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COMMENTARY

Ecological economics and sustainable governance of the oceans

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Abstract

This paper is an introduction and synthesis of the papers that appear in this special issue devoted to the sustainable governance of the oceans. The special issue contains papers on various aspects of the problem, including: the

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ecological and economic importance of the oceans, the problems facing the oceans from an ecological economics perspective, the links between science and policy, the rationale for sustainable ocean governance, and examples of sustainable institutions and governance structures. We developed the 'Lisbon principles' of sustainable governance (responsibility, scale-matching, precaution, adaptive management, full cost allocation, and participation) as a core set of guidelines for sustainable ocean governance. We then describe the major problems facing the oceans in terms of how the principles are violated, and evaluate some suggested institutions in terms of how the principles are incorporated.

Keywords: World's oceans; Ecological and economics; Lisbon principles

1. Background and summary

In recognition of the fundamental importance of the world's oceans in the development of human society, the maintenance of peace, and the health of the biosphere the United Nations established the Independent World Commission on the Oceans (IWCO). The Commission seeks to:

- draw attention to relevant issues of ocean development and the direct and indirect impact of human activity on ocean resources;
- encourage the development of the ocean governance regime;
- study ways to promote the implementation of the Law of the Sea and other existing legal instruments and programs;
- examine the existing and future economic potential of the ocean;
- promote the incorporation of the marine dimension in national development plans;
- analyze the requirements of integrated coastal zone management;
- explore new forms of cooperation for technology development;
- study the threats to the seas and oceans and the sustainability of their resources and uses;
- endeavor to define ways of strengthening the institutional framework for ocean governance at various levels; and
- contribute to the development of peaceful uses of the ocean.

The emerging field of ecological economics provides new perspectives and tools that can contribute to many of the Commission's objectives. In particular it provides a framework for integration of economic uses and potentials, protection from threats from human activities, and procedures for ocean management and governance which help achieve sustainability. Towards this end the IWCO, in conjunction with the Luso-American Development Foundation sponsored a workshop of selected experts on July 7–9, 1997, in Lisbon, Portugal, to provide advice on how ecological economics could assist in reaching the goal of sustainable governance of the oceans. This paper is a synthesis of the ideas contained in the papers presented at the workshop (which are also included in full in this volume) and a summary of the consensus achieved at the workshop.

The consensus achieved includes the following major elements (each of which are elaborated more fully later in this document and in the accompanying individual papers):

1. a growing recognition of the ecological, economic and social dependence of sustainable human welfare on the oceans (Costanza, 1999);
2. a framework, based on the value of the ecosystem and other services they provide (Costanza et al., 1997a), for evaluating ocean problems including potential threats to those services (Antunes and Santos, 1999). The major problems include: (1) overfishing; (2) land-based contamination; (3) ocean disposal and spills; (4) destruction of coastal ecosystems; and (5) climate change;
3. an integrated ecological economic view of ocean governance that acknowledges the value of natural capital and ecosystem services, the large uncertainty inherent in ocean science and governance, the importance of the problem of scale mismatches between ecosystems and human governance institutions, and the limitations of current property rights regimes in

addressing ocean governance issues (Boesch, 1999; Hanna, 1999; Low et al., 1999; Wilson et al., 1999);

4. a set of six core principles for achieving sustainable governance of the oceans based on this perspective, which we call the *Lisbon principles*. They are: (1) responsibility principle; (2) scale-matching principle; (3) precautionary principle; (4) adaptive management principle; (5) full cost allocation principle; and (6) participation principle;
5. an analysis of the major problems and threats to the oceans in terms of how they violate the Lisbon principles;
6. a set of possible example solutions to the problems that represent implementation of the principles, including: share-based fisheries (Young, 1999), integrated watershed management (Boesch, 1999; Costanza, 1999), marine protected areas (Boersma and Parrish, 1999), and environmental assurance bonds (Costanza, 1999).

2. An ecological economic view of ocean governance

Sustainable governance of the oceans requires a broad, transdisciplinary perspective that can integrate across the natural and social sciences and the policy process. Ecological economics provides such a perspective (Costanza, 1991; Costanza et al., 1997b). Ecological economics has historical roots as long and deep as any field in economics or the natural sciences, going back to at least the 17th century (Cleveland, 1987; Martinez-Alier, 1987), but its immediate roots lie in work carried out in the 1960s and 1970s. Kenneth Boulding's classic, 'The economics of the coming spaceship Earth' (Boulding, 1966), sets the stage for ecological economics with its description of the transition from the 'frontier economics' of the past, where growth in human welfare implied growth in material consumption, to the 'spaceship economics' of the future, where growth in welfare can no longer be fueled by growth in material consumption. This fundamental difference in vision and world view was elaborated further by Daly (1968) in recasting economics as a life science—akin to biology and especially ecology, rather than a physical science like chemistry or physics.

The importance of this shift in 'pre-analytic vision' (Schumpeter, 1950) cannot be overemphasized. It implies a fundamental change in the perception of the problems of natural resource allocation and how they should be addressed: specifically, the focus of analysis should be shifted from marketed resources in the economic system to the biophysical basis of interdependent ecological and economic systems (Odum, 1971; Clark, 1973; Cleveland et al., 1984; Cleveland, 1987; Martinez-Alier, 1987; Christensen, 1989).

