

Symposium overview: incorporating ecosystem objectives within fisheries management

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Following an introduction to the broader context of the Symposium, the scope of the oral presentations is summarized under three themes: a global synthesis of fisheries impacts in different ecosystems; an overview of the methods available for quantifying ecosystem impacts; and the integration of fisheries and environmental management. The presentations generated substantial evidence that marine ecosystems have been impacted by fishing. Also there appeared to be a broad consensus that the present approach to achieving conservation objectives of fisheries management does not sufficiently take into account ecosystem considerations. There was not, however, a consensus on what additional restrictions are required, or on what features of ecosystems need to be protected. A way forward is to add ecosystem objectives to the conservation component of fisheries management plans, as well as to the management plans for other ocean-use sectors. The aggregate ocean-use activities would need to be evaluated in a nested manner, at a range of geographic scales, in relation to the more broadly defined conservation objectives. It is suggested that the geographic scales for evaluation of ecosystem considerations could be defined in a pragmatic manner based on the somewhat artificial boundaries of political and administrative systems already in place. The six conservation objectives proposed are maintenance of (1) ecosystem diversity, (2) species diversity, (3) genetic variability within species, (4) directly impacted species, (5) ecologically dependent species, and (6) trophic level balance. Indicators for each objective are discussed, as well as reference points that would trigger management actions. Such a broadening of conservation objectives for fisheries management would require both enhanced monitoring and a greater workload added to the process of provision of scientific advice through peer review. Of equal importance would be the challenges of establishing a governance framework to address multiple uses of marine resources. The spirit of the Symposium was that these coupled scientific and governance challenges will be very stimulating.

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Context of the Symposium

With the UN Convention on the Law of the Sea, nations accepted an obligation to consider the impacts of their policies on marine ecosystems (Belsky, 1993). This obligation has been reiterated by the FAO Code of Conduct for Responsible Fisheries (FAO, 1995) and by many recent policy documents around the world. It no longer

suffices to focus on the sustainable yield of the target species itself; the impacts of fishing on the structure and functioning of the ecosystem have to be considered as well.

This change in focus is not surprising considering the general concern for environmental issues and the potential impact of present fishing activities. The global annual marine catch is in the order of 110 million

tonnes. The amount of primary production necessary to sustain this catch corresponds to 25 to 35% of the primary production in the shelf areas where most of the fisheries take place (Pauly and Christensen, 1995). About 25% of the catch is discarded (Alverson *et al.*, 1994), and the discards constitute an important source of food for seabirds and other scavenging species. In the North Sea, it has been estimated that discards constitute one-third of the food of the seabird population (ICES, 1994). Bottom trawls and other gear that are towed over the seabed disturb the sediment and injure and kill animals in the path of the gear. In some areas, an average square metre may be swept several times per year (ICES, 1995).

With the predicted increase in the world population, the demand for fish will rise above the present supply (Garcia and Newton, 1994). Unless efficient management plans are put in place, the increasing demand will inevitably result in a further increase in fishing effort. Many of the important fish resources are already in a state of full or overexploitation, and for these resources it is likely that further increases in effort will result in stock collapses. What will happen to non-target species and to the rest of the ecosystem is far from clear, but the possibility that the increase could lead to changes in the structure and functioning of ecosystems cannot be discounted.

Although significant progress has been made during the last decade, we are only beginning to understand how fishing activities affect life in the sea. The lack of understanding arises partly because the effects of fishing on marine ecosystems are far more difficult to observe and quantify than effects of man's activities on land. It is difficult, both for science and for the general public, to gain a balanced picture of what goes on under the surface of the sea. Even so, the idea that the oceans represent the last great wilderness or frontier for man to discover and explore is now being replaced by the notion that man is having a large, but still poorly understood, impact on marine life. In those parts of the world where intensive fisheries have long been in operation, marine ecosystems are likely to have been influenced by man's activities in a manner similar to the impacts of our activities on terrestrial ecosystems.

The ecosystem effects of fishing can be classified as direct or indirect effects. The direct impacts are the easiest to measure and quantify. It is possible to estimate the area of the seabed that is swept annually by bottom gears, the amount of target species and other biota that are caught, the resulting mortality, the discards, and the changes in the physical habitat caused by various fishing practices.

