ELSEVIER

Ecological Economics 31 (1999) 199–213

ECOLOGICAL ECONOMICS

www.elsevier.com/locate/ecolecon

ANALYSIS

The ecological, economic, and social importance of the oceans

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Received 9 January 1998; received in revised form 22 June 1998; accepted 23 February 1999

Abstract

The oceans have long been recognized as one of humanity's most important natural resources. Their vastness has made them appear to be limitless sources of food, transportation, recreation, and awe. The difficulty of fencing and policing them has left them largely as open access resources to be exploited by anyone with the means. However, in recent times we have begun to reach the limits of the oceans and must now begin to utilize and govern them in a more sustainable way. This paper summarizes emerging information on the interrelated ecological, economic, and social importance of the oceans, and on developing institutions for their sustainable governance. In addition to their traditional importance as sources of primary and secondary production, and biodiversiy, the importance of the oceans in global material and energy cycles is now beginning to be better appreciated. Integrated models of the global ocean–atmosphere–terrestrial biosphere system reveal the critical role of the oceans in atmospheric gas and climate regulation, and for water, nutrient, and waste cycling. Recent estimates of the economic value of the marketed and non-marketed ecosystem services of the oceans indicate a huge contribution to human welfare from the functions mentioned above plus raw materials, recreational, and cultural services. The oceans have been estimated to contribute a total of ~21 trillion US$/year to human welfare (compared with a global GNP of ~25 trillion US$), with ~60% of this from coastal and shelf systems and the other 40% from the open ocean, and with the oceans contributing ~60% of the total economic value of the biosphere (Costanza et al., 1997. The value of the world's ecosystem services and natural capital. Nature 387, 253-260). The social importance of the oceans for global transportation and as a unifying element in the cultures of many coastal countries cannot be overestimated. However, the cultural traditions of open access must be replaced with more appropriate property rights regimes and governance structures. Some alternative sustainable governance ideas are briefly discussed, emphasizing the need for an expanded deliberative process to develop a shared vision of a sustainable use of oceans.

Keywords: Oceans; Ecological, economic, and social importance; Sustainable governance

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PII: S0921-8009(99)00079-8

1. Ecological importance of the oceans

The fact that 71% of the earth's surface is ocean determines a significant part of its climate and ecology. The hydrologic cycle is dependent on the vast amounts of water evaporated by solar energy from the oceans and deposited as rain on the land. Without this vast reservoir of open water, the earth would quickly become a desert. The oceans also provide a sink for nutrients eroded from the land. The seas regulate the global climate by serving as an enormous thermal mass for heat storage and as a reservoir for CO_2. From a purely physical point of view, the presence of the oceans can be seen as essential for a climate on earth suitable for human life.

The seas were not always a part of the earth's surface. When the earth first formed its surface had little water or atmosphere. Early models of the formation of the earth's atmosphere were based on the idea of volcanic outgassing slowly building up a primitive atmosphere containing mainly methane, ammonia, water vapor and hydrogen (but no oxygen). As the earth cooled, the water vapor condensed and formed the early seas. More recent models hypothesize that accretion of material from impacts continued until around 4.5 billion years ago, after which the steam atmosphere which had built up rained out to form the oceans (Kasting 1993).

Life on earth probably began in these primitive seas. Although there is some controversy, the most likely scenario for the formation of life on earth has it evolving from organic molecules to primitive single-celled organisms about 3.5 billion years ago (Kasting, 1993). A key next step was the development of photosynthesis, enabling both the utilization of light energy and the production of oxygen as a by-product. Life on dry land was only possible much later after many eons of prolific photosynthetic production in the sea had increased the oxygen level in the atmosphere to something close to current levels and produced a high ozone layer to screen out damaging ultraviolet light.

After preparing the atmosphere and the land physically, the seas also contributed the genetic stock that would ultimately evolve into the enormous variety of life we now see in the terrestrial biosphere. Even now, almost all life on earth, both on land and in the seas, takes place in an internal aqueous medium, not much different from the chemical composition of the oceans. In several very real senses, the oceans are the source of all life on earth.

The oceans have been estimated to produce more than 35% of the primary production of the planet (Lalli and Parsons, 1993). But they also provide almost 99% of the 'living space' on the planet. This is true because on land, plants and animals live in a shallow vertical zone from a few meters below the surface to perhaps a hundred meters above the surface, while life in the seas extends from the surface to depths of 13,000 m. So, while the surface area of the oceans is 71% of the planet, their volume represents almost 99% of the available living space. Most of this space is only now being explored.

Some of the terrestrial life made possible by the oceans eventually made its way back to the seas as well, including a species of primate just recently arrived on the evolutionary scene. This clever primate could not only take fish and other food resources from the seas, but could also use the seas for migration and transport routes. Its success at exploiting both the oceans and the land caused the population of this species to explode, ultimately threatening its own resource base. However, more on that will be discussed later.