The core problem addressed in ecological economics is the sustainability of interactions between economic and ecological systems. This problem involves issues that are fundamentally cross-scale, transcultural and transdisciplinary, and calls for innovative approaches to research, to policy and to the building of social institutions (Costanza and Daly, 1987; Common and Perrings, 1992; Berkes and Folke, 1994; d'Arge, 1994; Holling, 1994). In order to achieve this 'systems' approach, ecological economics needs to transcend the normal territorial boundaries of the academic disciplines.

Ecological economics is thus not a single new discipline based in shared assumptions and theory. Rather it represents a commitment among natural and social scientists and practitioners to develop a new, pluralistic understanding of the way in which different living systems interact with one another, and to draw lessons from this for both analysis and policy. There is not one *right* approach or model because, like the blind man and the elephant, the subject is just too big and complex to touch it all with one limited set of perceptual or computational tools.

Whereas ecological economics retains some aspects of neoclassical environmental economics, and links these analytic approaches with natural science and policy, it also encourages completely new, potentially more integrated, ways to consider linkages between ecological and economic systems.

Ecological economics also focuses on a broader set of goals than do the traditional disciplines of

ecology and economics. Here, again, the differences are not so much the novelty of the goals, but rather the attempt to integrate them. Daly (1992) lays out these goals as:

1. assessing and insuring that the scale of human activities within the biosphere are ecologically sustainable;
2. distributing resources and property rights fairly, both within the current generation of humans and between this and future generations, and also between humans and other species; and
3. efficiently allocating both marketed and non-marketed (natural capital and ecosystem services) resources under the constraints of points 1 and 2 above.

As applied to ocean governance, an ecological economics perspective thus:

1. recognizes *both* the marketed and *non-marketed* values of marine natural capital and ecosystem services (Costanza, 1999). A major question that can be posed by ecological economics is: to what degree do impacts created by human activities, which are often externalized from economic and political decisions, interfere with marine ecosystem services and thereby reduce their value to human society (as embedded in the larger matrix of the biosphere);
2. acknowledges the large degree of uncertainty inherent in ocean science and governance, and attempts to communicate and deal with it rather than ignore it (Boesch, 1999);
3. advocates a broad systems view that incorporates not only the complex dynamics of the natural system, but also the interactions between natural systems and human stakeholders and governance institutions;
4. acknowledges the importance of scale (physical, temporal, institutional, etc.) and the importance of choosing the appropriate level(s) of decision making. Scale mismatches between ecosystems and human governance institutions are at the root of many ocean management problems (Low et al., 1999; Wilson et al., 1999). This is also related to stakeholder involvement and the notion that rights to use ecosystem services come with attendant responsibilities to use them efficiently, fairly, and sustainably;
5. recognizes the limitations of current property rights regimes in addressing ocean governance issues and advocates regimes that are better able to match the scale and complexity of the ecosystem itself (Hanna, 1999);
6. advocates integrated assessment and modeling as a way to bring all of these considerations into the analysis and move beyond the linear, and often incomplete, mode of much current planning, decision making, and management. Adaptive management (which views policy making as an iterative experiment rather than a static answer) is seen as a more appropriate approach (Holling, 1978).

3. Lisbon principles of sustainable governance

Based on these considerations, we formulated and adopted six principles that embody the essential criteria for sustainable governance.[1] Some of them are already well-accepted in the international community (i.e. the precautionary principle). Others are variations on well-known themes (i.e. the scale-matching principle is an extension of the subsidiary principle). Others are new (i.e. the adaptive management principle). They are seen as forming an indivisible collection of basic guidelines governing the use of all environmental resources, including but not limited to marine and coastal resources.

3.1. Responsibility principle

Access to environmental resources carries attendant responsibilities to use them in an ecologically sustainable, economically efficient, and socially fair manner. Individual and corporate responsibilities and incentives should be aligned with each other and with social and ecological goals.

[1] A short summary of the Lisbon principles and their relevance to ocean governance also appeared as Costanza et al. (1998).

3.2. Scale-matching principle

Ecological problems are rarely confined to a single scale. Decision-making on environmental resources should: (1) be assigned to an institutional level or levels that will maximize information about the relevant ecological system and recognize that ecological information needs to flow between them; (2) take ownership and actors into account; and (3) internalize costs and benefits. The appropriate scales of governance will be those which have the most relevant information, can respond quickly and efficiently, and are able to integrate across boundaries.

3.3. Precautionary principle

In the face of uncertainty about potentially irreversible environmental impacts, decisions concerning the use of environmental resources should err on the side of caution. The burden of proof should shift to those whose activities potentially damage the environment.

3.4. Adaptive management principle

Given that some level of uncertainty always exists in environmental resource management, decision-makers should continuously gather and integrate appropriate ecological, social, and economic information with the goal of adaptive improvement.

3.5. Full cost allocation principle

All of the internal and external costs and benefits (social and ecological) of alternative decisions concerning the use of environmental resources should be identified and allocated. When appropriate, markets should be adjusted to reflect full costs.

3.6. Participation principle

All stakeholders should be engaged in the formulation and implementation of decisions concerning environmental resources. Full stakeholder participation contributes to credible, accepted rules that identify and assign the corresponding responsibilities appropriately.

The following questions are provided to assist in the interpretation and application of the principles and should be answered in connection with any decision concerning environmental resources.

