvantages of integrated and sequential peer reviews. Advantages of integrated peer reviews are that they are timely, the reviewers gain an in-depth understanding of the scientific study under consideration and their expertise can be used effectively to improve the quality of the scientific work (rather than criticizing it after it has been completed). The disadvantage is that peer reviewers may be overwhelmed or dominated by the scientists primarily responsible for the scientific work. The advantage of sequential peer review is that the reviewers have greater independence. The disadvantages are that this type of peer review takes extra time and often it is impractical or imprudent for peer reviewers to correct work that they think is unsound (e.g. when the peer reviewers lack sufficient detailed knowledge). We believe that both forms of peer review should be used.

Both integrated and sequential peer reviews are usually conducted in a relatively transparent manner (certainly more transparently than journal reviews). The identity of participants is almost always known. Shortcomings of the scientific work that is under review are usually made public (whereas the comments of journal reviewers are not), and it is common for there to be observers of the peer review process.

The advantage of transparency is that it enhances stakeholders' understanding of the scientific advice. It should also increase confidence in the integrity of the process (i.e. that participants are acting objectively). The disadvantages are that: (i) participants in the process may be reluctant to be forthcoming with scientific opinions; (ii) points of discussion during meetings may be misinterpreted or misused to serve agendas of interest groups; and (iii) meetings might become excessively long or unruly.

Another aspect of peer review that affects the credibility of scientific advice is the appearance of a potential conflict of interest. Peer reviewers should be unbiased (i.e. no motives for being for or against the scientists and the scientific activities and products they are reviewing).

A perfectly unbiased review is difficult to achieve, but there are obvious factors that increase at least the appearance, if not the reality, of bias. These factors are: (i) the association between the reviewers and the scientists being reviewed (e.g. are they colleagues, collaborators or part of the same organization?); (ii) financial considerations (e.g. will the outcome of the review influence the reviewers' financial opportunities in the future?); (iii) the implication to the prestige of the reviewer of the scientific work being reviewed (e.g. will acceptance of the work under review cast doubt on the past work of the reviewer?); and (iv) control over reviewers (e.g. can their organizational superiors influence their review so that the outcome is more consistent with organizational objectives or policy agendas?). The more controversial the issue, the more important it is that there be no appearance of potential conflict of interest.

A looming crisis

The scientists who provide advice on fisheries management must have an unusual combination of scientific skills, the desire to apply scientific results to policy decisions and willingness to give advice in the face of a high degree of uncertainty (to 'go out on a limb'). The willingness to give scientific advice, in the face of high uncertainty, is an essential element of the precautionary approach, which is now recognized as necessary for an ecosystem approach to responsible fisheries management.

However, because scientific advice increasingly is being subjected to criticism (sometimes non-constructive or even personal), litigation and externally mandated peer reviews that inevitably highlight shortcomings, even when the advice is generally sound, there are strong disincentives to being responsive to fisheries management needs. Of course, scientists should expect their work to be reviewed critically but, for most scientists, this is done in private with non-fatal flaws quickly forgotten (e.g. when a manuscript is submitted for publication), rather than in a public forum where the results of reviews sometimes attract so much attention that they are reported in the news media. Those opposed to fisheries management based on the scientific advice often focus on minor shortcomings, or areas that could be improved, while ignoring the fact that there often is overall endorsement of the scientific advice.

At what point will the personal aggravation and professional risk of becoming the focal point of controversial fisheries management decisions lead scientists to play it safe by not giving advice in the face of uncertainty? If this happens, will managers close down fisheries in the face of uncertainty (as some will argue is required by the precautionary approach), or will they presume that fisheries management is not needed (as some others will argue), since there is no scientific advice indicating there is a problem? Either extreme outcome is a looming crisis that might eventuate if current trends continue. Clearly, it is preferable to put in place institutions and processes that provide scientific advice that is responsive, respected and right.

Self-governance by the Fishing Industry

The fishing industry increasingly recognizes that it must govern itself in an appropriate manner for there to be responsible fisheries. Fishing industry organizations in Canada have initiated preparation of their own code of conduct for responsible fishing. In the USA, the New England Fishery Management Council established a Committee on Responsible Fishing. We want to highlight several important roles that the fishing industry can play in an ecosystem approach to governance for responsible fisheries. We hope the fishing industry will do the following.