1.1. Science and the seas

Because of the relative vastness and inaccessability of the oceans, their scientific exploration had, in many senses, lagged behind the study of terrestrial systems. But in recent times, new monitoring and remote sensing technologies have led to an explosion of new scientific information about the oceans. Deep sea diving submersibles have allowed exploration of the deepest regions of the oceans, with the dramatic discovery of completely new life forms inhabiting deep sea thermal vents (Grassle, 1985). Satellite remote sensing has allowed the observation and mapping of the entire ocean surface. This development led to the discovery and mapping of important new features of ocean structure and circulation, such as mesoscale eddies (Brown et al., 1989) and the complex spatial patterns of marine photosynthesis (Perry, 1986).

This explosion of new information has allowed the development of sophisticated models of various aspects of the ocean system and its links to the atmosphere and terrestrial biosphere. This activity has been stimulated by growing interest in the problem of global climate change and the important role of the oceans in moderating the climate and exchanging greenhouse gases with the atmosphere.

Several large, long-term, international, interdisciplinary research projects are now underway on the oceans as part of the International Geosphere–Biosphere Program (IGBP). One example is Global Ocean Ecosystem Dynamics (GLOBEC), a program that was developed and sponsored by the Scientific Committee on Oceanic Research (SCOR), the Intergovernmental Oceanographic Commission (IOC), the International Council for the Exploration of the Sea (ICES) and the North Pacific Marine Science Organization (PICES). GLOBEC's goal is to advance our understanding of the structure and functioning of the global ocean ecosystem, its major subsystems, and its response to physical forcing, to the point where we can develop the capability to forecast the marine upper trophic system response to scenarios of global change. In pursuing this goal, GLOBEC concentrates on zooplankton population dynamics and its response to physical forcing. It bridges the gap between phytoplankton studies, such as are being pursued by projects such as the Joint Global Ocean Flux Study (JGOFS), and predator-related research that more closely pertains to fish recruitments and exploration of living marine resources. More information on these programs can be found through the IGBP web site at: www.igbp.kva.se/index.html

2. Economic importance of the oceans

The services of ecological systems and the natural capital stocks that produce them are critical to the functioning of the earth's life support system, as described above. They contribute significantly to human welfare, both directly and indirectly, and therefore represent a significant portion of the total economic value of the planet. Costanza et al. (1997) estimated the current economic value of 17 ecosystem services for 16 biomes, based on a synthesis of published studies and a few original calculations. For the entire biosphere, the value (most of which is outside the market) was estimated to be in the range of 16–54 trillion US$/year, with an average of 33 trillion US$/year. Because of the nature of the uncertainties, this must be considered a minimum estimate. Coastal environments, including estuaries, coastal wetlands, beds of sea grass and algae, coral reefs, and continental shelves are of disproportionately high value. They cover only 6.3% of the world's surface, but are responsible for 43% of the estimated value of the world's ecosystem services. These environments are particularly valuable in regulating the cycling of nutrients which control the productivity of plants on land and in the sea.

2.1. GNP versus sustainable welfare

If ecosystem services were actually paid for, in terms of their value contribution to the global economy, the global price system would be very different than it is today. The price of commodities utilizing ecosystem services directly or indirectly would be much greater. The structure of factor payments, including wages, interest rates, and profits, would change dramatically. World GNP would be very different in both magnitude and composition if it adequately incorporated the value of ecosystem services. One practical use of the estimates mentioned above is to help modify systems of national accounting to better reflect the value of ecosystem services and natural capital. Initial attempts to do this paint a very different picture of our current level of economic welfare than conventional GNP. For example, Daly and Cobb (1989) calculated an Index of Sustainable Economic Welfare (ISEW) for the US economy from 1950 to 1986 which incorporates income distribution effects, congestion effects, and the loss and damage to natural capital. Since then, ISEW has been updated for the US and calculated for several other countries. These results are shown in Fig. 1. While GNP/capita continued to rise over the entire interval for the countries shown, ISEW/capita paralleled GNP/capita during the initial period, but then leveled off and in some cases began to decline. When exactly this leveling occurred varies by country, but it has occurred in all the countries studied so far. Max-Neef (1995) has postulated that this is evidence for the 'threshold hypothesis', in which economic growth increases welfare only until a threshold is reached where the costs of additional growth begin to outweigh the benefits. ISEW, by doing a