1. Have the full costs and benefits (including social and ecological) been identified?
2. Are individual incentives aligned with social and ecological goals?
3. Have all of the actors been identified to whom these costs and benefits accrue?
4. Have all of the stakeholders been engaged in decisions?
5. Are the costs fairly reflected in the prices, charges, and levies paid by beneficiaries?
6. Does the decision-making process adequately internalize costs and benefits?
7. Have the major sources of uncertainty (ecological, social, and economic) been identified?
8. Has a process been established to monitor new information periodically, and to use that information to revise the course of action?

4. Threats to the oceans evaluated according to the principles

The major problems facing the oceans have been summarized by Antunes and Santos (1999) as: (1) overfishing; (2) ocean disposal and spills; (3) the destruction of coastal ecosystems; (4) land-based contamination; and (5) climate change. These range from traditional ocean resource management issues to ever-broader ecological and social system management issues. In Table 1 we array these threats against the major categories of marine ecosystem services identified in Costanza et al. (1997a). For simplicity, we grouped these ecosystem services into six major categories: (1) gas and climate regulation; (2) disturbance regulation/erosion control; (3) nutrient cycling/waste treatment; (4) biological control/habitat/genetic resources; (5) food/raw materials production; and (6) recreation/culture. To these categories we added a seventh important category of value of the oceans not considered an 'ecosystem service.' This is the oceans' role in transportation and

Table 1
Direct effects of problems identified by Antunes and Santos (1999) on ocean goods and services as modified from Costanza et al. (1997a)

Marine and coastal wetland ecosystem services[a]	Estimated annual value of service in billion $US/yr[b]	Problems				
		Overfishing	Land-based contamination	Ocean disposal and spills	Destruction of coastal ecosystems	Climate change
Gas and climate regulation/erosion control	1272		Nutrient inputs affect C sinks	Affects productivity and C uptake		Affects heat content, current patterns
Disturbance regulation/erosion control	575		Loss of coral reefs		Changes in coral reefs, wetlands, shorelines	loss of coral reefs
Nutrient cycling/waste treatment	16 432	Affects top-down control of nutrient cycling	Overloading assimilative capacity		Loss of wetlands affects nutrient cycling and waste treatment	Changes in runoff and delivery of nutrients and wastes
Biological control/habitat/genetic resources	335	Affects food chains and structure, diversity and resilience	Degrades habitats, reduces diversity	Mortalities, alteration of habitat	Reduces habitats' carrying capacity, biodiversity	Changes temperature, sea level, currents, storms, runoff
Food/raw materials production	902	Reduces stocks	Reduces fisheries and poses health risks		Loss of critical habitat and alteration of food chains	Affects productivity
Recreation/culture	3077	Less recreational resource; artisanal cultures	Risks public health	Fouls beaches, reduces aesthetic values	Diminished resources, recreational value, sense of place	Displaced coastal populations
Transportation/security					Exposure and siltation of ports, loss of navigational access	Affects storm frequency and severity, sea level

[a] Marine and coastal wetland systems include open ocean, estuaries, seagrass/algae beds, coral reefs, marine shelf, and tidal marsh/mangrove ecosystems (from Costanza et al., 1997a). Their total global area is 36.5 billion ha (about 71% of the total global surface area). The services are aggregations of the 17 services given in Costanza et al., (1997a) into the first six groups with the addition of transportation/security services.

[b] From Costanza et al. (1997a). These estimates represent minimum values. Transportation/security services were not evaluated.

security. We can then examine how the current problems confronting the oceans affect the value of these seven categories of ocean services. Table 1 thus provides a framework for incorporating ecological economic assessments into sustainable management strategies. Within Table 1, the services which may be significantly affected by the problems are identified and briefly summarized in the body of the table. The threats to the oceans can now be analyzed in terms of the extent to which they violate the six Lisbon Principles.

4.1. Overfishing

Of 200 major fish stocks accounting for 77% of world marine landings, 35% are currently classified as overfished (Botsford et al., 1997). The degree of overfishing varies by geographic area and fish stock, but overall trends indicate overfishing of demersal, highly migratory, and straddling stocks. Currently, overfishing is diminishing the production of fish as food, limiting the economic productivity of fisheries, restricting subsistence and recreational uses, and reducing genetic diversity and ecological resilience.

Overfishing has multiple causes which vary by fishery, but usually involve violations of one or more of the Lisbon principles.

1. *Responsibility principle*: fishing is often treated as a right without attendant responsibilities. Individual incentives are not aligned with social goals. For example, under open access, the right to fish is accorded to anyone, and individuals are encouraged by the incentives of open access to capture as many fish as possible in as short a time as possible.
2. *Scale-matching principle*: fishery management decisions are often made at scales that do not incorporate all sources of ecological information, focus on user groups rather than public owners, and fail to consider all costs and benefits. For example, the process of setting a total allowable catch (TAC) may ignore seasonal differences in fish availability within a management area, focus on benefits to user groups rather than benefits to public owners, and ignore costs (such as by-catch) imposed on other parts of the ecosystem and at a different scale.
3. *Precautionary principle*: pressures within fishery management lead to decisions that err on the side of risk rather than caution. For example, when setting a TAC decision makers often choose the higher number over the lower number, even in the face of large uncertainty in biomass estimates. This outcome is due in part to industry overcapitalization that creates high opportunity costs when the expensive fishing boats are idle.
4. *Adaptive management principle*: fishery management decisions tend to be based upon a limited range of data, with few specific mechanisms for monitoring outcomes. In general, data on the biological status of stocks, typically fraught with uncertainty, nevertheless are more available than economic, social, or ecological data. Experimental and learning approaches to management for the purpose of learning (thus reducing uncertainty) are often prevented by rules designed to protect the integrity of the management process.
5. *Cost allocation principle*: the costs and benefits of fishery management actions are frequently under-identified. For example, an assessment of the effects of a regulation on related fisheries or on other ecosystem services typically is not included in analyses supplied to decision-makers.
6. *Full participation principle*: the level and quality of stakeholder participation in fishery management varies widely, as does the definition of 'stakeholder.' Participation varies from passive consultation to shared decision making authority. The definition of stakeholder usually includes target user groups, but often excludes representatives of environmental interests, alternate users, or the public at large. In general, fisheries that suffer from overfishing do not engage all the stakeholders, (although full participation by itself is not a panacea for overfishing).