- Accept responsibility for providing fisheries information (including yield, effort, biological and economic data). This may mean that the fishing industry must absorb some cost (such as paying for shoreside weighouts, at-sea observers or some interference with their normal way of doing business).
- Embrace collaborative research along the lines described in the previous section of this chapter. The industry may also need to absorb some of the costs for collaborative research.
- Be informed participants in the fisheries management decision process, and accept the outcome (i.e. no 'end runs').
- Comply with fisheries management regulations and not tolerate violations by others. In order to make regulations

enforceable, the fishing industry should accept that there may be some interference with its normal way of doing business.

- Avoid waste and destructive fishing practices.
- Be respectful of other stakeholders.
- Develop training programmes or apprenticeships to help instil a responsible fishing ethic.

Politicians and the Public: Behaviour that is Conducive to Responsible Fisheries

The behaviour of the public, including environmentalists and politicians, can be either conducive to, or a barrier against, responsible fisheries. We hope that:

- the public will consist of informed participants in the fisheries management decision process, and accept the outcome (i.e. no 'end runs');
- the public will be respectful of other stakeholders;
- politicians will produce legislation that is clear in intent and achievable within realistic funding levels – otherwise, the legislation invites costly litigation; and
- politicians will not condone 'end runs'.

Unfinished Business: Future Challenges

We realize that much of our description of governance for an ecosystem approach for responsible fisheries is not new. For example, there has been considerable recent progress in applying the precautionary approach, defining essential fish habitat, protecting species of special concern, making fisheries management more participatory and transparent, conducting collaborative research and applying peer review to scientific advice. In some places, managers are proud of the progress they have made towards an ecosystem approach (e.g. Witherell *et al.*, 2000, for Alaska).

However, the progress that has been made should not be taken as a signal that enough has been done. We want to use this concluding section of our chapter to highlight the governance challenges (in some cases daunting) that we think need more attention.

Rights-based allocation of shares in fisheries

We think this is a critically important challenge facing fisheries managers. The need for rights-based allocation to resolve entrenched problems related to harvesting overcapacity has been well known for decades, yet rights are either non-existent or ineffective for most of the world's fisheries. We believe that the failure to apply rights-based allocation approaches is a symptom of not paying enough attention to the transition costs (economic, social and political) in assigning rights (WHAT, 2000). Ironically, traditional fishing rights once existed in many fisheries throughout the world, but these have been eroded over time. While these traditional rights are unlikely to be sufficient today, they may serve as a useful starting point to re-establish rights, especially in developing countries where millions of people who are critically dependent on small-scale fisheries are in jeopardy.

Rights-based allocation or freedom of the high seas?

The need for rights-based allocation applies to all fisheries, yet international law treats fisheries on the high seas as a global commons with access open to all. Miles (1998) points out the dilemma and concludes that '. . . the days of high seas fishing as a freedom of the high seas are numbered . . .'

The general approach to dealing with the dilemma is to form regional fisheries organizations, and to expect all countries fishing within the region to join. However, once the initial members of the regional fisheries organizations have allocated shares in the fishery among themselves, they often are reluctant to give up a 'slice of the pie' to new members. Thus, prospective new members can either join with prospects of only getting a small share, if any, or they can continue to fish without joining, claiming that they are exercising their high seas freedom. At least two regional fisheries management organizations currently are trying to cope with this dilemma: the International Commission for Conservation of Atlantic Tunas and the Northwest Atlantic Fisheries Organization.

Clearly, creative solutions are needed. It seems to us that either members of fisheries management organizations must be willing to give up a reasonable share of their allocations, or it will be necessary to support Miles' prophecy.

Dispute resolution

Even if the dilemma above is solved, there is another threat to the effectiveness of regional fisheries management organizations. In most (maybe all) cases, members that dislike management decisions are not bound by them if they 'object'. This is a form of the 'end run'. Fortunately, objections are rare, but could become more common as tensions rise with potentially more members competing for a 'slice of the pie'. We think that responsible fisheries management requires a practical dispute resolution mechanism to pick the winner and loser in a dispute. Leaving the dispute unresolved usually means the fisheries resource loses.

