ELSEVIER

Ecological Economics 31 (1999) 189–198

ECOLOGICAL ECONOMICS

www.elsevier.com/locate/ecolecon

COMMENTARY

The role of science in ocean governance

Donald F. Boesch *

University of Maryland Center for Environmental Science, PO Box 775, Cambridge, MD 21613-0775, USA

Abstract

Sustainable governance of the ocean demands a more integral and timely role for science. Although, science has played a limited role in global ocean governance regimes, science has made essential contributions to governance on regional scales, particularly when there is strong scientific consensus, clear identification of problems and solutions, and convergence with cultural ideas. Science is especially challenged to contribute to: understanding intergenerational and interspatial effects, addressing inherent uncertainty about the behavior of marine ecosystems, and integrated ecological-economic models and assessments needed for adaptive management. Pressing issues requiring stronger inclusion of science in ocean governance include the global nitrogen cycle and coastal eutrophication, irreversible habitat degradation, sustainable exploitation of living resources, and the effects of climate change on ocean and coastal environments.

Keywords: Adaptive management; Ocean governance; Science policy

1. Introduction

The oceans simultaneously provide one of the greatest challenges and the greatest hopes for sustainable governance of Earth's resources and life support systems. Because so much of the oceans is not 'owned' by individuals or nations, the oceans are a common heritage of humankind. Yet, we have often abused the resources of this commons in tragic ways, treating them as shared resources without shared responsibilities. At the same time, we are increasingly realizing that the oceans are far more vital to humankind than just as a place to catch fish, transport materials, dispose of wastes, fight wars, recreate, and simply enjoy. They are places that regulate our atmosphere, control our weather, recycle nutrients, harbor much biodiversity, and buffer our excesses (Peterson and Lubchenco, 1997). In their recent valuation of Earth's ecosystem services, Costanza et al. (1997) estimated that ocean and coastal systems contribute 63% of the total value of these services, or $21 trillion/year. Most of these services fall outside of conventional market valuation. In fact, according to this estimate, the value of marine ecosystem services alone exceeds the world GNP based on conventional economic appraisal.

* Tel.: + 1-410-2289250; fax: + 1-410-2283843.
E-mail address: boesch@ca.umces.edu (D.F. Boesch)

0921-8009/99/$ - see front matter
PII: S0921-8009(99)00078-6

In short, there is every reason to expect that at the threshold of the 21st Century our society would have developed seasoned and effective governance mechanisms for the oceans to husband these shared resources and the common environment. But this is not the case. Many fish stocks, particularly those transcending national boundaries or occupying the high seas, have been seriously depleted and are yet without sound plans for their recovery and sustainable use. Destruction of important coastal habitats, such as coral reefs and wetlands, continues. Continental water resources are used and loaded with wastes without understanding, much less considering, the effects on the coastal ocean; and we continue to fly blindly regarding the effects of greenhouse gas emissions on ocean circulation and its effect on climate regulation (Broecker, 1997).

For humankind to achieve sustainable governance of the oceans in the 21st Century will require more effective use of science and involvement of scientists. Not only is it necessary for science to help unveil the mysteries, complexities, relationships, and consequences of our actions in the natural world and in human society, but, more than ever, science must meet its potential as a valued and influential component of modern society. While it may not be as straightforward as 'speaking truth to power', scientific discoveries and syntheses can be extremely catalytic in helping us move from unsustainable business as usual.

In this paper I provide some reflections on the role of science in achieving sustainable ocean governance based both on my own experiences and on the thoughts of others. My views are offered from the perspective of a natural scientist, a biological oceanographer who has worked on a variety of coastal environmental and resource issues. I have attempted to relate consideration of the role of science to the synthesis on ecological economics and ocean governance developed by Costanza et al. (1998, 1999), using in particular the paper by Costanza (1999) on the ecological, economic, and social importance of the oceans as a framework. After summarizing recent experiences concerning the role of science in ocean governance, I consider Costanza's observations on what constitutes sustainable development, the distinguishing characteristics of ocean environments and resources, principles of sustainable governance, and integrated ecological–economic modeling and assessment. I conclude by highlighting pressing challenges for ocean science and governance.