4.2. Water contamination

Water contamination spans a broad spectrum of insults, from small-scale (e.g. an individual pouring unused paint thinner down the drain) to

increasingly larger scales (e.g. domestic, municipal, and industrial discharges, or nutrient runoff from agricultural and deforestation practices). Further, effects may be conservative and accumulative, as in the case of chemical contaminants, or non-conservative and dispersive, as in the case of unintended introductions of exotic species through ballast water discharge. Contamination can directly and indirectly impact the ecology, society and economy of the affected area(s).

The problems associated with water contamination violate, to varying degrees, each of the six Lisbon principles.

1. *Responsibility principle*: there is a clear breach of the responsibility principle, which calls upon emitters to consider the impacts of their actions on sectors other than their own. At present, responsibility generally is attempted by punitive (regulatory enforcement) measures, rather than with incentives.
2. *Scale-matching principle*: there is presently a lack of 'scale-matching', because actions taken at local scales (such as fertilizer use) affect ecosystems at other scales, and are governed by institutions at other scales (county, state, or federal governments). Furthermore, cumulative impacts, which translate over a range of spatial and temporal scales, rarely are recognized by management institutions.
3. *Precautionary principle*: even though most of the impacts of water contamination are unknown or uncertain, there is generally the presumption of innocence on the part of emitters, thus violating the precautionary principle.
4. *Adaptive management principle*: the current system does not recognize the environment as a dynamic system, and the need for continual updating of information, for example, as regulations are imposed and the system responds.
5. *Cost allocation principle*: the act of contamination without attendant costs externalizes the emitter's costs. Whereas this is a short-term 'win' for the emitter, in the long run it usually creates a collective loss for the community, as ecosystem integrity is weakened or dissolves.
6. *Full participation principle*: lack of trust and cooperation among interest groups leads to lack of participation. Many times this is reinforced by inadequate communication, by lack of recognition of important participants (actual or potential) in causes or effects of contamination, or simply by personal or social conflicts.

4.3. Oil spills

Oils spills can occur as rare, dramatic events such as in the case of the Exxon Valdez. The effects are both acute and long lasting. Smaller events occur far more frequently as a result of releases of ballast water by tankers. Although we recognize that oil as a non-renewable energy source can be discussed in light of violating the principles, we focus on the spilling of oil in the marine environment.

1. *Responsibility principle*: the responsibility principle suggests that ocean-going transportation should come with the responsibility of minimizing the impacts of oil transport and transfer.
2. *Scale-matching principle*: at present, decision power is quite concentrated. The scale-matching principle suggests that other actors should be taken into account. Thus, coastal communities which potentially might be victims of oil spills should be involved in planning for spills and damage prevention, and this involvement should span a range of institutional scales.
3. *Precautionary principle*: this principle is obviously violated, because oil spills represent a clear case of uncertain events for which adequate precautions have not been taken. Well-known remedial measures, such as use of double-hulled vessels, reduce impacts in the face of uncertainty.
4. *Adaptive management principle*: even though many tankers have segregated ballast rooms, oil spills as a result of the dumping of ballast water still occur. Oil-fouled penguins frequently turn up on beaches, e.g. along the Patagonia coast, as a result of encountering contaminated ballast water. Under the principle of adaptive management, different approaches could be designed to mitigate these effects. The experiments potentially can be linked to fishing moratoriums in order to en-

hance reproductive success of organisms severely affected by both oiling and fishing side effects, as is the case for penguins.
5. *Cost allocation principle*: in the case of oil spills, the costs of damaging natural capital are not borne by those causing the damages, in violation of the full cost allocation principle. Typically this is because of the difficulty of assessing the true costs of the damage, either because the values of damaged ecosystems cannot be put into monetary terms, or because the damages may be transferred into the future (for instance, as loss of critical habitat for sensitive life stages of organisms, which may not be obvious at the time of the spill because it occurs at a different time).
6. *Full participation principle*: oil transportation decisions usually do not take into account other coastal stakeholders (for example, fisheries and tourism) in violation of the participation principle.

4.4. Disruptions of coastal ecosystems

Disruption of coastal ecosystems results in several of the Lisbon principles being violated. In general, disruptions of coastal ecosystems will become manifest at a relatively late stage of ecosystem abuse, as impacts that affect the functions of large, coastal ecosystems typically accumulate and act as long-term stressors. Often it is the case that populations of aquatic organisms respond more rapidly and directly to anthropogenic disturbances (Schindler, 1987, 1990) so that ecosystem functional disruptions may indicate a long history of chronic disturbance that may be difficult to undo.