Management of deep-sea fisheries on the high seas

These fisheries are increasing, particularly on mid-ocean ridges and on seamounts. However, little is known about the fisheries and the ecosystems that contain them, except that they are almost certainly fragile (Koslow *et al*., 2000). We believe that a responsible approach to fisheries management requires that all fishing activity be authorized and that an analysis of the risk of a fishery having an unacceptable impact should be conducted prior to authorization. This is not the case for most of the deep-sea fisheries that are developing on the high seas. Many of these fisheries are not subject to any existing fisheries management authority, except for the general provisions of LOSC. In general, they are not straddling or highly migratory fish stocks. We think the international community needs to address this apparent gap in the current international fisheries management system, perhaps by developing an international instrument capable of designating deepwater areas as 'marine protected areas'.

Develop mechanisms for coordinating alternative and potentially conflicting uses of ocean areas

As mentioned previously, there are many alternative uses of the ocean, including harvesting marine species for food, for reduction products, for the aquarium trade, for medicinal purposes and other uses; aquaculture, research, oil and gas exploration, ocean mining, dredging, ocean dumping, energy generation, ecotourism, marine transportation and marine defence. It is difficult to integrate the management of all such activities because the government agencies and legal authorities regulating these activities are usually independent of one another. Recently, there have been some initiatives undertaken at the national level. For example, in 1998, the Government of Australia announced a National Oceans Policy that provides the goals, principles and planning arrangements for integrated ocean management to be implemented through regional management plans requiring institutional coordination. Canada's Oceans Act of 1997 extends Canada's jurisdiction over the oceans to the full extent permitted under international law, and sets up a governance structure based on the principles of integrated management, sustainable development, precautionary approaches, collaboration and ecosystem-based approaches. In both countries, subsequent action so far has been limited to the planning stages for a small number of pilot projects. In the USA, the Oceans Act of 2000 set up a special commission to undertake a thorough review of USA ocean and coastal activities and develop a national ocean policy. While it is essential that efforts such as these continue and expand at the national level, the international community should also discuss the need for an international instrument to coordinate multiple uses of the high seas.

Create a new profession of practitioners giving scientific advice on fisheries and ecosystems

Providing scientific advice requires specialized knowledge of population dynamics, quantitative methods (i.e. mathematics and statistics), fisheries management systems and fishing practices. It also requires communication skills and the experience to work with people from diverse backgrounds (e.g. the commercial and recreational fishing industries, managers, politicians, news media and other scientists). Yet, the users of the advice (and those affected by it; e.g. the fishing industry) have little basis for judging the qualifications of the scientists who provide advice. Unnecessary controversy and confusion sometimes result from a naive or misguided remark by a seemingly well qualified scientist (in terms of academic training and a prestigious position) who, in reality, lacks the skills and experience to advise on fisheries management. The situation is analogous to that of an eminent professor of zoology second guessing a recommended medical procedure.

Over the last few decades, scientists of many disciplines (e.g. ecology, analytical chemistry, oceanography and economics) increasingly have gained experience providing scientific advice on fisheries management and ecosystem approaches. There are standard practices for some of this work (such as stock assessments), although they are not formally labelled as such. For many types of advice, the scientists giving the advice (again stock assessments scientists are a good example) generally can describe the scientific skills and professional experiences that they believe are necessary to be qualified to give advice. Arguably, a new profession of scientific advisors on marine ecosystems is emerging as an operational discipline, perhaps mature enough to use certification and standard practices to improve quality and credibility (as well as to elevate the prestige of the profession). We believe it is time for the scientific community that advises on fisheries and marine ecosystems to face up to the governance challenge of creating a new profession of certified practitioners to provide such advice.

References

Agardy, M.T. (1994) Advances in marine conservation: the role of protected areas. *Trends in Ecology and Evolution* 9(7), 267–270.

Boesch, D.F., Burroughs, R.H., Baker, J.E., Mason, R.P.M., Rowe, C.L. and Siefert, R.L. (2001) *Marine Pollution in the United States*. Pew Oceans Commission, Arlington, Virginia.

