The Concept of Ocean Governance: Evolution Toward the 21st Century and the Principle of Sustainable Ocean Use

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The concept of ocean governance encompasses norms, institutional arrangements, and substantive policies. The new ocean regime, for which the Third United Nations Law of the Sea Conference was the midwife, is based on the 1982 United Nations Convention on the Law of the Sea, but the 1982 convention by itself was clearly insufficient to take the world community into the twenty-first century. It has been supplemented by Agenda 21 of the UN Conference on Environment and Development (UNCED) of 1992; the Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities of 1995; and the United Nations Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks of 1995. Even with these additions the fabric of the new ocean regime is insufficient to confront the new challenges faced by human use of the marine environment. Present patterns of human utilization of the world ocean are not sustainable over an indefinite future. There is an urgent need to breathe life into the notion of "sustainability" to make it into a fundamental norm of the new world ocean regime. This article explores what such an effort would require in terms of norms, institutional arrangements, and substantive policies.

Keywords ocean governance, new ocean regime, 1982 UN Convention on the Law of the Sea, sustainable use of the world ocean

Elements of the Concept of Ocean Governance in the 20th Century and the Transition to the 21st Century

The current regime of the oceans, enshrined in the United Nations Convention on the Law of the Sea of 1982, its Annexes, and the Agreement relating to the implementation of Part XI of the Convention of December 10, 1994, is a deliberate attempt to design a comprehensive, integrated package containing a balance of interests between coastal states and the international community, including landlocked and geographically disadvantaged states. Two ingredients deserve emphasis, i.e., the notions of *integration* ("problems of ocean space are closely interrelated and need to be considered as a whole . . .") and *balance of interests*. Balancing interests of different classes of participants speaks to a concern about equity in access to the ocean environment and its resources and, over the long-term, to a concern for stability/order-in-change.

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The approach to regime design as it evolved in the Third United Nations Conference on the Law of the Sea (UNCLOS III) conceived of two packages with trade-off links between them. The package in Committees II, III, and the Informal Plenary on the Peaceful Settlement of Disputes is the dominant component of the regime. Herein are defined the critical norms governing coastal state competencies vis-à-vis the territorial sea, straits used for international navigation, conditions governing the claims to status of archipelagic states, resources and economic activities in the exclusive economic zone (EEZ) and on the continental margin, the control of marine scientific research in the EEZ, state responsibility for acts of marine pollution and the control of ship-generated pollution in the EEZ, the rights of landlocked and geographically disadvantaged states in the EEZs of neighboring states, protection of traditional high seas freedoms, a variety of procedures governing peaceful settlement of disputes, provisions related to technology transfer, and a procedure for amending the Convention as a whole.

A secondary component of the regime, at least as measured by practical economic prospects, relates to seabed minerals lying beyond national jurisdiction. While economic realities have marginalized this component, we acknowledge that its negotiation was the most contentious issue of UNCLOS III and that it prolonged the negotiations for at least three years beyond the point at which basic agreement on Package One had been achieved.

Not all fundamental concepts of the current ocean regime are of the same level of importance. Scholars and practitioners may differ over which elements are to be so regarded. My criterion for such designation is that the concept be a *sine qua non* for agreement by the different categories of parties with operational programs in the ocean: advanced maritime coastal states, developing coastal states, large-margin states (both developed and developing), the advanced industrial countries, and the Group of 77 (G77) vis-à-vis issues related to Part XI of the Convention. Those constraints yield the following list of most crucial fundamental norms:

1. coastal state sovereign rights over resources and economic activities in the EEZ and on the continental margin;
2. the notion of transit passage and archipelagic sealanes passage, i.e., protections for international navigation;
3. the status of the EEZ as a zone *sui generis*;
4. state responsibility for acts of marine pollution;
5. coastal state control of marine scientific research in the EEZ;
6. the balance of jurisdictions vis-à-vis control of ship-generated marine pollution, i.e., flag-state jurisdiction vs. port-state control;
7. protection for high seas freedoms;
8. dispute settlement procedures, including the exceptions as promulgated in Art. 297; and
9. the notion of the "common heritage of mankind," originally defined in Part XI and its Annexes but as modified in Resolution II and the Memorandum of Understanding.