1. *Responsibility principle*: the responsibility principle is violated when parties are allowed to cause damage to coastal ecosystems without mitigation or recompense. This happens easily with sprawled activities where many individuals are involved.
2. *Scale-matching principle*: because the impacts of many activities are cumulative from relatively small sources (for instance, siltation from eroding fields, nutrient runoff, septic tank failure, etc.), or are transferred over space and time (e.g. atmospheric deposition of nitrogen), the scale-matching principle is violated as it becomes difficult to control and regulate the sources of trouble at appropriate scales or one particular scale.
3. *Precautionary principle*: the precautionary principle is often violated as a result of a lack of coordination and planning. It is hard to see the bigger picture for individual operations contributing to coastal disruption.
4. *Adaptive management principle*: coastal ecosystem structure and function will have to be monitored in order for adaptive management procedures to be designed. Indicators will have to evolve over time.
5. *Cost allocation principle*: the principle of full cost allocation is often difficult to fulfill because it may be (a) hard or impossible to identify all the costs and benefits; or (b) hard or impossible to determine all those who should bear the cost and who benefits (violation of the participation principle).
6. *Full participation principle*: residents of the coastal zone have no part in decisions up stream (about fertilization), but pay the costs down stream (of eutrophication and siltation).

4.5. Climate change

The oceans play an important role at the level of the global earth system. There are concerns about the possibility that climate change could cause significant changes to global ocean currents. Currents help to cool the atmosphere by bringing cold water from the deep oceans to the surface and conveying warmer surface to deep oceans where it is able to cool. The relation between ocean currents and climate is illustrated by the so-called El Niño Southern Oscillation (ENSO) which occurs in the Pacific Ocean off the coast of South America. ENSO has caused unusually hot and dry summers as far afield as Washington, DC and Jakarta.

Conventional climate discourses usually place responsibility for climate change on the historical greenhouse gas emissions from the industrialized world. However, the emissions from the less-industrialized countries are rapidly catching up and

will soon exceed those of the North. On a per-capita basis, the individual emissions from Northern citizens are much higher than those of the South.

Two-thirds of the world's population lives in coastal zones. They rely on their proximity to the oceans indirectly and directly for the maintenance of their ways of life. Indirectly, proximity to the ocean provides benefits such as the moderation of harsh climates and the fertility of deltaic regions. Oceans directly provide food, transportation, and recreation (including tourism). Climate change is likely to affect coastal zones in several ways. It will probably:

- alter the patterns of precipitation feeding freshwater to estuaries and river deltas;
- directly warm coastal waters;
- lead to increased frequency and severity of extreme weather events;
- change the shape of the coastline through sea-level rise.

Hence, climate change is likely to be the source of additional stress on ecosystems whose capacities to provide both sinks and extractive resources are already stretched.

1. *Responsibility principle*: the responsibility principle is violated in complex ways in the case of climate change and the oceans. The criterion of economic efficiency would suggest that actions taken in less-industrialized countries should be a priority, but the criterion of individual responsibility suggests that actions should be taken first in the industrialized countries. Attempts to reconcile these approaches through actions financed by the North but implemented in the South have run into significant political opposition in both industrialized and less-industrialized countries. Whatever the distribution of the blame for increased atmospheric concentrations of greenhouse gases, the blame for increasing the vulnerability of both human and natural populations to climate change does not merely depend on changes in the climate, such as temperature, or even of less direct impacts' such as sea-level rise. Vulnerability depends also on the resilience of the systems that are affected by climate. In the case of densely populated coastal zones, responsibility for their vulnerability to climate is clearly local as well as global. Significant responsibility for the severity of climate impacts on coastal zones therefore lies with the human populations that inhabit them. However, these populations are often poorly placed to exert decision making authority over issues that profoundly influence coastal ecosystem health, such as land-use practices upstream of coastal rivers, and ocean dumping of pollutants.
2. *Scale matching principle*: at first sight the scale-matching principle seems to suggest that earth-system issues should be dealt with by international bodies and coastal zone management by local, national, or regional decision makers. However, the issue of scale is much more complex. At the global level, the traditional model of environmental management is gradually giving way to recognition that the realities demand a somewhat different model of decision making and implementation — a model of environmental governance. Although international bodies, and even national governments can provide normative or legal frameworks for action, in the final analysis, it is families, firms, and communities that emit greenhouse gases. Furthermore, the actions leading to such emissions are varied and often very basic to the daily lives of people, such as preparing food, heating and cooling homes and workspaces, and providing transportation. In any case, even prompt and effective action to reduce emissions at the global level would still leave the earth with a commitment to some warming. For example, during the decade since the Toronto Conference at which 20% emissions reductions were first proposed, the so-called radiative forcing (the heating effect at the earth's surface) has increased by about half a Watt per square meter — about one-third of the total warming since the beginning of the industrial revolution. In other words, local actions to increase the resilience of coastal populations, human and natural, to climate impacts must be a priority. Such actions are more likely to be successful to the extent that they can integrate climate change

concerns with existing mainstream policy issues such as economic development and national security.