It is much more difficult to quantify and predict the indirect and longer-term consequences of these impacts. These effects reveal themselves as changes in abundance and size structure of affected populations,

with resulting changes in trophic structure. Over the years, fishing may lead to evolutionary changes in the genetic composition of the populations. However, with a few exceptions, we do not have the knowledge that will enable us to make quantitative, or even qualitative, predictions of these longer-term impacts. This is due to several factors. First of all the effects manifest themselves against a background of natural environmental variations that are the major agent of change in the systems. There are well-documented examples, such as the effect of El Niño on the Peruvian anchovy, or the decadal-scale regime shifts in the North Pacific (Francis *et al.*, 1998), where major changes in environmental conditions have resulted in dramatic shifts in species abundances.

Secondly, even at the population levels our knowledge is incomplete. Many marine populations generate large numbers of offspring that initially suffer high rates of mortality. In the equilibrium situation only two individuals need to survive to replace their parents. Advances have been made in understanding how environmental and biological factors influence year-class strength in marine fish populations. However, the sometimes heated debate about stock-recruitment relationships in the scientific literature (Gilbert, 1997; Myers, 1997; Hilborn, 1997; Francis, 1997) reveals how little we know about the factors responsible for generating either the shape of, or the variability around, the stock-recruitment relationship for even the most intensively studied fish populations.

Moving from the population to the ecosystem level increases complexity. The little we have learned from community ecology is that few general rules are available to help us predict changes in the abundance of interacting species (Lawton, 1999). With great effort, we can work out the details of how a particular system is put together, but the insights gained seem difficult to generalize for export to other systems. The lack of general rules to predict how an assemblage of interacting populations reacts does not, however, preclude the existence of emergent properties at higher levels of organization. Changes in overall size composition, species abundance relationships, or other summary metrics could still prove to be useful indicators.

Finally, we have little knowledge about the unexploited situation. In most cases, biologists did not arrive on the scene until after a fishery had developed, and data from the unfished situation are therefore either of poor quality or simply unavailable. Apart from the question of whether the system would return to its original structure if fishing was stopped, the lack of data makes it very difficult to know how the unexploited system would look. Even though reference points based on the undisturbed situation seem intuitively attractive, they are difficult to establish in practice.

Scope of the Symposium

The recognition that fishing could have an important impact on marine ecosystems has generated considerable research in the last decade. The intention of the ICES/SCOR Symposium was to provide an updated review of the results and to point out new directions. Much of the planning of the Symposium was done by SCOR Working Group 105 on the Impact of World Fisheries Harvests on the Stability and Diversity of Marine Ecosystems established in 1996. The Working Group defined the scope of the Symposium to include three themes:

- (1) a global synthesis of fisheries impacts in different ecosystems;
- (2) an overview of the methods available for quantifying ecosystem impacts; and
- (3) the integration of fisheries and environmental management.

The first theme focused on differences and similarities in the responses of different marine ecosystems and specific species groups in various parts of the world. The presentations covered coastal and estuarine systems, coral reefs, kelp forests, semi-enclosed seas, eastern boundary currents, boreal seas, and sea-mounts. The species groups included demersal fish communities, tunas and billfish, sharks and rays, benthos, seabirds, and marine mammals. The evidence for cascading effects of fisheries on zooplankton and primary production was also reviewed.

The contributions under the second theme discussed the definition of overfishing in an ecosystem perspective, the quantification of the vulnerability of individual species to fishing, selection, and phenotypic evolution caused by fishing, and the risk of species extinction. At the community or ecosystem level, the usefulness of trophodynamic models, multispecies models, and indices of community structure was summarized.

The final theme addressed the development of an integrated approach to fisheries and environmental management. This will necessitate a selection of indices of ecosystem change that are perceived to be scientifically sound, important to society, and operational in a management context. The contributions reviewed management objectives and expectations from the points of view of NGOs, the fishing industry, and fisheries and environmental managers. This was followed by the presentation of a framework for designing operational ecosystem management strategies, after which some of the technical, legal, and economic tools that might be used to achieve the objectives were described. The current experience with integrating environmental and fisheries objectives was summarized in reviews of the approaches developed within ICES, CCAMLR, Philippine coastal zone management, Australian multiple-use manage-

ment, and US fisheries management. The future trends and constraints in the development of an integrated approach to fisheries management were outlined.