At the global level, these concepts constitute the crucial elements of ocean governance. Are they enough to take us into the 21st century? The answer clearly is no. Since UNCLOS III, scholars and practitioners have learned many things about the design of international environmental regimes. Applying this knowledge to the world ocean regime, the international community has extended the regime in three directions.

1. The UN Conference on Environment and Development (UNCED) of 1992 has given rise to the notion of "sustainable use" of the ocean and its resources as a

new governing principle of soft law which, as elaborated in Agenda 21, focuses on the growing crisis of the world coastal ocean and outlines the need for integrated coastal zone management (ICZM). See also the Noordwijk Guidelines (The World Bank, 1993), World Coast Conference Report (1993), and GESAMP (1996).

2. Based on a growing awareness of the pervasiveness and intensity of land-based pollution of the marine environment, considerable effort was expended to elaborate a program of action to ameliorate the problem (Kimball, 1995).
3. Reacting to the growing intensity of international conflict over straddling stocks which threatened the stability of the world ocean regime, the UN General Assembly convened an international lawmaking conference which produced an Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks, extending the 1982 Convention in 1995.

Because, as will be demonstrated, present patterns of utilization of the world ocean are not sustainable over an indefinite future, there is a need to breathe life and content into the notion of "sustainability" to make it into a fundamental norm of the world ocean regime for the 21st century. This condition is based on the following considerations (Miles, 1995).

1. The largest impacts on the quality of the world coastal ocean are derived from a combination of world human population growth and density, people's preferences for living near coasts and rivers, and human activities in urban and rural environments.
2. Land-based pollution of marine environments, particularly from nonpoint sources via river run-off and atmospheric transport, represents the most serious hazard to the coastal environment.
3. Since technological advances in combination with population growth and economic development facilitates rapid growth of multiple uses of ocean space in neritic zones, ICZM is the only adequate *policy response,* combined with controlling and reducing land-based pollution.
4. The severe overcapitalization of the world fishing fleet and continued overharvesting of most commercially important species continues in spite of the fact that coastal states themselves now control more than 95% of demersal and coastal pelagic species and an estimated 60% to 65% of highly migratory species. It must therefore be said that the current governing norm of sovereign entitlement, enshrined within the 1982 Convention, does not and cannot provide any remedies for massive coastal state failures in fisheries management *within* EEZs.
5. There is an urgent need to change the conceptual paradigm under which fisheries are managed. The paradigm must be changed in at least two, and perhaps three respects:
    (a) Fisheries management must become centrally linked to ICZM because degradation of fisheries habitats and coastal water quality originate in land-based activities like agriculture, deforestation, and industry.
    (b) The most critical tasks facing governments in the management of fisheries is control over access to resources by domestic as well as foreign fleets and the development of a capability to size fishing effort dynamically to fluctuations in available yield.
    (c) The latter is so difficult and costly to administer that it may be a good idea to experiment with creating and transferring property rights in the fisheries to a combination of individuals and/or communities via individually trans-

ferable quotas (ITQs) and drastically reducing the role of government in favor of stakeholders, as has been tried in New Zealand in particular (Miles, 1997; Christy, 1996; Hilborn, Walters, & Ludwig, 1995).

6. The international community must declare unequivocally, once and for all, that open access regimes, whether within or beyond EEZs, are incompatible with sustainable use of marine living resources. This means that the days of high seas fishing as a freedom of the high seas are numbered and that a norm permitting closure on the high seas, once total allowable catches (TACs) are fully allocated, is desirable.