3. *Precautionary principle*: given the huge stakes involved in climate change issues, and the real possibility of damage to the ecological life support system, the precautionary principle is obviously being violated by continued high levels of emissions. The precautionary principle is often invoked in support of emissions reduction targets. However, some staunch advocates of emissions reductions have shown themselves to be reluctant to exercise precaution against the ineffectiveness of emissions reduction efforts. As we point out in the previous section, global warming has accelerated during the 10 years during which emissions reductions have been under consideration. During the 1990s, only Britain and Germany have met voluntary targets to return emissions to 1990 levels and their achievements are only coincidental side-effects of political events entirely unconnected with climate change. The high concentration of human population in coastal zones and the particular vulnerabilities of coastal ecosystems suggests that remedial and precautionary efforts directed towards overfishing, land-based contamination, ocean disposal and spills, and destruction of coastal ecosystems, will have high payoffs in the face of the climate change we can expect over the next century.
4. *Adaptive management principle*: climate change has not been handled from an adaptive management perspective. Particularly in the face of climate change impacts (but also even if there were no climate change) the growing population density along the coasts will put further pressure on the resource base, including ocean fishing, wetlands-dependent products, and unique ecosystems and species. This pressure will likely result in deteriorating living conditions for many inhabitants, especially in less industrialized countries. Hence, there are strong imperatives to adopt integrated coastal zone management strategies of which adaptive management should be a part that will combine responses to growing demands on coastal and ocean resources and the threat of climate change.
5. *Full cost allocation principle*: when it comes to climate change all of the costs and benefits are certainly not allocated properly. Some of these costs and benefits can be easily identified, but they are not borne by the appropriate parties. Other costs and benefits, which are more difficult or impossible to quantify, are even more assuredly not being borne by the appropriate parties. At the local level, when markets are not operating effectively to internalize costs, the kindergarten principle that each family, firm, or community should clean-up after itself can still be made operational through community agreement, monitoring, and enforcement, as occurs in effective common-property management regimes. However, climate change highlights many of the problems encountered at the macro level in valuing nonmarket goods. The problem of factoring loss of human life into cross-national climate change damage estimates has been the subject of acrimonious controversy. Hurricanes in Florida are expensive, but deaths are few. Cyclones in Bangladesh cost little in property damage, but claim many lives. One thing is clear, however, small island nations and poor countries with large, densely populated low-lying coastal areas are likely to suffer disproportionately from climate change impacts.
6. *Participation principle*: the full range of stakeholders are obviously not participating in climate change problems. The adaptive coping abilities of coastal, often rural, and often nonliterate people have enabled their survival under stress. They have detailed knowledge of local conditions and past responses, as well as the complex and varied patterns of ownership and use of marine and coastal resources. In the policy hierarchy they seldom receive their due recognition or participation. Consultative and participatory approaches that bring local stakeholders into both analysis and decision making offer challenges and opportunities for both analysis and decision making.

5. Applying the principles to find solutions

Several instruments can be used to solve the problems outlined above, as summarized in Antunes and Santos (1999). Below we highlight, by way of example, a few cross-cutting strategies that can incorporate many of the Lisbon principles simultaneously. Achieving sustainable governance of the oceans will require an ongoing, participatory and open process involving all the major stakeholder groups (the participatory principle) and will require integrated assessment and adaptive management (the adaptive management principle). The examples below could form an important starting point and input to that process.

5.1. Share-based fisheries

Fisheries management has traditionally been carried out on a species-by-species basis with little regard to: (1) interactions with other species or ecological effects at relatively small scales, even for the species of concern; and (2) the pattern of individual incentives created by regulation. 'Share based' fisheries and co-management schemes might remedy these problems.

Initial steps in this direction have been taken with the creation of systems of individual transferable quotas or ITQs. The ITQ system is one in which the individual harvester is given a tradable right in a share of the annual quota for a single species fishery. In other words, if a harvester holds a 1% share, each year the harvester is entitled to harvest 1% of whatever the quota happens to be that year. Quota rights generally can be leased or sold. ITQs have had very positive economic effects. Compared with open access quota fisheries, ITQs have eliminated the 'race for fish' and the excessive levels of capitalization that result. ITQs also give their owner an asset whose value is tied to the value of the resource. In theory this should provide a strong incentive for conservation, but in practice it is not yet clear whether other conflicting micro-incentives (re: resource uncertainties, enforcement, employees, etc.) minimize the actual conservation effects. And, of course, ITQs are single species schemes that tend to treat the species as if it existed in an ecological vacuum.

Alternatives to ITQs are beginning in a number of locations (the papers by Wilson et al., 1999 and Young, 1999 report on two of these experiments).

The New South Wales (NSW, Australia) system described by Young (1999) is a flexible adaptation of an ITQ system. Unlike an ITQ system, the NSW system is applied to broadly defined fisheries that might include a number of component fisheries defined in terms of species, gear types and areas. In this system harvesters will be given rights based on past fishing experience; these rights will be tradable perpetual shares in the broadly defined fishery. In quota managed component fisheries these shares translate into the equivalent of an ITQ, and in non-quota fisheries the shares provide the basis for participation. For example, the plan for a non-quota fishery with a particular gear type may stipulate that 15 000 shares (in the broadly defined fishery) are required to operate a 6 m vessel in that component fishery; that is, stipulations on participation in any component fishery may be stated in terms of inputs as well as outputs with either translatable into shares in the broader fishery. Shares in the system are strictly limited, as in a corporate setting, and entry is possible only by purchasing existing shares.

A unique aspect of the NSW scheme is the system of continually revised plans and contracts and the option of 'drop through' provided to harvesters. Plans for each fishery, including terms for individual contracts, are initiated by the managing agency. Contracts extend for 10 years but are renewable every 5 years; however, when a new plan/contract is initiated, harvesters have the ability to reject the plan and continue operations for up to 5 years under their old contract. The contract stipulates the conditions under which users are permitted to exploit the fishery. This provides users with considerable negotiating leverage at the time of contract renewal and is designed to assure local user input. It is expected that the shares/contract approach will enable a flexible management system that is able to evolve continuously, but in an orderly fashion.