Conclusions of the Symposium

The diverse presentations, oral and poster, provided substantial evidence, generated by improved observational methods, that ecosystems have been impacted by fishing. The new methods have provided greater contrasts in the observations, and this has allowed conclusions based on statistical procedures. In addition, there has been an increase in the number of both controlled and uncontrolled field experiments. Results from the studies of closed areas for certain fishing gears, as well as marine protected areas (MPAs), have been fruitful in evaluating fishing impacts. There is also an increase in the availability of descriptions of ecosystem properties before and after the inception of fisheries. Finally, there has been an enhanced consolidation of data in review articles and meta-analyses.

The evidence for direct responses to fishing is very strong, including observations on reduced abundance levels, changes in size and species composition, and modifications in life-history parameters (age-at-maturity and weight-at-age) of target and by-catch species. The evidence for indirect responses is less obvious. It is often difficult to separate out the effects of fishing from other anthropogenic influences (e.g., pollution, habitat modification) and from natural environmental variability. This is particularly the case in nearshore ecosystems (Blaber *et al.*, 2000) and within inland seas (Caddy, 2000). Nevertheless, indirect effects have been documented in several ecosystem types (coral reefs, McManus *et al.*, 2000; and kelp forests, Tegner and Dayton, 2000). However, the power to detect indirect effects of fishing in marine ecosystems is low, and therefore some such impacts may be masked.

There was some discussion of whether single-species management, in aggregate, at conservative existing reference points (such as minimum spawning stock biomass levels and fishing mortality caps) would be sufficient for achieving ecosystem objectives of fisheries management. Although this approach could be right in principle, it is likely to fail under present fisheries management approaches because these do not include monitoring of the appropriate information to assess and evaluate achievement of ecosystem objectives. A key challenge to incorporating ecosystem objectives within fisheries management is to define measurable indicators and cost-effective monitoring programmes that relate to ecosystem objectives, as well as the reference points that trigger management actions. There is a need to consider impacts on both the structure (biodiversity) and the function (habitat productivity) of marine ecosystems.

Table 1. Examples of ecosystem objectives, indicators and reference points for ocean management areas (OMAs).

Objective	Indicator	Reference point
Maintenance of:		
Ecosystem diversity	Areas of shelf disturbed by fishing	% of each habitat type that is undisturbed
Species diversity	Abundance of spp. at risk	Maximum annual by-catch
	Area of distribution	% of distribution area relative to period of moderate abundance
Genetic variability within spp.	No. of spawning populations	% reduction in spawning areas
	Selection differentials	Minimum selection differential
Directly impacted spp.	Fishing mortality	$F_{0.1}$
	Spawning stock biomass	Minimum stock biomass for safeguarding recruitment and forage
	Area of distribution	% of distribution area relative to period of moderate abundance
Ecologically dependent spp.	Abundance of predator	Minimum abundance predator
	Condition of predator	Minimum condition predator
	% of prey spp. in diet	Minimum % in diet
Trophic level balance	Slope of size spectrum	Minimum slope
	Pauly's FIB index	Minimum value index
	Aggregate annual removals for each trophic level	Maximum % removals

The Symposium provided some suggestions on these needs (Table 1).

Several general problems were identified, including the difficulty in assessing causality, the lack of data on pristine conditions, the penury of taxonomists at a time when diversity studies are a high priority, and insufficient data on marine ecosystems in the face of the plea by many stakeholders for the incorporation of ecosystem objectives within integrated oceans management. Also, several approaches to solve these problems were suggested.

Evaluation of causality can best be addressed using an experimental approach, including the use of MPAs and fishery management measures, and by taking into account spatial and temporal contrasts. A range of hypotheses needs to be envisaged, not just the role of fishing. Fisheries impacts need to be evaluated in conjunction with the influences of environmental variability and the role of other ocean industries (e.g., marine transportation, oil and gas exploitation, aquaculture, and eco-tourism).

There is a need to reconstruct our image of historical conditions of marine ecosystems in a scientific manner, in order to define accurate reference points. Studies should involve archival data mining, oral and written histories, and physical evidence from other disciplines. The study of taxonomy must be given a high priority within universities, and collections of marine specimens in museums require enhanced funding.

The evaluation of ecosystem impacts, and the incorporation of ecosystem objectives within integrated oceans management, demand enhanced monitoring. There is a need to define what data are really needed.