What other changes in the normative structure of the world ocean regime are desirable? There would appear to be a need for resolving conflicts between Part XII of the Convention on "Protection and Preservation of the Marine Environment," the London Convention, 1972 (formerly the Convention on the Prevention of Marine Pollution by the Dumping of Wastes and Other Matter, or the London Dumping Convention of 1972 as amended in 1996–1997), and the development and elaboration of Annexes to International Maritime Organization's (IMO) MARPOL Convention of 1973, as amended.

These conflicts at the global level really demonstrate a more generic problem, i.e., that different global and regional entities produce both soft and hard law but the main locus of decision is always the nation-state. The law-formation process is therefore highly decentralized and interactive and it does not occur in a straight line. As particularly regional agreements proliferate, gaps and inconsistencies abound and compliance control is a pervasive problem. This point has been made by Nollkaemper (1993) in his comprehensive evaluation of the international regime for transboundary water pollution:

> The regime for transboundary water pollution pre-eminently illustrates the observation that the development of international rules is a process of trial and error. The rules that have been developed in order to limit the discretion of states sometimes appear adequate, in other cases are soon modified, supplemented, or replaced, and in still others come to lead a virtually meaningless existence. The result is a complex superimposition or juxtaposition of norms and institutions. Inevitably, the ongoing development of rules leads to the point where it jeopardizes the coherency of the regime, defined as the degree to which the elements of an international regime are internally consistent. (Nollkaemper, 1993, 307)

From the point of view of policy and management requirements, the situation is also unsatisfactory. GESAMP (1991) notes the following deficiencies in the normative tapestry: Most agreements are very narrowly based and are inflexible with respect to new, unforeseen problems; monitoring and preoperational impact assessment are usually prescribed (though not actually done in any systematic way), but risk assessment and the need to set specific objectives are usually not mentioned; few agreements specifically require a systematic appraisal of alternative disposal options, including minimizing waste; few agreements set limits of acceptability of pollution by specific substances; instead, most agreements deal only generally with the properties of substances defined in terms of toxicity, persistence, and bioaccumulation "without regard to other factors such as quantity, local ecological characteristics, and dispersion patterns."

From an operational perspective, one further critical comment of GESAMP is extremely important:

> Of greater relevance, however, is the tendency for international instruments to express an "overall goal" in the form of a commitment to prevent marine pollution (generally defined as a harmful effect or propensity to cause a harmful effect) without clearly linking this goal to the basic principles of environmental protection. Thus, the occurrence or risk of pollution becomes the major criterion for regulatory action. This would be entirely reasonable if the definition of marine pollution were amenable to uniform interpretation; however, this is not the case at present, nor is it likely that an alternative definition would overcome this difficulty. Thus, by divorcing the principles of environmental protection from the stated overall goal, there is no obvious mandate to make decisions that achieve a balance between protection of the marine environment, the protection of other environmental sectors and the need for socio-economic development. (GESAMP, 1991)[1]

The normative dimension is only one of three components in the concept of ocean governance. It is crucial because the norms not only prescribe permissible behavior (standards) but also allocate authority to particular individuals or entities themselves to prescribe and apply policy. But were that all there is to ocean governance, nothing would necessarily follow. Therefore, it is necessary to confront the two missing dimensions. These are institutional arrangements and substantive policies.

I have argued before that the 1982 Convention was explicit about the need to view the ocean as a whole and to take into account the interrelationship of the activities conducted therein. UNCLOS III called for a shift to integrated national ocean policy, especially as regards the EEZ, but this dimension remains sadly neglected by coastal states, most of which gained mightily in territory and resources. The institutional inertia in moving from traditional short-term sector-based management to integrated, long-term sustainable management is almost overwhelming, and relatively few have even tried (Vallejo, 1991).