Bohnsack, J.A. and Ault, J.S. (1996) Management strategies to conserve marine biodiversity. *Oceanography* 9, 73–82.

Daan, N. and Sissenwine, M.P. (eds) (1991) Multispecies models relevant to management of living resources. *ICES Marine Science Symposium* 193.

Dayton, P.K. (1998) Reversal of the burden of proof in fisheries management. *Science* 279, 821–822.

Ecosystem Principles Advisory Panel (1999) *Ecosystem-based Fishery Management*. USA Department of Commerce, Washington, DC.

Edeson, W. (1999) Closing the gap: the role of 'soft' international instruments to control fishing. *Australian Year Book of International Law* 20, 83–104.

FAO (1995a) *Code of Conduct for Responsible Fisheries*. FAO, Rome.

FAO (1995b) *Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas*. FAO, Rome.

FAO (1996) *Precautionary Approach to Capture Fisheries and Species Introductions*. Elaborated by the Technical Consultation on the Precautionary Approach to Capture Fisheries (Including Species Introductions). Lysekil, Sweden, 6–13 June 1995. Published as FAO Technical Guidelines for Responsible Fisheries No. 2. FAO, Rome.

FAO (1999) *Indicators for Sustainable Development of Marine Capture Fisheries*. FAO, Rome.

FAO (2001) *Ecosystem-based Fisheries Management: Opportunities and Challenges for Co-ordination Between Marine Regional Fisheries Bodies and Regional Seas Conventions*. RFB/II/2001/7. FAO, Rome.

Gislason, H., Sinclair, M., Sainsbury, K. and O'Boyle, R. (2000) Symposium overview: incorporating ecosystem objectives within fisheries management. *ICES Journal of Marine Science* 57, 468–475.

Hall, S.J. (1999) *The Effects of Fisheries on Ecosystems and Communities*. Blackwell Science, Oxford.

Harte, M. (2001) Opportunities and barriers for industry-led fisheries research. *Marine Policy* 25, 159–167.

Hannesson, R. (1998) Marine reserves: what would they accomplish? *Marine Resource Economics* 13(3), 159–170.

Hollowed, A.B., Bax, N., Beamish, R., Collie, J., Fogarty, M., Livingston, P., Pope, J. and Rice, J.C. (2000) Are multispecies models an improvement on single-species models for measuring fishing impacts on marine ecosystems. *ICES Journal of Marine Science* 57, 707–719.

Holt, S.J. and Talbot, L.M. (1978) New principles for the conservation of wild living resources. *Wildlife Monographs* No. 59.

Hutchings, J.A., Walters, C. and Haedrich, R.L. (1997) Is scientific inquiry incompatible with government information control? *Canadian Journal of Fisheries and Aquatic Sciences* 54, 1198–1210.

Jentoft, S. (1989) Fisheries co-management – delegating government responsibility to fishermen's organization. *Marine Policy* 13(2), 137–154.

Jentoft, S. and McCay, B. (1995) User participation in fisheries management – lessons drawn from international experiences. *Marine Policy* 19(3), 227–246.

Juda, L. (1996) *International Law and Ocean Use Management. The Evolution of Ocean Governance*. Ocean Management and Policy Series. Routledge, New York.

Juda, L. (1998) Considerations in developing a functional approach to the governance of large marine ecosystems. *Ocean Development and International Law* 30, 89–125.

Juda, L. and Hennessey, T. (2001) Governance profiles and management of the use of large marine ecosystems. *Ocean Development and International Law* 32, 43–69.

Koslow, J.A., Boehlert, G.W., Gordon, J.D.M., Haedrich, R.L., Lorance, P. and Parin, N. (2000) Continental slope and deep-sea fisheries: implications for a fragile ecosystem. *ICES Journal of Marine Science* 57, 548–557.

Larkin, P.A. (1977) An epitaph for the concept of maximum sustainable yield. *Transactions of the American Fisheries Society* 106(1), 1–11.

Lauck, T., Clark, C.W., Mangel, M. and Munro, G.R. (1998) Implementing the precautionary principle in fisheries management through marine reserves. *Ecological Applications* (Supplement) 8(4), S72–S78.