New technologies, such as remote sensing by satellite for estimates of phytoplankton biomass and productivity, may be helpful. Stakeholders need to be engaged in observational networks. The Global Ocean Observing System (GOOS) should incorporate indicators for ecosystem objectives of oceans management within their overall monitoring framework. In the absence of data on ecosystem features of interest, a more precautionary approach to management is obligatory under present conventions and the Codes of Conduct.

Governments and stakeholders want scientists to provide their best advice on potential indicators that relate to broader conservation objectives of management (for fisheries as well as other ocean industries). The indicators need to have some predictive power, and to be sensitive to ecosystem change. It is the time to propose a wider range of conservation and ecosystem objectives for fisheries management, as well as corresponding indicators and reference points that trigger management action. The indicators and reference points may be altered with experience, but there is a need to start somewhere. We have sufficient knowledge and monitoring tools to start the process.

There would appear to be broad consensus that the present approach to achieving conservation objectives of fisheries activities, even if successfully implemented, would not achieve yet-to-be-defined ecosystem objectives. There is not, however, consensus amongst scientists on what additional restrictions are required, or on what features of ecosystems need to be protected. Discussions at Montpellier led to consideration of the next practical steps. One approach is to add ecosystem objectives to the conservation component of each

single-species fisheries management plan, as well as to the management plans of other ocean-use sectors. Then the aggregate activities would need to be evaluated at a range of geographic scales in relation to the broadly defined conservation objectives.

The problem of geographical boundaries

In many situations, the geographical boundaries of marine ecosystems are difficult to define in a rigorous manner. Their definition is a somewhat arbitrary process, dependent upon the particular interests of the ecologist and the details of the issue being addressed. This is not to say that there is no spatial structure in the oceans, but rather that such structure varies considerably, depending on upon the species and ecosystem features of interest. The geographical distributions of marine populations vary enormously, as do the geographic scales of the processes and interactions that maintain populations in an ecosystem. For example, the Northwest Atlantic as a whole is the appropriate geographic scale of the ecosystem for populations of bluefin tuna (*Thunnus thynnus*), swordfish (*Xiphias gladius*), and some shark species. In contrast, the Scotian Shelf and Gulf of Maine area comprises the overall distributional area of cusk (*Brosme brosme*). Most populations of plankton species cover broad geographical areas, and there may be considerable exchange of individuals between areas. In sum, the relevant oceanographic and biological features are generally large scale and are species specific. In contrast, the management areas of interest to fisheries are often defined at smaller scales within national, provincial, regional, and municipal boundaries.

The mismatch between the appropriate geographical scales for a range of ocean-use activities has obvious implications for governance of the ecosystem objectives. The geographic extent of ecosystems to be considered in ocean-use management plans probably needs to be defined in a pragmatic manner, based on the required stakeholder involvement for the management activities and the artificial boundaries of the political and administrative systems already in place. For some sectoral management issues, putative Ocean Management Areas (OMAs) may encompass the relevant biological area. For others it will not. Thus there is a requirement for a nested approach, within which ecosystem evaluations would need to be carried out at a range of spatial scales. For example, some single-species management plans would only need to be evaluated within a single OMA, whilst others may need to be considered within contiguous areas.

Ecosystem objectives for ocean management areas

The ecosystem objectives for fisheries (and other ocean-use activities) need to be set by society at large, rather

than by scientists. The scientific community should, however, provide technical options, and the Symposium discussed a number of issues relating to both ecosystem objectives and their related indicators and reference points. The objectives should be similar, or possibly identical, for the wide range of ocean uses. We assume that such objectives will include the maintenance of biodiversity and of habitat productivity. The challenge to science is to reach consensus on indicators and reference points that will support decision making on ocean-use activities that threaten biodiversity and habitat productivity. The biodiversity objective will need to include several components, such as ecosystem and species diversity, and genetic variability within species. The habitat productivity objective will need to address directly impacted species, ecologically dependent species, and trophic level considerations. The above components are considered to capture the necessary ecosystem features that need to be protected in the aggregate sectoral management plans. That is, the ecosystem objectives should include:

- maintenance of ecosystem diversity;
- maintenance of species diversity;
- maintenance of genetic variability within species;
- maintenance of directly impacted species;
- maintenance of ecologically dependent species;
- maintenance of trophic level balance.