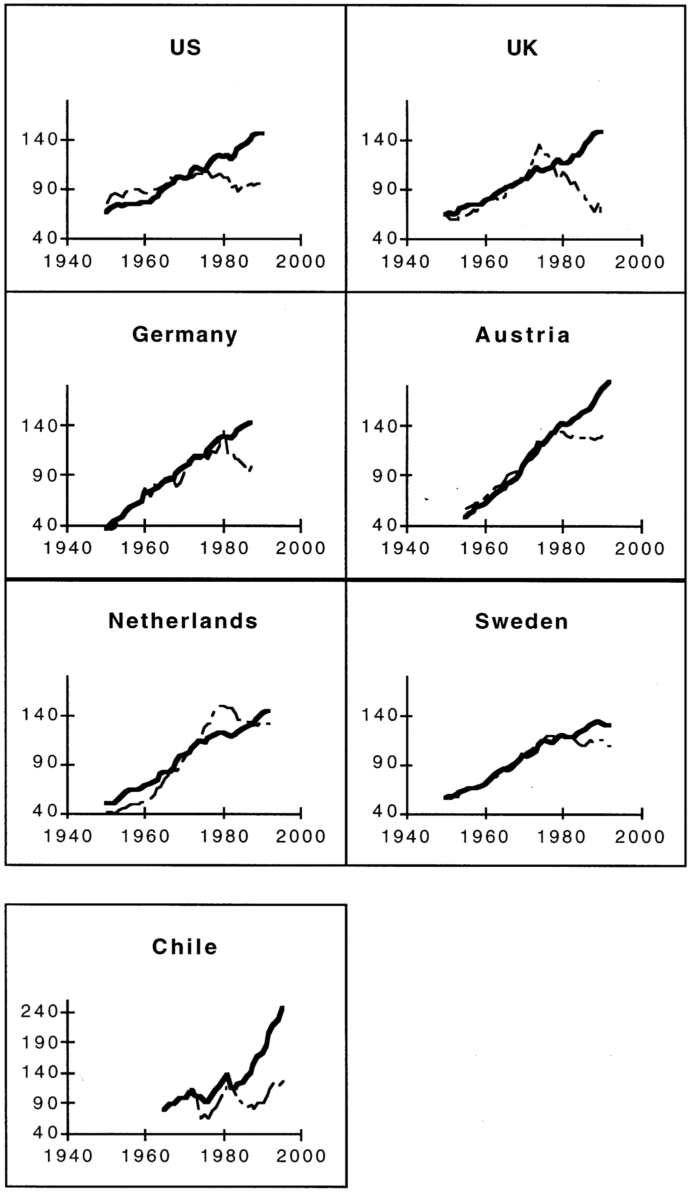

Fig. 1. Indices of GNP and ISEW (1970 = 100) for seven countries (from Max-Neef, 1995).

better job of including both the costs and benefits of growth, can clearly show when this threshold has been passed. In the US it was around 1970. In the UK it was around 1975, and in the other cases (Germany, Netherlands, Austria) around 1980.

The ISEW and similar measures are based on national accounts and do not adequately incorporate international resources like the oceans. If we have passed the sustainable threshold without even taking the oceans into account, our real position is almost certainly much worse.

3. Social importance of the oceans

The social importance of the oceans for global transportation and as a unifying element in the cultures of many coastal countries cannot be overstated. The oceans are so large that during the development of most of the world's cultures they could be considered to be almost infinite, with little risk of their overexplotation. However, the cultural traditions of open access that developed during this period are no longer adequate in the 'full world' in which we now find ourselves, where humans and their artifacts are beginning to stress the very life support functions of the biosphere. Open access to the oceans must be replaced with more appropriate property rights regimes. This has already begun to happen with the extension of territorial waters to 200 miles offshore, the law of the sea treaty, and the development of coastal zone management agencies and plans in most countries. But there is much more to be done, as outlined in Section 3.2.

First let us look at how human population and consumption of resources have changed over time.

3.1. Population and consumption

The global human population has been growing exponentially. For the first 99.9% of human history, the life support functions of the biosphere had to be shared among 10 million people at most. The human population did not reach 100 million until around 500 BC (Weber and Gradwohl, 1995). However, advances in health and

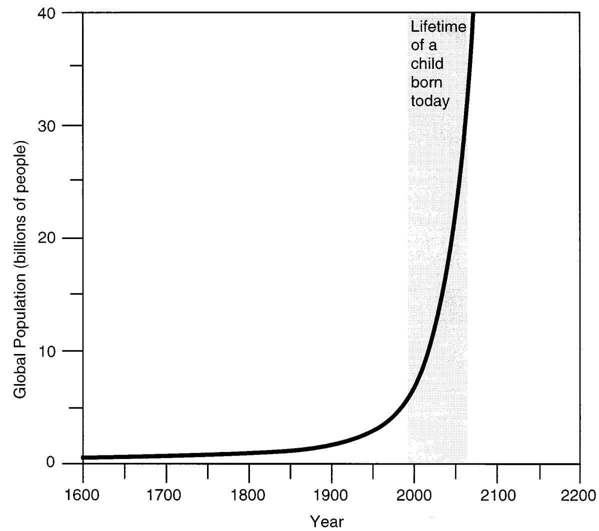

Fig. 2. Human population from 1600 to present and projected to 2100 if current fertility and mortality rates remain unchanged (after Barney, 1993).

agriculture have removed many of the natural checks on human population growth. In 1998, the life support functions of the biosphere will have to be shared among 6 billion humans. If current fertility and mortality rates were to remain unchanged, the world will have to be shared by more than 40 billion humans by the year 2100, when some of the children born today will still be alive (Fig. 2).

Many believe that a human population of 40 billion would be either unsupportable, or at least highly undesirable — given the potential implications for the average standard of living and quality of life (Barney, 1993). Of course, fertility and mortality rates are not expected to remain unchanged, but we face hard choices about both what level of human population is possible and what level is desirable.

In addition, we face hard choices about how resources are to be shared. Currently, the distribution of economic income is highly skewed in the shape of a 'champagne glass', with the richest fifth of the world's population receiving 82.7% of the world's income while the poorest fifth receive only 1.4% (UNDP, 1992).