The system under development in the state of Maine (USA) has similar objectives to the NSW scheme; it is based upon the premise that harvesters recognize their collective dependence upon sustainable resources, but lack the governing institutions required to achieve that collective end. Consequently, the Maine system is designed as an ecosystem governance scheme in which the authority for fishery rule making is divided among local, regional and statewide elected representative bodies of users. The principle of subsidiarity is used to assign authority to the different governance levels; that is, rule making authority is taken to the lowest level at which it can be expected that the costs and benefits of the rule are contained within the jurisdiction of that authority. As a consequence, rules whose direct ecological and economic effects are felt throughout the fishery are made at the statewide level; rules whose direct and preponderant impact is at the local level are made at that level. A primary advantage of this division of authority is the ability to address a great deal of local ecological and fishery-specific detail that would overwhelm a centralized system.

Unlike the NSW system or ITQs, the Maine system does not place strict limits on entry nor does it create a tradable individual right. Instead the system depends upon an apprenticeship program of 2 years; the program is designed to slow or eliminate the periodic spurts of entry that appear to be responsible for most new effort and, equally, to create a long-term personal commitment to the health of the resource. As in the NSW system, the Maine system will cover the entire range of species. An overall license is required for participation in any fishery and in addition a person must hold a card for particular component fisheries, but not for all. For example, of the, say, ten component fisheries covered by the overall license a person may hold cards for only four. If the person wishes to participate in another fishery, the card for participation in one of the four currently used must be given up. Rules governing the timing and amount of movement between component fisheries are made at the state level. The purpose of this licensing scheme is to provide the traditional flexibility required by inshore harvesters, but at the same time to restrain movement when necessary to avoid boom and bust responses to the natural variability of the various stocks.

1. *Responsibility principle*: share-based, fishery approaches tend to create local level management institutions to supplement existing 'top down' management structures. In these new institutions fishermen are required to assume responsibility for conservation of the resource while the governmental institution retains the authority for the management of broad scale ecological events.
2. *Scale-matching principle*: decentralization has a number of attributes that facilitate ecological approaches to fisheries management. Local level institutions are generally better able to identify the recipients of both costs and benefits and assign responsibilities that internalize both. They tend to bring local ecological information about habitat and stock interactions into the management system quickly and with a minimum of information costs.
3. *Precautionary principle*: by adequately allocating property rights, these systems encourage a more precautionary approach to management. Fishers are more likely to be precautionary if their share of the system is at risk and they can reap the benefits of behaving in a more precautionary way.
4. *Adaptive management principle*: as in an ITQ system the tradable property right provided to users is relied upon to generate incentives for conservative behavior on the part of individuals and, equally, collective incentives to sanction or report those harvesters who violate the contract. The Maine system began operation in July of 1996, implementing legislation of the previous year. Initially only the lobster fishery was brought into the scheme, but this fishery is the 'core' fishery in the state with nearly 80% of licensed fishermen. As operating procedures are worked out and experience gained with the system other fisheries will be gradually brought in. It is expected that relatively sedentary fisheries will be brought in first with the more mobile fisheries coming in later. Finally, it should be noted that as the system develops more and more control will devolve to the

elected bodies of users and they will determine its further evolution, in a manner consistent with the adaptive management principle.

5. *Cost allocation principle*: the principal objective of these systems is the creation of individual incentives that are consistent with the collective objective of a sustainable resource. It is expected that the high level of participation required by the system will result in rules that (1) are credible (i.e. that users will have confidence that restraint on their part will have the intended effect); (2) provide assurances that others will follow the rules or be prepared to collectively sanction those who don't; and (3) are equitable in the sense that individual costs are borne roughly in proportion to the benefits received.
6. *Full participation principle*: these systems are organized to maximize user participation and, if local level institutions are given authority for management rules whose impact is contained within the locality, those rules tend to be credible, viewed as aligned with individual interests and, consequently, are less subject to difficult enforcement problems.

5.2. Integrated watershed management

It is becoming increasingly clear that coastal ecosystems, and indeed the oceans themselves, are affected greatly by human activities that take place inland from the immediate coastal margin. Activities throughout watersheds influence the delivery of fresh water, sediments, and pollutants to estuaries, bays, and continental shelf waters. Large areas have been affected by alterations in salinity, with attendant changes in circulation, nutrient over-enrichment, sedimentation or sediment starvation, and contamination by land-based toxicants. Addressing these problems requires not only the regulation of emissions, but also managing the distribution of populations, land uses, and consumption patterns throughout the watersheds. Increasingly, regional (e.g. North, Mediterranean, and Baltic Seas) and sub-regional (estuary management programs) ocean governance schemes are addressing land-based sources of pollution through integrated watershed management approaches. Integrated watershed management can incorporate the Lisbon principles in several ways.

1. *Responsibility principle*: a watershed level of analysis and management can better identify those responsible for 'exportation' of the problems downstream and aid in implementing the responsibility principle.
2. *Scale-matching principle*: all stakeholders for specific management decisions — both upstream and downstream — can be engaged in the decision making processes. The concept of 'watershed councils' as an integrating body can be implemented and these councils can be represented at all levels decision.
3. *Precautionary principle*: managing the distribution of human populations, the 'ecological foot prints' and land uses is an important component of watershed management. This may involve restricting the spread of land development and, limiting density in particularly sensitive coastal and riparian areas, and, particularly in developing nations, steps to provide opportunities for settlement away from densely occupied and stressed coastal areas in line with the precautionary principle.
4. *Adaptive management principle*: information on the status of the watershed and downstream effects can be made broadly available to stakeholders and integrated in the decision-making process in line with the adaptive management principle.
5. *Cost allocation principle*: watershed councils and other bodies can also implement the full cost allocation principle via environmental taxes, bonds, or other mechanisms (see below).
6. *Full participation principle*: mechanisms can be included in order to ensure that decisions are made with full participation of stakeholders, in line with the participation principle.