Integration is required at four space scales: global, regional (international), national, and subnational. At the global level, the integration required cuts across both normative development and organizational programs. The global and regional dimensions have been treated in earlier papers (Miles, 1989, 1992), and Kwiatkowska (1990) and Kimball (1997) have analyzed the difficulties inherent in the regional (international) dimension in far greater detail. In this article, however, the focus is on the global/normative dimension and the coastal state national dimension as the critical nodes in the system. UNCED should be read as the logical consequence of cumulative coastal state failure to implement the integrative ocean management approaches they had designed into the 1982 Convention. How then is it possible to facilitate the development of coastal state capacities to make integrated national ocean policy? And how is it possible to identify and facilitate the development of a suite of policies to produce sustainable use of the ocean environment and its resources? The argument now turns to these two questions.

Institutional Arrangements at the National Level: From Sector-Based to Integrated Management

What questions must an integrated national ocean policy answer? At least the following:

- Who decides?
- On the basis of what overall national objectives?

- How to resolve multiple use conflicts?
- How to halt and reverse increasingly severe coastal pollution problems?
- On what basis and in what ways to seek to develop each of the sectors to facilitate sustainability?
- How to approach the need to rationalize structures, policies, and operational procedures in order to achieve national welfare gains?

Most coastal states currently lack the capacity both to meet their obligations under the current regime and to maximize their returns from the new jurisdiction they have gained. The 1982 Convention exhorts states to see the problem whole. Seeing the problem whole means juxtaposing all ocean uses against some set of weighted criteria to determine value and to remember that the point is to seek to maximize the net benefit the coastal state will derive from the ocean over some defined period of time. The criteria may include measures like contribution to gross domestic product or gross national product, national income, employment, food security, environmental security, and the like. How these measures are to be weighted must be decided by the political authorities. They must also decide what constellations of national objectives will be pursued over time.

Seeing the problem whole also means designing a structure to oversee the development of policy by and for the traditional marine sectors and holding the sectors accountable for implementation. At the very least, the following components are usually involved:

- Determination of national positions on delimitation of the EEZ and the continental shelf vis-à-vis opposite and adjacent states:
  —requires knowledge of geomorphology of continental margin, of resource distributions (living and nonliving), and relative values of each.
- Development/adaptation of fisheries management system:
  —national legislation;
  —knowledge of trends in distribution and abundance of resources, fishing pressure, location of spawning areas and times, distribution of responses of populations and stocks to catch and fishing effort by area, etc.;
  —control over fishing effort via comprehensive licensing arrangements and quota allocation (foreign *and* domestic);
  —setting biological and socioeconomic objectives;
  —negotiation of joint venture arrangements (production, processing, marketing); and
  —surveillance and enforcement.
- Control of land-based marine pollution.
- Land-use planning.
- Regulation of industrial and agricultural activities.
- Waste disposal, etc.
- Control of pollution from ships:
  —standards, regulations, facilities;
  —designation of sea lanes; and
  —implementation of passive/active versal traffic systems (VTS) as necessary.
- Development of the chain of ports and shipping services:
  —shipping/ports/infrastructure/haulage/ancillary services; and
  —control over marine pollution.

- Development of off-shore mineral resources (soft and hard) where deposits exist:
  - —national legislation;
  - —negotiation of joint venture agreements with mining companies;
  - —consideration of potentially adverse impacts:
    - (a) on shore,
    - (b) on marine ecosystems,
    - (c) on other marine uses; and
  - —devise approaches for prevention/mitigation.
- Establishment of artificial islands, installations, and structures.
- General EEZ surveillance/enforcement.
- Tourism and recreational uses.

For developing countries, large-scale ocean development must be linked to national development planning. And for all countries, adequate attention must be paid to ensure the protection and preservation of the marine environment. None of these capabilities can be developed without substantial national investment in developing marine scientific research capabilities and the capability to monitor the effects of natural events and anthropogenic activities in the EEZ.

If a coastal state decides to pursue development of a national ocean policy, it should be understood that the directive must come from the highest level and that the effort must be coordinated across all relevant agencies by a cabinet unit. If not, there will be difficulty overcoming existing inertia. It should also be understood that the interested public, i.e., ocean users as well as those interested in environmental protection, must be involved in some way because it is vital to seek and maintain public support to facilitate policy implementation and compliance.