The next step is to provide the respective indicators and reference points for the six potential ecosystem objectives.

Indicators, reference points, and management tools

Some indicators and their reference points that were suggested for future development and evaluation are summarized in Table 1. An overall indicator of ecosystem diversity could be the areas of the shelf for each habitat type that are disturbed by fishing activity. The associated reference point could be a percentage of each habitat type that is undisturbed. This particular objective could be achieved by a patchwork of closed areas for certain categories of ocean-use activities that influence benthic habitat. In the initial stages, the percentage of habitat that is undisturbed (and the spacing of MPAs) will probably be somewhat arbitrary, in the absence of a theoretical framework.

Operational indicators of species diversity have not yet been defined. However, for species at risk, IUCN and other conservation bodies have defined a range of indicators (including population numbers, rate of decline, and contraction of area of distribution). The reference point for a fishing plan could be the total permissible by-catch level of the species at risk. The indicator for genetic variability within target species could be a combination of the number of spawning

populations in the management unit and selection differentials as defined by Law (2000). Again the reference points could be a combination of percentage reduction in spawning areas and a minimum selection differential.

The indicators for directly impacted species (target and by-catch species) are well established. They include, for example, measures of exploitation rate (using size- and age-structure changes), spawning stock biomass and geographic distribution. The reference points are also well defined (for example, the use of Minimum Biologically Acceptable Level – MBAL – of spawning stock biomass in ICES advice).

Reference points for forage species may include consideration of prey requirements in addition to spawning stock biomass requirements for safeguarding recruitment. CCAMLR has taken this approach for the management of the krill resource in the Antarctic (Constable *et al.*, 2000). Reference point for non-commercial, directly impacted species could also be based on by-catch limits (percentage or absolute), with fisheries being stopped when the limits are reached. This approach is already well developed for many fisheries.

The choice of indicators for ecologically dependent species is less well developed. CCAMLR has made some progress at the conceptual level. The approach is to identify key food-chain linkages between target species in a fishery and some dependent species. For one or more key linkages, the dependent species is monitored in some way (condition, diet composition, abundance). The trickier part is defining reference points associated with the indicators, as cause and effect for any observed change in the indicator for the ecologically dependent species will be difficult to evaluate in practice. CCAMLR is taking a pragmatic approach to this challenge (i.e., start with a range of indicators on dependent species and decide on reference points at some later time, in the expectation that understanding of the food-chain dependencies will emerge). Multispecies models may aid in the establishment of quantitative reference points (Hollowed *et al.*, 2000).

Indicators that take trophic level into consideration are controversial. ICES (1999, pp. 217–218) states at the end of the section entitled “Biological reference points from an ecosystem perspective”: “The challenge is not to derive the metric, but to relate it to changes in the affected system that are of relevance to society.” The approach recommended here is to select several indicators of relevance to ecosystem structure to be monitored in an exploratory manner. These could be:

- shape of the size spectrum of species caught in trawl surveys (Bianchi *et al.*, 2000);
- the FIB (whether a Fishery Is Balanced) index developed by Pauly *et al.* (2000) that measures changes in trophic level structure;
- aggregate removals at each trophic level by combined fishing activities.

Bianchi *et al.* (2000) have analysed trends in the slope of the size spectrum of groundfish as a function of fishing effort. With further research the results may provide justification for the selection of a minimum acceptable slope as a reference point for ecosystem overfishing. The FIB index and empirical observations on how it responds to aggregate fishing effort may also generate reference points of practical use for management. There is a need for considerable research on the indicators of relevance to trophic level considerations. At this stage, a broad-based exploratory approach is proposed. The first step is to describe trends in these ecosystem-level indicators in relation to natural and anthropogenic forcing. Definition of reference points can be deferred to some later date.

It is important to recognize that the fisheries management tools to achieve ecosystem objectives are the same as those already in use to achieve present conservation objectives: gear restrictions, closed areas and seasons (including MPAs), quotas and by-catch limits, and restrictions on days-at-sea. The OECD (1996) describes these tools more formally as input controls, output controls, and technical measures. Protected areas seem to offer a possibility for maintaining ecosystem diversity provided they are selected in a way that ensures protection of a significant fraction of the major habitat types and their interdependencies. In recent years there has been exciting progress in our capability to map benthic habitat, using a combination of multi-beam sonar and photography of the macrobenthos (Todd *et al.*, 1999). This capability could also provide practical and measurable indicators for the benthic component of ecosystems.