5.3. Environmental bonding

Environmental bonding has been proposed (Costanza and Perrings, 1990) as a method to incorporate the uncertainty about environmental impacts in market incentives. It requires posting a financial bond to cover the worst expected dam-

ages from an activity which could be refunded if the damages did not occur. Otherwise it can be used to mitigate damages. This instrument complies with the Lisbon principles in the following ways.

1. *Responsibility principle*: it complies with the responsibility principle by making parties financially responsible for their potential impacts.
2. *Scale-matching principle*: it complies with the scale-matching and cost allocation principles by internalizing costs at all scales.
3. *Precautionary principle*: it complies with the precautionary principle by requiring payment up front for uncertain future damages. In fact, it represents a combining of the cost-allocation and precautionary principles that gives some guidance as to how precautionary we should be. The system has also been called the 'precautionary polluter pays principle' or 4P (Costanza and Cornwell, 1992).
4. *Adaptive management principle*: it could be an important component in an adaptive management system (see watershed management above).
5. *Cost allocation principle*: it represents an instrument for allocating the full costs of not only known environmental impacts, but also the much larger and more important category of uncertain impacts.
6. *Full participation principle*: finally, in order to be effective, it would require full participation in the details of its design and implementation for specific problems.

For example, the problem of oil spills could be addressed by designing a system (with full participation) that required environmental bonds to be posted on all oil in transit. The bond would be refunded if the oil arrived safely and forfeited if a spill occurred. This would internalize costs and give oil transport operations strong economic incentives to reduce the possibility of spills. They could, for example, invest in double-hulled tankers and on-shore treatment facilities while still remaining economically competitive. In fact, under the bonding regime, these kinds of environmentally protective activities would also be the most economical way to behave, because they would reduce the size of the bonds and the amount of bonds ultimately forfeited.

5.4. Marine protected areas

Currently, marine protected areas compose less than 1% of the marine environment. This is insufficient to maintain the ecological services of the ocean. Marine protected areas (MPAs) simultaneously address several of the Lisbon principles. Low et al. (1999) provides a detailed simulation analysis of the effectiveness of protected areas. In the face of uncertainty, marine protected areas offer a way to buffer ocean services from climate change, and degradation by economic activities (such as fishing and depletion of fishery resources) which externalize the actors' costs. Fisheries can benefit from MPAs, which have been shown to contain a higher density and larger fish than adjacent areas. MPAs may reduce water contamination and oil spill damage by zoning areas so that uses in any area are more compatible. MPAs will benefit coastal ecosystems by improving recreational resources, protecting highly productive areas (benefiting commercially important biological resources) and maintaining the resiliency of coastal systems. We recommend an assessment using ecological economics for sustainable governance to set MPAs. In particular, a network of MPAs should be established that is sufficient in size and spatial distribution to assure that ocean services are sustainable in the face of increasing human impacts, environmental variability and ecological uncertainty. Recent professional assessments have suggested 20% of marine areas should be designated as marine protected areas.

1. *Responsibility principle*: MPA's conform to the responsibility principle by allowing fisheries to be sustainable in the face of harvesting pressure, implying a responsible use of the resource.
2. *Scale-matching principle*: MPA's provide a solution to marine overfishing that is consistent with the ecological scale of the problem, thus conforming to the scale matching principle.
3. *Precautionary principle*: MPA's represent a form of ecological insurance against the uncertainties inherent in fish population dynamics

and harvesting, thus conforming to the precautionary principle.

4. *Adaptive management principle*: ideally, MPA's should be embedded in an adaptive management system that monitors their effectiveness and modifies their size and attributes appropriately.
5. *Cost allocation principle*: MPA's allocate the costs of conservation to the appropriate parties (the harvesters), by setting aside a certain percentage of the potential harvest to assure future harvests, thus satisfying the cost allocation principle.
6. *Full participation principle*: to be effective, MPA's need to involve full participation from all stakeholders. While one can imagine an MPA enforced by government edict against the will of the local community, this approach would be much less effective and politically sustainable than one which engaged stakeholders in establishment and enforcement of the MPA.

6. Conclusions

At a time when humanity's expanding pressures on global resources have begun to manifest impacts on even the vast oceans, ecological economics provides a new and timely paradigm for governance of ocean resources in the face of uncertainties. These uncertainties — from our limited knowledge of ocean-terrosphere-atmosphere interactions, to how fish populations change in response to natural and human influences, to future societal demands on oceans — must be dealt with as we design a sustainable and desirable world for humans and other species.

Just as fisheries scientists have learned the counterproductive nature of maximum sustainable yield policies (Hilborn and Walters, 1992), we recognize that any attempts to achieve 'globally optimal' ocean governance policies are chimeras. Nevertheless, efforts that adhere to the six Lisbon principles outlined here will help to ensure that governance will be inclusive, inquisitive, careful, fair, scale-sensitive, and adaptive.

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