2. The governance context for science

When examining the present agreements and structures for governance of the world's oceans one is struck by their lack of comprehensiveness and the fairly modest role science has played in their development and execution. International agreements exist for direct disposal of wastes in the ocean—the London Dumping Convention (1972)—and the discharge of wastes and hazardous substances from ships—the MARPOL Convention (1973)—but these have only a general scientific basis with a modest ongoing role for science. The Law of the Sea (1983) provides a basis for governing science in the oceans, but not a scientific basis for governing the oceans, at least not an explicit one. Under the treaty scientific considerations play a role, however, in allocating fish stocks that straddle international boundaries. The International Commission for the Conservation of Atlantic Tunas, Interamerican Tropical Tuna Commission and International Center for Living Aquatic Resources Management are examples of efforts that work to apply science to international resource management. The Marine Mammal Commission develops scientifically based goals for managing or restoring marine mammal populations, but scientific findings are frequently overwhelmed by cultural or political considerations. The Oceans Subchapter of Agenda 21 of the United Nations Conference on Environment and Development (UNCED) details a number of objectives, based at least in part on scientific understanding. It calls for integrated coastal management, improved conservation of living resources, reduction of land-based sources of pollution, and understanding of the effects of climate change on ocean and coastal management. These objectives are founded as much on notions of common sense and fairness as science. The post-UNCED follow-up on this agenda has been rather weak and the organization of the scientific effort to serve these goals even weaker.

It is not much more encouraging to look at the global-scale environmental science. Other than programs that address dimensions of global climate change, such as the World Ocean Circulation Experiment, Joint Global Ocean Flux Study, and Global Ecosystem Dynamics Program, there are no substantial international ocean science efforts designed to address issues important for sustainable governance of the ocean. Even these global change-oriented programs are, at best, weakly linked with the development and function of governance.

On regional scales, the interactions between science and governance are more substantial, ongoing and effective (but see NRC (1997) for perspectives on needed improvements). Scientists involved in regional seas governance or regional fisheries management have rich experiences and diverse, albeit subjective, perspectives on this process. However, it is instructive to consider the more detached perspectives of political scientists who have studied the interactions between science and policy.

Haas (1990, 1997) observed that institutional bargaining usually emphasizes national self-interest, maximizes rational utility, and operates with incomplete information. This generally results in least ambitious commitments among the parties. In contrast, in the development of the Mediterranean Action Plan activities within the scientific community resulted in consensus among individuals with an authoritative claim to knowledge. Scientists from the Mediterranean nations effectively constituted what Haas called an epistemic community, which has shared values, causal beliefs and judgment and common notions of validity and the role science should play in environmental policy. The effect was the adoption of an action plan that progressed further toward environmental goals than would have been possible through typical diplomatic interactions, particularly considering the significant north–south, religious, and cultural differences that exist in the region.

Haas (1997) argued that scientists, acting collectively, can result in epistemically informed bargaining that is more likely to contribute to a sustainable level of ecological equilibrium, economically efficient environmental measures (but he noted the problem that ecologists and economists have focused on different objectives), anticipatory action, and greater flexibility. On the other hand, institutional bargaining provides for fuller participation and representation of stakeholders in management of shared resources, while epistemic models favor technocratic over democratic or representative decision-making.

Haas (1993) contrasted the Mediterranean experience with that of the North Sea, where, despite more advanced scientific information and enterprise, a multinational epistemic scientific community did not develop and policy decisions were based more on institutional bargaining than science. Over several conferences of environmental ministers from nations bordering the North Sea, commitments were made regarding the cessation of ocean disposal and incineration, adoption of the precautionary principle, and across-the-board reductions of land-based sources of pollutants by 50% (70% for dioxin, mercury, cadmium and lead). But, there was little input from the scientific community. Instead, reacting to domestic public pressures for a clean environment, the governments of The Netherlands, Germany, and Denmark engaged in one-upmanship in proposing stringent controls without regard to scientific advice or technical or economic feasibility. The geopolitics of leaders and laggards, Haas argued, was more in play than policy formulation based on science. In fact, even the precautionary principle policy was controversial within the scientific community, particularly in terms of the practicality in defining certainty (Stebbing, 1992). In another view from a scientist engaged in the North Sea Task Force, Ducrotoy (1997) gave science more credit in the formulation of North Sea environmental policy, but notes failures and shortcomings in the implementation. The conventions of the earlier Oslo (1972) and Paris (1974) Commissions and the agreements of the North Sea Ministerial Conferences have evolved into the Convention for the Protection of the Marine Environment of the North-East Atlantic, encompassing both the Baltic and North Seas.