In terms of impact on the environment and the carrying capacity of the environment for humans, the level of consumption per capita is at least as important as the total number of people. Cultural evolution has an interesting effect on human impacts on the environment. By changing the learned behavior of humans and incorporating tools and artifacts, it allows individual human resource requirements and their impacts on their resident ecosystems to vary over several orders of magnitude. Thus it does not make sense to talk about the 'carrying capacity' of humans in the same way as the 'carrying capacity' of other species since, in terms of their carrying capacity, humans are many subspecies. Each subspecies would have to be culturally and temporally defined to determine levels of resource use and carrying capacity. For example, the global carrying capacity for *homo americanus* would be much lower than the carrying capacity for *homo indus*, because each American consumes much more than each Indian does. And the speed of cultural adaptation makes thinking of species (which are inherently slow changing) misleading anyway. *Homo americanus* could change its resource consumption patterns drastically in only a few years, while *homo sapiens* remains relatively unchanged. I think it best to follow the lead of Daly (1977) in this and speak of the product of population and per capita resource use as the total impact of the human population. It is this total impact that the earth has a capacity to carry, and it is up to us to decide how to divide it between numbers of people and per capita resource use. This complicates population policy enormously since one cannot simply state an optimal population, but rather must state an optimal number of impact units. How many impact units the earth can sustain and how to distribute these impact units over the population are very dicey problems indeed.

There is also one other important complicating factor of particular relevance to the oceans. The geographic distribution of humans over the face of the earth is nowhere near homogenous. Most of the human population lives near the coast, where the impacts on the ocean environment are greatest, and this percentage is increasing.

3.2. Property rights regimes and the oceans

It is fairly easy to assign and enforce property rights to some resources and ecosystems such as agricultural fields, trees or a lake because excluding non-owners from using the resource is fairly straightforward. However, it is much more difficult to assign and enforce property rights to resources such as migrating fish populations, biological diversity, nutrient cycles, water cycles, and many other ecological services. The reason is that it is either too expensive or literally impossible to exclude non-owners from using these resources and services, partly because they are highly interconnected with other ecosystems thereby transcending several property rights regimes.

The oceans are the classic case of an open access (i.e. no property rights) resource because of their fluid interconnectedness, their vast size, and the resulting difficulty of enforcing property rights to any particular area or resource. However, even the vast oceans are gradually coming under various property rights regimes as the technology to monitor and enforce these regimes advances. The extension of territorial waters to 200 miles, the Law of the Sea, international fishing commissions, and various other institutions are beginning to establish property rights regimes on various parts of the ocean.

There is also a growing recognition that property rights regimes are complex social institutions, encompassing much more than simply establishing and enforcing boundaries (Hanna et al., 1996). These institutions must be matched to the complexity of the behavior of the ecological systems they are attempting to manage. In this regard, various forms of community ownership (such as share-based ownership of fisheries as discussed further below) are proving to be better adapted to complex systems like the oceans. The real challenge in the sustainable governance of the oceans is in designing an appropriate set of institutions, including property rights regimes and other management institutions, that can adequately deal with the complexities of both the ocean system itself and the humans involved.

4. Sustainable governance

The special characteristics of the oceans mentioned above lead to several unique problems that need to be addressed if the oceans are to be governed sustainably. These include:

1. The open access and common property characteristics of the oceans requires that special measures need to be taken to regulate access. Some possibilities are discussed below.
2. The role of the oceans in the global ecological system, as discussed above, favor a tendency to free ride on conservation issues. This means that some countries or actors can benefit from the system without having to pay the cost of using it.
3. The intergenerational and interspatial effects of the use of ocean resources result in a tendency to ignore effects that might be distant in time and space. There is a need to change the way such effects are handled.
4. The impact of human activity on the oceans is subject to fundamental uncertainty about the behavior of the system, partly because of its complexity. This calls for new models of decision-making and different management rules based on maintaining the system within sustainable bounds and on exercising the precautionary principle in order to keep uncertainty within acceptable limits.
5. All of the above lead to 'market failure.' Hence, market prices are inadequate measures of the social value of ocean assets and require corrective incentives to guide behavior.
6. Relative poverty is exacerbated by forms of globalization which ignore environmental externalities. Ocean use is particularly susceptible to this problem.

Several principles of sustainable ocean governance have been developed (Costanza et al., 1998). Below are some ideas about how to implement these principles.

4.1. The deliberative process in governance

What we are learning about the change process in various kinds of organizations and communities is that the most effective ingredient to move change in a particular direction is having a clear vision of the desired goal which is also truly shared by the members of the organization or community (Senge, 1990; Weisbord, 1992; Weisbord and Janoff, 1995).

In another context, Yankelovich (1991) has described the crisis in governance facing modern societies as one of moving from public opinion to public judgment. Public opinion is notoriously fickle and inconsistent on those issues for which the public has not confronted the system level implications of their opinions. Coming to judgement requires the three steps of: (1) consciousness raising; (2) working through; and (3) resolution. A prerequisite for all three of these steps is breaking down of the gap between expert knowledge and opinion and the public—a breaking down of what Yankelovich calls the 'culture of technical control'. Information in the modern world is compartmentalized and controlled by various elites who do not communicate with each other. This allows experts from various fields to hold contradictory opinions and the public to hold inconsistent and volatile opinions. Coming to judgement is the process of confronting and resolving these inconsistencies by breaking down the barriers between the mutually exclusive compartments into which knowledge and information have been put. For example, many people in opinion polls are highly in favor of more effort to protect the environment, but at the same time are opposed to any diversion of tax revenues to do so. Coming to judgement is the process of resolving these conflicts.