Link, J. (1999) (Re)constructing food webs and managing fisheries. In: *Ecosystem Approaches for Fisheries Management*. Proceedings of the 16th Lowell Wakefield Fisheries Symposium. AK-SG-99-01. University of Alaska Sea Grant, Fairbanks, Alaska, pp. 571–588.

Mace, P.M. (1994) Relationship between common biological reference points used as thresholds and targets for fisheries management strategies. *Canadian Journal of Fisheries and Aquatic Sciences* 51, 110–122.

Mace, P.M. (1997) Developing and sustaining world fisheries resources: the state of science and management. (Keynote presentation). In: Hancock, D.A., Smith, D.C., Grant, A. and Beumer, J.P. (eds) *Developing and Sustaining World Fisheries Resources: the State of Science and Management*. Proceedings of the Second World Fisheries Congress. CSIRO Publishing, Australia, pp. 1–20.

Mace, P.M. (2001) A new role for MSY in single-species and ecosystem approaches to fisheries stock assessment and management. *Fish and Fisheries* 2, 2–32.

Mangel, M. *et al*. (1996) Principles for the conservation of wild living resources. *Ecological Applications* 6, 338–362.

Mantua, N.J., Hare, S.R., Zhang, Y., Wallace, J.M. and Francis, R.C. (1997) A Pacific interdecadal climate oscillation with impacts on salmon production. *Bulletin of the American Meteorological Society* 78, 1069–1079.

Miles, E.L. (1998) The concept of ocean governance: evolution toward the 21st century and the principle of sustainable ocean use. *Coastal Management* 27, 1–30.

Murawski, S.A. (2000) Definitions of overfishing from an ecosystem perspective. *ICES Journal of Marine Science* 57, 649–658.

Murawski, S.A., Brown, R., Lai, H.-L., Rago, P.J. and Hendrickson, L. (2000) Large-scale closed areas as a fishery management tool in temperate marine ecosystems: the Georges Bank experience. *Bulletin of Marine Science* 66, 775–798.

NCSE (National Council for Science and the Environment) (2000) *Recommendations for Improving the Scientific Basis for Environmental Decisionmaking*. Washington, DC.

NRC (National Research Council) (1997) *Striking a Balance: Improving Stewardship of Marine Areas*. National Academy Press, Washington, DC.

NRC (1999) *Sustaining Marine Fisheries*. National Academy Press, Washington, DC.

Pace, M.L., Cole, J.J., Carpenter, S.R. and Kitchell, J.F. (1999) Trophic cascades revealed in diverse ecosystems. *Trends in Ecology and Evolution* 14, 483–488.

Pajak, P. (2000) Sustainability, ecosystem management, and indicators: thinking globally and acting locally in the 21st century. *Fisheries* 25(12), 16–30.

Pauly, D., Christensen, V., Dalsgaard, J., Froese, R. and Torres, F., Jr (1998) Fishing down marine food webs. *Science* 279, 860–863.

Pinkerton, E.W. (1989) *Co-operative Management of Local Fisheries: New Directions for Improved Management and Community Development*. University of British Columbia Press, Vancouver, British Columbia.

Pinkerton, E.W. (1992) Translating legal rights into management practices: overcoming barriers to the exercise of co-management. *Human Organization* 51(4), 330–341.

Pitcher, T.J. (2000) Ecosystem goals can reinvigorate fisheries management, help dispute resolution and encourage public support. *Fish and Fisheries* 1, 99–103.

Restrepo, V.R., Thompson, G.G., Mace, P.M., Gabriel, W.L., Low, L.L., McCall, A.D., Methot, R.D., Powers, J.E., Taylor, B.L., Wade, P.R. and Witzig, J.F. (1998) Technical guidelines on the use of the precautionary approach to implementing National Standard 1 of the Magnuson–Stevens Fishery Conservation and Management Act. *NOAA Technical Memorandum* NMFS-F/SPO 31.

Roberts, C.M. (1997) Ecological advice for the global fisheries crisis. *Trends in Ecology and Evolution* 12, 35–38.

Sen, S. and Nielsen, J. (1996) Fisheries co-management: a comparative analysis. *Marine Policy* 20(5), 405–418.

Sherman, K. (1994) Sustainability, biomass yields, and health of coastal ecosystems: an ecological perspective. *Marine Ecology Progress Series* 112, 277–301.