For coastal areas at scales smaller than regional seas, the interaction between science and policy formulation and its implementation is generally more intimate. I provided comparative perspectives on four coastal ecosystems in the US that present environmental governance challenges in that they are all heavily influenced by inputs of water and materials from land (Boesch, 1996): the Chesapeake Bay, San Francisco Bay, the Mississippi Delta system, and Florida Bay. The four ecosystems are at differing stages in the evolution of both scientific understanding and environmental management, with the Chesapeake Bay being most advanced. I examined the role science played in defining problems of environmental sustainability and identifying causes and solutions. Among the important factors affecting the success of science are: (1) sustained scientific investigation, responsive to, but not totally defined by managers; (2) clear evidence of change, the scale of change and the causes of change; (3) some level of consensus among the scientific communities associated with various interests; (4) the development of models to guide management actions; and (5) identification of effective and feasible solutions to the problems.

In assessing the role science plays in ocean and regional seas governance, one should understand that political decisions regarding environmental protection and resource management are frequently made for cultural and ethical reasons which lie outside ecological or economic rationale. Sagoff (1992) emphasized the importance of the sense of place, i.e. a strong identity with the well-being of a region by its citizens, in decisions made by societies concerning environmental protection. A detached economic appraisal of the values that the ocean and coastal environments provide to human society, Sagoff suggested, would place a much higher value on these environments as waste processors than fish producers. Curiously, one could draw a similar conclusion from the ecological economic appraisal of Costanza et al. (1997) of the value of nature's services, particularly in consideration of the high estimated value of waste processing and nutrient cycling in coastal environments. In another dimension, perspectives assembled by Kellert and Wilson (1993) in support of a biophilia hypothesis illustrate the influence that the strong feelings humans have for other living things on decision-making.

The fact is that society makes decisions to treat wastes and protect fisheries not only for detached economic reasons, or even documented ecological reasons, but also for ethical, social, cultural and even spiritual reasons. Moreover, these human values vary greatly in different societies around the globe and even among communities within nations. If we are to achieve sustainable governance of the oceans these values need to be considered as well as ecological and economic ones. This is illustrated by the differences in approach in controlling coastal eutrophication in the US, one nation with relatively strong central government and rather homogeneous culture. The multistate effort to reduce eutrophication of the Chesapeake Bay enjoys strong public and political support throughout the watershed, even in Pennsylvania which does not border on the Bay but encompasses a large part of its watershed. There is a sense of place, a sense of responsibility. In contrast, the will to control nutrient sources emanating from the upper Mississippi River Basin that result in large-scale oxygen depletion (Rabalais et al., 1996) in the northern Gulf of Mexico—over 1500 km downriver—has, at this point, scarcely been stirred. This even though the ecological and economic consequences are probably greater than that in the Chesapeake. The greater distances between cause and effect and cultural differences limit the development of the same sense of place or responsibility.

3. Sustainable development

Costanza (1999) suggested there is a growing social consensus for sustainable development as a long-term goal: development that is sustainable ecologically, socially, and economically. Although one might think of science, particularly natural science, playing a role only in defining ecological sustainability, it must also play roles in defining sustainability in the social and economic dimensions. Obviously, sociology, anthropology and economics have much to contribute to determining social and economic sustainability. Fishery and other marine sciences not only define the sustainability of economically exploited stocks, but also inform decisions regarding distribution of resources and opportunities within the current human population and among present and future generations.

Costanza also pointed out the importance of transdisciplinary approaches which integrate the natural and social sciences in order to address the interrelated issues of sustainable scale, fair distribution, and efficient allocation in a sustainable way. Such approaches reach beyond interdisciplinary and break down, or at least transcend, disciplinary boundaries by striving to be truly integrative rather than just agglomerative. No one can argue with the desirability of this vision, but like sustainable development itself, transdisciplinary science should be considered an ultimate goal, seldom ever fully achieved.

4. Ocean environments and resources

In bringing concepts of governing for sustainable development to bear on the oceans, Costanza (1999) listed six special characteristics of the ocean which must be considered. I will focus on two of these characteristics: (a) intergenerational and interspatial effects and (b) the fundamental uncertainty about the behavior of marine ecosystems. (The other characteristics concern common property rights and access, tendency for a free ride on conservation issues, failure of markets, and exacerbation of poverty resulting from ignoring environmental externalities.)