According to Yankelovich, one of the most effective ways to start the dialogue and move quickly to public judgement is to present issues in the form of a relatively small number of 'visions' which lay bare the conflicts and inconsistencies buried in the technical information. The decisions we face today about the future of the oceans (and the planet as a whole) are by far the most complex we have ever faced, the technical information is daunting (even to the experts), and we have very little time to come to public judgement. Integrated, participatory modeling and analysis of the problems is one way to pull the disparate bits of the problem together into a coherent picture that can help move to judgement (van den Belt et al., 1997).

How does one integrate these goals and visions and their related forms of value into a social choice structure which preserves democracy? A two-tiered conceptual model (Norton et al., 1998) makes value formation and reformation an endogenous element in the search for a rational policy for managing human activities. Fig. 3 outlines this process. Tier 1 is the 'reflective' level, where social discourse and consensus is built about the broad goals and visions of the future, and the nature of the world in which we live. This consensus then motivates and mediates the second, or 'action' tier, where various institutions and analytical methods are put in place to help achieve the vision. There is feedback between the two tiers and the process of envisioning, goal setting, and value formation is an ongoing and critical one. There is a critical connection between value formation and decision-making, but the very existence and necessity of tier 1 is often ignored. The 'culture of technical control' (Yankelovich, 1991), which dominates our current social decision making, views the problem as merely a tier two implementation of fixed values.

Conventional social choice theory has, in general, also tended to avoid this issue of the connection between value formation and the decision-making process. As Arrow (1951, p. 7) put it: 'we will also assume in the present study that individual values are taken as data and are not capable of being altered by the nature of the decision process itself.' However, this process of *value formation through public discussion*, as Sen (1995) suggests, is the essence of democracy. Or, as Buchanan (1954, p. 120) puts it: 'The definition of democracy as 'government by discussion' implies that individual values can and do change in the process of decision-making.' Limiting our valuations and social decision making to a fixed set of goals based on fixed preferences prevents the needed democratic discussion of values and future options and leaves us with only the 'illusion of choice' (Schmookler, 1993).

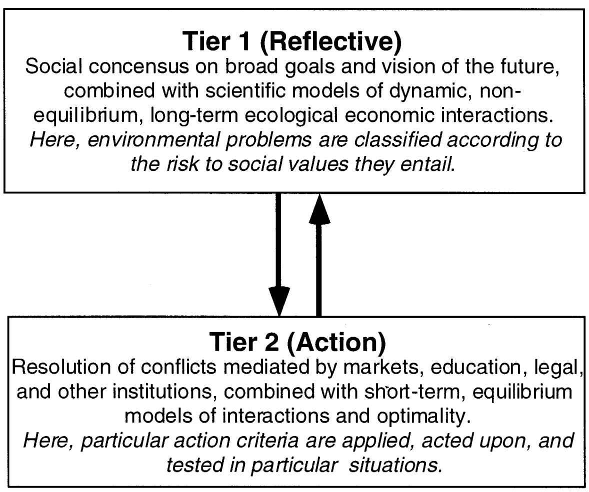

Fig. 3. Two-tiered social decision structure (from Norton et al., 1998).

4.2. Integrated ecological–economic modeling and assessment

Once the goal of ecological sustainability has been established in tier one, addressing it in tier two requires a large measure of scientific assessment and modeling (Faucheux et al., 1996). The process of integrated ecological economic modeling can help to build mutual understanding, solicit input from a broad range of stakeholder groups, and maintain a substantive dialogue between members of these groups. In the process of adaptive management, integrated modeling and consensus building are essential components (Gunderson et al., 1995).

A recent SCOPE project on Integrated Ecological Economic Modeling and Assessment (IA for short) developed the following basic framework (Costanza and Tognetti, 1996).

General principles and defining characteristics are that:

- *Predictability is limited.* We should not confuse our models of the system with reality. There is no one correct way to model the world, nor are there any absolute answers.
- There will be *multiple assumptions held by the different stakeholders* within different cultures, which will affect the articulation of visions, goals, problems and perceptions of reality.

- *Different paradigms* will be involved in shaping and interpreting problems and solutions.
- *Transdisciplinary approaches* (i.e. transcending disciplines rather than monodisciplinary or interdisciplinary) will be necessary to achieve the horizontal linkages necessary for IA.
- The IA *process is as important as the product* because it achieves participation and builds consensus and can overcome power differentials.
- *Legitimacy is derived from the process of involvement* of all stakeholders and the development of an overlapping consensus that can be used to resolve or reduce conflicts. It can also help to harmonize bottom up and top down approaches and to educate and build capacity to handle future problems.
- *Researchers are included as stakeholders*. They cannot be neutral of unbiased and must consider their own role in the process.
- It is important to acknowledge and deal with the many forms of *uncertainty* inherent in complex systems. This includes parameter uncertainty, process uncertainty, and data quality.