Sherman, K. and Alexander, L. (1993) Large marine ecosystems: a new focus for marine resource management. *Marine Policy* 17, 186–198.

Sissenwine, M.P. (1987) Councils, NMFS, and the Law. In: Stroud, R. (ed.) *Recreational Fisheries* 11. Sport Fishing Institute, Washington, DC, pp. 203–204.

Sissenwine, M.P. and Daan, N. (1991) An overview of multispecies models relevant to living marine resources. *ICES Marine Science Symposium* 193, 6–11.

Sissenwine, M.P. and Kirkley, J.E. (1982) Practical aspects and limitations of fishery management techniques. *Marine Policy* 6(1), 43–58.

Sissenwine, M.P. and Rosenberg, A.A. (1993) Marine fisheries at a critical juncture. *Fisheries* 18(10), 6–14.

Sissenwine, M.P., Mace, P.M., Powers, J.E. and Scott, G.P. (1998) A commentary on western Atlantic bluefin tuna assessments. *Transactions of the American Fisheries Society* 127, 838–855.

Steele, J.H. (1996) Regime shifts in fisheries management. *Fisheries Research* 25, 19–23.

Thompson, W.F. (1919) The scientific investigation of marine fisheries, as it relates to the work of the Fish and Game Commission in Southern California. *Fisheries Bulletin (California)* 2, 3–27.

United Nations (1996) *Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks*. United Nations General Assembly, New York.

Weiskel, H.W., Wallace, R.L. and Boness, M.M. (2000) *The Marine Mammal Commission Compendium of Selected Treaties, International Agreements, and Other Relevant Documents on Marine Resources, Wildlife, and the Environment*. USA Government Printing Office. Washington, DC.

WHAT (World Humanity Action Trust) (2000) *Governance for a Sustainable Future. II. Fishing for the Future*. WHAT, London.

Witherell, C., Pautzke, C. and Fluharty, D. (2000) An ecosystem-based approach for Alaska groundfish fisheries. *ICES Journal of Marine Science* 57, 771–777.

Appendix

List of Regional Marine Fishery Bodies

FAO bodies

APFIC	Asia–Pacific Fisheries Commission
CECAF	Fishery Committee for the Eastern Central Atlantic
GFCM	General Fisheries Commission for the Mediterranean
IOTC	Indian Ocean Tuna Commission
RECOFI	Regional Commission for Fisheries
SWIOFC	South West Indian Ocean Fishery Commission (in process)
WECFC	Western Central Atlantic Fishery Commission

Non-FAO bodies

CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
CCSBT	Commission for the Conservation of Southern Bluefin Tuna
COREP	Comité régional des pêches du Golfe de Guinée
CPPS	South Pacific Permanent Commission
CSRP	Commission Sous-régionale des Pêches
CTMFM	Joint Technical Commission for the Argentina/Uruguay Maritime Front
CWP	Coordinating Working Party on Fishery Statistics
FFA	South Pacific Forum Fisheries Agency
IATTC	Inter-American Tropical Tuna Commission
IBSFC	International Baltic Sea Fishery Commission
ICCAT	International Commission for the Conservation of Atlantic Tuna
ICES	International Council for the Exploration of the Sea
ICSEAF	International Commission for the Southeast Atlantic Fisheries
IPHC	International Pacific Halibut Commission
IWC	International Whaling Commission
MHLC	Commission for the Conservation and Management of Highly Migratory Fish Stocks in the Western-Central Pacific Ocean (Convention signed; Commission not yet established)
NAFO	Northwest Atlantic Fisheries Organization
NAMMCO	North Atlantic Marine Mammal Commission
NASCO	North Atlantic Salmon Conservation Organization
NEAFC	North-East Atlantic Fisheries Commission
NPAFC	North Pacific Anadromous Fish Commission
OLDEPESCA	Latin American Organization for the Development of Fisheries
PICES	North Pacific Marine Science Organization
PSC	Pacific Salmon Commission
SEAFO	South East Atlantic Fishery Organization (in process)
SPC	Secretariat of the Pacific Community
WIOTO	Western Indian Ocean Tuna Organization