Interspatial effects involve actions taken in one location having consequences, often undesirable and unanticipated, elsewhere. Even scientists may simply not recognize such effects for some time. Addressing them when they are understood is still difficult. Ecosystem degradation and resource losses emerge when human responsibilities do not match the spatial, temporal, or functional scale of natural phenomena and will persist until the scale mismatches are cured (Lee, 1993b). Moreover, the multiple human activities and uses that take place in the ocean, particularly in the coastal zone, are pursued without accounting for or accommodating the repercussions of one to the other, requiring more effective integration of both science and management (Antunes and Santos, 1999).

To underscore the intergenerational and interspatial challenges in ocean governance consider the Louisiana delta example included in my comparison of four US coastal ecosystems (Boesch, 1996). The exploitation of oil and gas resources underlying the deltaic wetlands during the last half of the 20th century resulted in a legacy of canals built for well access and boat and pipeline transportation through the tidal wetlands. The hydrological disruption caused by this extensive channelization continues to be a major cause of the loss of these wetlands, threatening the traditional base of the economy, coastal fisheries (Boesch et al., 1994). Although a large portion of this wetland loss resulted from short-term human activities in the wetlands themselves (Turner, 1997), the long-term solutions for restoration or enhancing longevity of remaining wetlands must involve return of river flow into these wetlands, i.e. effective solutions involve not just reversal of the causes. Moreover, the build up of carbon dioxide in the atmosphere from combustion of this (and much more) oil and gas is warming the planet, resulting in rising sea level that threatens inundation and further loss of the wetlands. At same time, as mentioned above, just off the coast as much as 15 000 km^2 of the sea bed of the continental shelf of the northern Gulf of Mexico experiences serious seasonal hypoxia as a result of a multi-fold increase in nutrient discharge from the Mississippi and Atachafalaya rivers (Rabalais et al., 1996). Most of these nutrients come from agricultural sources in the US Corn Belt, an area that exports large amounts of grain throughout the world to feed the growing demand for animal protein. Growing the grain and transporting it have greatly influenced how water flows down the river, driving the construction of levees isolating flood plains, reservoirs, channels and locks. The resulting hydrological modifications, in turn, influence the delivery of sediments—needed for wetland survival—and nutrients to the river delta. Clearly, addressing the economic driving forces and environmental interactions influencing wetland loss and eutrophication in and around the Mississippi delta requires interspatial (even intercontinental) and multigenerational thinking and action.

Costanza (1999) called for new models for decision-making and different management rules based on maintaining the system within sustainable bounds and keeping uncertainty within acceptable limits. While one can hardly disagree, it seems to me that the practical challenge in accomplishing this is more daunting than this prescription would indicate. Two new models which have emerged are the precautionary principle and adaptive environmental management (Costanza et al., 1999). Both seem intuitively sensible but can be contradictory. In the minds of many, the precautionary principle means 'do not take chances,' yet the principles of adaptive management require experimentation and chance taking, within limits, of course (Walters, 1986; Gunderson et al., 1995; Holling, 1995). In a practical sense, how do we reconcile and integrate these two notions, balancing risk avoidance and adaptation?

5. Principles of sustainable governance

Costanza (1999) argued that sustainable governance must be subsidiary, responsible, precautionary, and participatory. These notions underpin the principles of sustainable governance espoused by Costanza et al. (1998, 1999). To a certain extent, these are Western ideals, which require some adaptation in other cultural settings. Nonetheless, they have implications and challenges for the contributions of science to sustainable governance. For example, the subsidiary principle requires that governance should occur at the lowest possible organizational level in order to enhance democratic participation, yet science is not organized or performed at the lowest level in a governance structure, nor is it particularly democratic. For reasons of efficiency and communication, science tends to be organized primarily at national or even international levels. How then can science be brought to bear to governance at subnational scales? Similarly, the power and influence of the scientific epistemic community is in part based on its elite status (Haas, 1997). How, then, can science enhance informed democratic participation?