The framework is seen as a creative and learning process rather than as a purely technical tool — within which a well-rounded decision can be achieved through the consensus of stakeholders. Within this framework, a process consisting of 12 steps was developed to implement integrated assessment. The process assumes feedback loops from later steps to earlier steps in an adaptive management context where policy recommendations are viewed as experiments rather than as answers (Holling, 1978; Walters, 1986).

1. *Define the focus of attention*. This would likely result from a proposed development opportunity and/or an ecological concern.

2. *Identify stakeholders*. These typically would include government, business, land-owners, non-governmental organizations, funding agencies, community-based organizations, researchers, etc.

3. *Establish techniques to bring stakeholders together (e.g. roundtable)*. This step presupposes that one or more of the stakeholders has sufficient interest to draw the remaining stakeholders to a meeting. It may be that specific stakeholders need to be persuaded that it is in their best interest to convene in such a roundtable. Other stakeholders may need to convince them of the value of developing a participatory approach.

4. *Seek agreement on acceptable facilitator*. Ideally such a person should be as neutral and unbiased as possible and without a stake in the outcome of the process. The facilitator should nevertheless be committed to the process and be able to balance the differing powers of the stakeholders.

5. *Define stakeholder interests*. Ahead of the roundtable meeting, stakeholder groupings should be encouraged to meet and discuss their own interests.

6. *Hold roundtable*. The roundtable should ideally be convened jointly by several stakeholders. The agenda should include opportunities for:

- Sharing of individual visions
- Identifying complementarity and conflicts
- Agreeing that a process is necessary to address conflicts
- Seeing that integrated assessment is a way forward with the potential to develop consensus and arrive at a 'win–win' situation
- Establishing a structure for ongoing dialog including a stakeholder committee to oversee the process and feedback opportunities to the stakeholder groups and to all stakeholders collectively.

7. *Undertake a scoping exercise*. This process is necessary to identify the key issues, questions, data/information availability, land use patterns, proposed developments, existing institutional frameworks, timing and spatial considerations etc. It provides a means to determine whether a specific action will have significant effects on expressed values and to link the model with those values. This scoping exercise is also seen as building trust among the stakeholders and an acceptance of the process. The stakeholders build upon knowledge and capacity.

8. *Build and run a scoping model*. A scoping model provides a relatively quick process of identifying and building in the key components to:

- generate alternative scenarios
- identify critical information gaps
- understand the sensitivity of the scenarios to uncertainty

- identify and agree on additional work to be undertake by one or more methods of detailed modeling.

Stakeholders participate in the development of the scoping model.

9. *Commission detailed modeling*. Additional information is gathered and the chosen model(s) are modified, extended and run.

10. *Present models* and results of model scenarios and discuss findings among stakeholders.

11. *Build consensus recommendations*.

12. *Proceed with, and monitor the development* of the preferred scenario. Learn from the results and iterate the IA process as necessary. Perceptions change as things actually happen, thus the process must reflect changing values in the modeling process that can have a feedback to decisions at each step in the process. As iterations occur, the scenario conception changes, leading to new issues for resolution among groups.

4.3. New property rights regimes

There is a major challenge in designing institutions and property rights regimes that are in tune with the functions of ecosystems and the goods and services that they generate. How do we design institutions and property rights regimes that account for the complex flows and feedback between systems and that maintain the buffer capacity to ensure a continuation of these flows? Luckily, there are design principles derived from studies of long-enduring institutions that have, at least to some extent, been successful in managing ecological resources in a sustainable fashion (see e.g. Ostrom and Schlanger, 1996). The design principles include: clearly defined boundaries for the use of the resources, as well as clearly defined individuals or households with rights to harvest the resources; rules specifying the amount of harvest by users related to local conditions and to rules requiring labor, materials, and/or money inputs; collective-choice arrangements; monitoring of resource conditions and user behavior; graduated sanctions when rules are violated; conflict-resolution mechanisms; long-term tenure rights to the resource and rights of users to devise their own institutions without being undermined by governmental authorities; and for resources that are parts of larger systems appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities need to be organized in multiple layers of nested enterprises (Becker and Ostrom, 1995).

Some of the most sophisticated property rights institutions are found in areas in which these systems have developed over a long period of time, on the order of hundreds of years. Examples include Spanish huertas for irrigation, Swiss grazing commons, and marine resource tenure systems in Oceania (see Berkes, 1996). Yet other systems have collapsed and recovered over a period of time, sometimes more than once. In contrast, many traditional local communities have recognized the necessity of the coexistence of gradual and rapid change. In their institutions they have accumulated a knowledge base for how to respond to feedbacks from the ecosystem. Holling et al. (1995) argue that these societies are successful in managing their resources sustainably because they have developed social mechanisms that interpret the signals of creative destruction and renewal of ecosystems and cope with them before they accumulate and challenge the existence of the whole local community. Disturbance has been allowed to enter at smaller scales, instead of being blocked out as is often the case in contemporary society. There is culturally evolved 'monitoring' system that reads the signals, the disturbances, and thereby is more successful in avoiding the build up of an internal structure that will become brittle and invite large-scale collapse. The local institutions have evolved so that renewal occurs internally while overall structure is maintained. The accumulation and transfer of this knowledge between generations has made it possible to be alert to changes and continuously adapt to them in an active way. It has been a means of survival (Holling et al., 1995).