Monitoring needs

Each of the above approaches to defining indicators for ecosystem structure and function requires monitoring. Fortunately, there is a considerable amount of information relevant to ecosystem objectives that is already being collected within ongoing monitoring programmes in many countries. Nevertheless, there will be the need for some additional monitoring, and the development of routine data products on descriptors of ecosystem structure and function. The specific programmes will need to be defined in relation to the chosen indicators for each ecosystem objective. The costs of monitoring to achieve the broader conservation objectives will need to be evaluated and approaches to financing must be worked out.

Peer review

Some extra work on peer review will also be required. In addition to the evaluation of the conservation objectives of the target species in the fisheries-management units, there will be a need to evaluate the ecosystem objectives

for groups of management units within the defined OMAs. The combined evaluations will also need to consider impacts of non-fishing industrial activities.

As mentioned earlier, a major difficulty in the evaluation of ecosystem objectives within fisheries-management plans is the identification of cause and effect. The full range of local and distant human activities, as well as natural environmental variability, may influence ecosystem structure and function. Consequently, there will be considerable uncertainty concerning the role of fishing on any observed changes. Thus scientific peer review will face a new set of challenges.

Some thought is required on how the precautionary approach should be applied in this context. There will be an increase in the degree of uncertainty when one moves from the evaluation of whether fisheries-management actions will meet present conservation objectives to the consideration of the achievement of additional ecosystem objectives by combined ocean-use activities. There is at present limited explanatory power in ecological theory, and several generalizations about ecosystem structure and function developed on the basis of observations and experiments within terrestrial and freshwater systems may not be applicable to marine ecosystems. Should we, as a starting point, assume that ecological generalizations having their empirical basis in terrestrial and freshwater systems apply to marine ecosystems? Such assumptions could result in a higher degree of precaution than required on the basis of marine ecological studies alone. An example is the trophic cascade hypothesis for lakes, for which there is limited support from marine studies. Under this hypothesis, the removal of larger fish leads to changes in the species composition of the zooplankton community (see Reid *et al.*, 2000). These are questions that we have not routinely asked within the framework of scientific advice on fisheries management, which will need to be addressed when considering ecosystem objectives.

The governance challenge

The scientific peer-review bodies for fisheries management are structured to absorb the new demands for advice (even though there is already a workload problem for most such organizations). In contrast, the governance structure as a whole, of which scientific advisory bodies are a part, will require substantial change. A major challenge is involving an appropriate range of stakeholders and managers as we move from consideration of present conservation objectives of sectoral management plans (including those for single-species fisheries) at a range of spatial scales to explicit consideration of the additional ecosystem objectives at the geographic scale of OMAs. There will be the need for regional advisory committees that cross commercial fisheries, as well as other ocean uses. Analyses of the

state of the ecosystem in relation to the aggregate human activities that are or should be managed will need to be carried out on a multi-year cycle. New institutional structures that involve municipalities, government departments, and NGOs, as well as representatives of the relevant commercial interests, need to be developed in a cost-effective manner. Fortunately, as with monitoring, in most countries a range of institutional structures that can be used is already in place. The principal functions that need to be achieved are the audit of the degree to which the sectoral management plans are being implemented in relation to the overarching conservation objectives, as well as the capability to resolve conflicts amongst competing users.

The way forward

The Symposium achieved its major objectives. The syntheses on impacts have identified the scope of the management challenge. There is a need to enhance the conservation objectives of fisheries-management plans to include explicitly ecosystem considerations. The papers (and the discussions over dinner!) suggest some practical approaches to incorporating ecosystem objectives within integrated oceans management. It is timely now that the scientific community provides the technical options to managers and stakeholders. The work to be done will be stimulating, as it will force us to consider the broader ecological literature. This wider perspective in fish-stock assessment and management advice will be a great challenge for fisheries science at the turn of the millennium. The scientific community will have to respond to a new category of questions from their customers. It will require a wider cooperation amongst scientists, managers, fishing industry, non-governmental organizations, and other stakeholders. It is our impression that the Symposium provided a first step in this direction.

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