The responsibility principle requires that the rights to use environmental resources carry attendant responsibilities to use them sustainably and fairly. Yet, in many instances where responsible participation by stakeholders has been the paradigm for ocean resource governance, such as regional fishery management councils in the US, self-interests have overshadowed scientific assessments, leading to unsustainable exploitation of the resources (Hanna, 1999). Indeed, because of the dominance of economic ratcheting in fishery management decisions, scientific information has often been overwhelmed or marginalized (Ludwig, et al. 1993). How can science effectively moderate self-interests, which tend to be narrow and shortsighted? This presents a major challenge for ecological economics.

Again, on the precautionary principle, it is important to recognize that fundamentally this principle has its basis in policy and not science. It is a subjective notion that should take scientific assessments into account, but is not a scientific exercise in itself (Stebbing, 1992; Ducrotoy, 1997). Determination of acceptable levels of risk cannot be left to science alone.

6. Integrated modeling and assessment

Costanza (1999) listed a number of principles and defining characteristics of integrated ecological–economic modeling and assessment. The first again deals with the challenge of limited predictability. I have already discussed the precautionary principle and its potential conflicts with adaptive management. I will just add that adaptive management presents its own set of challenges for science and scientists. It requires that scientists be far more engaged in the governance process than just submitting reports or publishing papers (Lee, 1993a). It requires that they do things that many scientists are uncomfortable with, have not developed skills for, do not like to spend time on, and are often not acknowledged by peers and superiors, such as making predictions that are not yet solidly founded and interacting extensively with stakeholders and managers (Lubchenco, 1998). Scientists should also have a better understanding of the policy-making process and the different roles scientists may play in the adaptive cycles linking crisis identification, weighing alternatives and the evaluation of implementation (Gunderson et al., 1995). Our scientific societies and institutions should be working to change the scientific culture and reward systems to make this needed expansion of the role for science more feasible.

Integrated modeling and assessment clearly calls for a transdisciplinary approach, which, as I wrote earlier, is high goal for which to strive but never fully achieved. In practice, environmental science does a rather poor job in integration beyond the physical sciences, much less among the natural and social sciences. The attention received by the rather audacious, but courageous, effort of Costanza et al. (1997) to estimate the value of the world's ecosystem services and natural capital will, in at least some small way, either incite or inspire ecologists and economists to move toward the goal of more completely transdisciplinary integration.

As integrated monitoring and assessment challenges us to redefine the role of science and the scientist, it is useful to consider further what that role has been in theory and practice.

Jasanoff (1990, 1997) described our common notion of the nature of scientific knowledge as realism. This implies that truths about the natural world arise in an autonomous domain of science, cleanly separated from social influence and the uses of political power. Under this traditional view, the duty of expert policy advisors, then, is to bring facts to bear on the process of political evaluation and judgment, and so to keep public actions from falling prey to passion and irrationality. Such logical positivism associates scientific activities with special normative commitments designed to promote objectivity, such as the experimental approach, the higher status in which basic research is held, and review by peers.

Jasanoff contrasted this with the perspective of radical relativism that, in practice, mediates this realist view. This concept is based on the notion that science must achieve moral as well as epistimological authority. It requires that scientific discourse and political discourse must be put into a mutually sustaining relationship. Scientists cannot be expected to resolve uncertainty on their own (e.g. the precautionary principle), but can only work with social actors, or within advocacy coalitions (Sabatier and Jenkins-Smith, 1993) to 'repair' uncertainty. Jasanoff views that scientific ideas prove influential because they: (1) converge with prevailing cultural ideas about responsibility and fault; (2) support politically acceptable forms of discourse and reasoning; or (3) are ratified by communities that have established, within well-defined boundaries, a privileged right to formulate policy. Rather than the 'best' possible science for policy, we must ask how to achieve the level of certainty needed for real-time political decisions, given that much knowledge about the environment will continue indefinitely to elude the firm grasp of science.

With these observations in mind and the imperative of reaching a sustainable biosphere during the 21st century, scientists need to reassess their roles and priorities (Lubchenco et al., 1991; Lubchenco, 1998). Too often, when scientists assemble to address priorities and needs, they provide rationale about why the support for the science they want to do is needed for society (NRC, 1992, 1995b), but seldom (NRC, 1994, 1995a) spend much time considering how the products of their scientific efforts can be used by society. Yet, the great expansion of science during and after the World War II was based on a social contract wherein societies have supported science because of its ultimate benefits to humankind. Sarewitz (1996) suggested it is time for scientists to reassess their contract with society and tackle the connection—or lack thereof—between progress in science and technology and progress in society. He advanced a new guiding myth for society: working toward sustainability, or developing technologies and solutions that allow humans to survive into the long-term future.