We can learn from those local institutions that do not undermine their existence by degrading their ecological life-support system, thereby losing ecological and institutional resilience. A major task for modern society is to find similar ways of responding to changes in ecosystems. At present there is a pervasive lack of social mechanisms for dealing with changing environmental conditions.

Sustainability requires that human social systems and property rights regimes are adequately related to the larger ecosystems in which they are embedded. Understanding the complex evolutionary dynamics of these ecosystems is essential, but we must acknowledge and deal with the inherently limited predictability of complex systems. Because our knowledge of the structure and function of ecological systems is limited, and because we do know that sustainability depends on these systems, we must take a precautionary approach to their management (O'Riordan and Jordan, 1995). Complex adaptive systems require 'adaptive management' (Holling, 1978). This means that we need to view the implementation of policy prescriptions in a different, more adaptive way that acknowledges the ever-present uncertainty and allows participation by all the various stakeholder groups. Adaptive management views regional development policy and management as 'experiments', where interventions at several scales are made to achieve understanding and to identify and test policy options (Holling, 1978; Walters, 1986; Lee, 1993; Gunderson et al., 1995) rather than as 'solutions.'

There are several recent examples of new property rights systems employing adaptive management. One particularly relevant example is the recently passed legislation in the Australian state of New South Wales (NSW) to introduce a fishery share system (New South Wales, 1994). It is similar in general form and purpose to the 'ITQ' or individual transferable quota fishery management systems found in New Zealand, Iceland, Australia, Canada and other countries, but has special design features, including the allotment of shares for 'fisheries' that include many different species (Young, 1992). The system is designed to give fishers security within the context of an adaptive resource management system designed to ensure that fishery use is sustainable and consistent with social objectives as they change through time.

Young (1998) describes the NSW share system and its relationship to quota systems as follows:

> "Most individual transferable quota regimes are for single species; accordingly, they do not encourage fishers to recognize the interdependence of species. Moreover, it is arguable that they neither create a strong sense of industry responsibility for the state of a fishery nor encourage participation in the management process. Weighing these and other considerations, the NSW system grants each fisher a guaranteed opportunity and compensative right to a proportional share of all the commercial opportunities in the fisheries they use. The term 'share' is used intentionally to stress the idea that each shareholder owns a legally enforceable share of each fishery's commercial opportunities. The legislation establishes a 'core property right' as a legally transferable entitlement to a proportional share of all the commercial fishing opportunities associated with the fishery.
>
> Wherever possible, corporate-like administrative structures are used, as these are well understood by fishers. Effectively, each person is given a guaranteed share of the opportunity set out in a periodically revised management plan for the species that comprise the fishery. Formally, each fisher is entitled to a share of any allocation of quota and gear or input restriction in proportion to the number of shares they hold. If they want to use a larger boat or bigger net, then they must buy shares from people already in the fishery. Similarly, allocation of any quota is in proportion to the number of shares held. The corporatised structure enables reference to corporate management experiences and enables both input and output controls to be varied equitably without effecting resource security."

The NSW share system's conceptual framework is of relevance to other fisheries and also many other natural resources. It represents an approach to adaptive management and common property regimes that appears to be efficient, fair, and sustainable. Because it conforms to the principles discussed above and in Costanza et al. (1998), it may be a viable model for broader ocean governance issues.

4.4. Taxes and other economic incentives

Using economic incentives to achieve environmental goals can be much more efficient than traditional command and control regulation, if the incentives can be put in place and enforced at relatively low cost. This is a key point for the oceans since one of their main characteristics has been the difficulty of monitoring and policing almost any kind of intervention. This situation is changing, however, and the time may be ripe for various kinds of economic incentives, especially if they can be incorporated into community-based management and co-management approaches as discussed above. Using self-policing, share-based common property systems and trust building mechanisms can significantly lower the costs of implementing any incentive scheme, or any direct regulation scheme for that matter.

The key point is that taxes or other economic incentives must be seen as one instrument from which the community can choose in designing its ecosystem management systems. While it is not a panacea, this instrument can be quite effective in the appropriate situations. For example, one such situation discussed recently is the idea of 'ecological tax reform'.

There is a growing consensus among a broad range of stakeholder groups in the US, and even more so in Europe, concerning the need to reform tax systems to tax 'bads' rather than 'goods'. Taxes have significant incentive effects which need to be considered and utilized more effectively. The most comprehensive proposed implementation of this idea is coming to be known under the general heading of 'ecological tax reform' (von Weizsäcker and Jesinghaus, 1992; Costanza and Daly, 1992; Passell, 1992; Repetto et al., 1992; Hawken, 1993; Costanza, 1994). Earlier discussions of similar schemes were given by Page (1977) who considered a national severance tax, and Daly (1977) who discussed a depletion quota auction.

The basic idea is to limit the throughput flow of resources to an ecologically sustainable level and composition, thus serving the goal of a sustainable scale of the economy relative to the ecosystem, a goal until recently neglected. The more traditional goal of efficient allocation of resources is also served by this instrument because it raises the tax on bads and lowers the tax on goods — it internalizes externalities. The third goal of distributive equity is both helped and hindered. Since the throughput tax is basically a capturing for public purposes of the scarcity rent to natural capital as economic and demographic growth increases its value, it has some of the equity appeal of Henry George's rent tax. However, like all consumption taxes it is regressive. This could be counteracted by retaining the income tax at the extremes — a positive income tax for high incomes, a negative income tax for very low incomes, and a negligible income tax between the extremes. Of the three major goals of economic policy (sustainable scale, efficient allocation, and just distribution) the ecological tax reform serves the first two quite well, and the third partially, requiring some supplement from an attenuated income tax structure.

The idea is to gradually shift much of the tax burden away from 'goods' like income and labor, and toward 'bads' like ecological damages and consumption of non-renewable resources.

Such a system would need three components:

1. A natural capital depletion tax aimed at reducing or eliminating the destruction of natural capital. Use of nonrenewable natural capital would have to be balanced by investment in renewable natural capital in order to avoid the tax. The tax would be passed on to consumers in the price of products and would send the proper signals about the relative sustainability cost of each product, moving consumption toward a more sustainable product mix.
2. The precautionary polluter pays principle (4P) (Costanza and Cornwell, 1994) would be applied to potentially damaging products to incorporate the cost of the uncertainty about ecological damages as well as the cost of known damages. This would give producers a strong and immediate incentive to improve their environmental performance in order to reduce the size of the environmental bond and tax they would have to pay.
3. A system of ecological tariffs aimed at allowing individual countries or trading blocks to apply (1) and (2) above without forcing pro-

ducers to move overseas in order to remain competitive. Countervailing duties would be assessed to impose the ecological costs associated with production fairly on both internally produced and imported products. Some of the revenues from the tariffs could be reinvested in the global environment, rather than added to general revenues of the host country.

Such a system would have far-reaching implications, and would simultaneously encourage employment and income, reduce the need for government regulation, and promote the sustainable use of natural resources and ecosystems. Reducing taxes on income and labor encourages employment because it reduces the cost of labor to employers. It also encourages work because it increases net pay for workers. Both are good for the economy. Taxing depletion of natural resources and pollution effectively works them into the market system so polluters and depletors pay for their actions, and have a reason to lighten their impact on the environment. Because of the revenue neutral aspect of the tax shift, it does not raise costs for business, but rather gives businesses appropriate incentives to develop new technology, improve production efficiency, and improve their environmental performance.

Such a tax shift could work well for national economies, and by extension their exclusive economic zones in the oceans. But the problem remains of what to do about the fact that the open oceans are under no country's exclusive jurisdiction. This will require new international agreements and institutions. But, as indicated above, the possibilities for using taxes and other economic incentives should be among the tools available to the international community as it begins to design a sustainable governance system for the oceans.

5. Conclusions

The oceans are ultimately the heritage of all of humanity. Their role and value in supporting human life are only now becoming fully recognized. Ecological sustainability, economic efficiency, and social fairness need to become joint objectives in order to adequately maintain the oceans as humanity's common heritage. The oceans are too important to humanity's survival to allow their continued exploitation as if they were infinite.

Governance systems, property rights regimes, economic incentives and other institutions that can adequately deal with the inherently common property nature of the oceans are sorely needed. Creative deliberation and consensus building among the various stakeholder groups is an essential, and still largely missing, element. Innovative common property regimes, like the 'share-based' fishery system in New South Wales, may provide models that take this approach and simultaneously meet the joint goals of efficiency, fairness, and sustainability.

Movement toward these goals at larger scales is being impeded not so much by lack of knowledge, but by a lack of a coherent, relatively detailed, shared vision of what a sustainable society would actually look like. Developing this shared vision is an essential prerequsite to generating any movement toward it. The default vision of continued, unlimited growth in material consumption is inherently unsustainable, but we cannot break away from this vision until a credible and desirable alternative is available. The process of collaboratively developing this shared vision can also help to mediate many short-term conflicts that will otherwise remain irresolvable. Envisioning and 'future searches' have been quite successful in organizations and communities around the world (Weisbord, 1992; Weisbord and Janoff, 1995). This experience has shown that it is quite possible to persuade disparate (even adversarial) groups to collaborate on envisioning a desirable future, given the right forum. The process has been successful in hundreds of cases at the level of individual firms and communities up to the size of large cities. The challenge is to scale it up to whole states, nations and the world, and to make it a routine part of the democratic process, as described above in the 'two-tier' decision process. This new paradigm of governance holds some promise for actually achieving the goal of sustainable governance of the oceans, and the rest of the planet as well.

Acknowledgements

This paper was originally prepared for the Independent World Commission on the Oceans, (IWOC) 14, Avenue de Joli-Mont, 1209 Geneva, Switzerland. I thank the IWOC and the Luso-American Development Foundation for supporting work on the paper. I also thank Marjan van den Belt, Don Boesch, Bobbi Low, Susan Hanna, Paula Antunes, Michael Gjerde and Charles Hall for helpful comments on earlier versions of the manuscript.

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