Finally, the integrated monitoring and assessment principles provide the sound advice to acknowledge and deal with the many forms of uncertainty inherent in complex systems, including parameter uncertainty, process uncertainty, and that associated with data. Not only do these different forms of uncertainty have different solutions, but they also have different meanings and influence in policy formulation.

7. Pressing challenges to ocean science and governance

In conclusion, I would like to identify several interconnected issues that present pressing challenges for ocean science and governance. These should be focal points for the development of more effective processes for the generation and use of science, both natural and social science, in achieving a sustainable future:

7.1. The global nitrogen cycle and coastal eutrophication

One of the most pervasive problems confronting coastal ocean ecosystems is their over-enrichment by nutrients from land-based sources (NRC, 1994; Nixon, 1995; Carpenter et al., 1998). This is particularly due to the dramatic increase (doubling on a global basis within a human generation) in the loading of the terrestrial environments with fixed nitrogen from chemical fertilizers, leguminous crops, and combustion of fossil fuels (Vitousek et al., 1997a,b). While eutrophication has produced deleterious results in the coastal ocean around developed nations where nitrogen loadings have increased 5- to 10-fold or more (Howarth et al., 1996), the need for agricultural production to feed growing populations and lifestyles elsewhere suggests a similar fate for developing nations (Nixon, 1995). Dealing with coastal eutrophication is a particularly challenging problem for ocean governance and science. The causes and solutions often lie far from the ocean, involve multiple political jurisdictions, and are subject to many societal activities. Addressing these causes and solutions requires the contributions of many sciences, such as agronomy, meteorology, geochemistry, hydrology, and oceanography, as well as economics and other social sciences, which do not regularly interact.

7.2. Irreversible habitat degradation

Marine habitats are being degraded in terms of their ability to harbor living resources, maintain biodiversity, and support ecosystem services by a wide variety of human activities, including draining and filling of wetlands, sedimentation, reductions in freshwater inflow, trawling and other fishing activities (Kaufman and Dayton, 1997). Of particular concern are those habitats that depend on the establishment of long-lived organisms to provide the complex structure of the habitat, such as coral reefs, coastal marshes and mangroves. If damaged, they are very slow to recover. In practical terms from the human perspective such habitat degradation may be considered irreversible. While governance mechanisms have had success in limiting the direct destruction of some habitats, e.g. dredging and filling of wetlands, habitats continue to degrade due to unwitting effects of human activities, including nutrient and sediment runoff, salinity changes, fishing activities, introductions of alien species, and climate change. Science must play a more effective role in governance by describing the mechanisms and consequences of habitat degradation and, where possible, developing methods for habitat restoration.

7.3. Sustainable exploitation of living resources

Two-thirds of the major world marine fish resources are fully exploited, overexploited or depleted (Vitousek, et al., 1997b). In many cases, resources became overexploited despite the availability of fairly accurate scientific assessments of stocks (Botsford et al., 1997; Hanna, 1999). Furthermore, the pressures on the remaining resources are mounting, driven by short-term economic opportunities or imperatives and accessible technologies for location and capture of fish. To reverse this trend requires not only interdisciplinary science that places the exploitation of these resources in an ecosystem context, but also new local and regional institutions and frameworks capable of integrating scientific information into political and economic decisions (Botsford et al., 1997; NRC, 1997).

7.4. Effects of climate change on ocean and coastal environments

The multinational commitments made at Kyoto for controlling greenhouse gas emissions reflect the growing scientific consensus that the world's climate is changing and that future emissions will result in significant climate changes within the next century. For the ocean environment, the role of the ocean in moderating the build up of atmospheric CO_2 and the consequences of sea level rise have attracted the most attention. But, there are likely to be many additional consequences of global climate change to marine environments, resources and their governance. For example, changing coastal currents may affect the distribution and recruitment of fish populations. Changing patterns of precipitation and runoff may affect estuarine management and strategies to control nonpoint sources of nutrients and other pollutants. As we pursue improvements in governance of estuaries, regional seas, and fisheries in the next millennium, science will be increasingly challenged by governance to predict the consequences of climate changes and develop means to cope with those changes.

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