The problems that have been identified cannot be solved without both horizontal coordination across national agencies and vertical coordination between different levels of government, from national to municipal. However, coordination is a complex concept ranging from harmonization of policies across agencies with an emphasis on negotiation, consensus, and other bottom-up techniques to centralized authority systems with top-down chains of command dictating formulation and implementation of policy. Hybrid systems are also possible.

Because, in most cases, any attempt to impose centralized coordination on previously uncoordinated systems will trigger high degrees of bureaucratic conflict over issues of "turf" and the right to manage, the emphasis in both approaches should be on harmonization of policy via some kind of integrative mechanism for formulating and overseeing the implementation of policy. This shift in focus from single-sector management to bottom-up multisector management presupposes common identification of overarching national objectives and common identification of the problems to be solved. These presuppositions also assume that: (a) existing management systems can learn over time, hence the emphasis on iterative processes; (b) institutional arrangements can be changed; and (c) we should pay attention to providing incentives for agencies to cooperate, avoiding clear trade-offs without compensating the losers.

How Is It Possible to Identify and Facilitate a Suite of Policies to Produce Sustainable Use of the Ocean Environment and Its Resources?

In many respects this is the crux of the problem, since it is policy, in the sense of courses of action pursued by governments in response to critical problems, that will drive the system. In real life we know that policy is constrained to varying degrees by dominant organizational cultures and processes, bureaucratic competition and conflict, and interstate rivalries and conflicts over a variety of issues. However, I shall relax those real-life constraints to focus solely on what needs to be done to induce a collective shift from nonsustainable to sustainable use. As a first step, it behooves me to define my terms.

It is not at all clear what "sustainable development" is. The concept itself is inherently vague: beyond the general vision, operationalizations are scarce and weak, the practical policy implications of different definitions are usually not elaborated, and the difficult trade-offs involved are therefore not confronted.

Consider just a few selected definitions. First, the World Commission on Environment and Development (Brundtland Commission) Report (1987) defined sustainable development as development that does not compromise the ability of future generations to meet their needs. This definition has been very influential, but in treatment, the scope has been less than systemic since there is a primary emphasis on *species conservation*. Not surprisingly, this definition reemerged in 1992 in the Rio Treaty on Biodiversity, in which sustainable development was defined as use of components of biological diversity in ways and at rates that do not lead to their long-term decline and that permits maintenance of the potential to meet the needs and aspirations of present and future generations.

Relative to the multidimensional way in which the policy problem has been defined above, this definition of "sustainable development" is uncomfortably narrow and not fully acceptable. Instead, the definitions offered by two economists go much further toward encompassing all facets of the problem in an operationalizable way.

Repetto (1986) seemed much closer to the mark when he argued that the condition of sustainable development would exist when future economic growth begins to emulate natural productivity. Such a shift would involve:

1. recycling materials and energy,
2. reducing generation of wastes and use of virgin materials per unit output,
3. substitution of more abundant for scarcer materials,
4. showing greater concern for the future implications of current economic policies, and
5. living off the dividend of resources while maintaining and improving the asset base.

This definition is attractive because it is both multidimensional and operationally specific and it does not necessarily imply the preservation of the current stock of natural resources or any particular mix of human, physical, and biological assets. Repetto (1986) explicitly recognized that the asset base must and will change with time. However, getting from where we are to where we want to be is no easy matter since it will involve a series of quite fundamental transitions.

These transitions are defined to include:

- a demographic transition to a stable world population of low birth and death rates;
- an energy transition to high efficiency in production and use and increasing reliance on renewable sources;
- a resource transition to reliance on nature's "income" without depletion of its "capital";

- an economic transition to sustainable development and a broader sharing of its benefits;
- a political transition to a global bargain grounded in complementary interests between North and South, East and West. (Repetto, 1986)

The path outlined by Repetto has been developed further by Solow (1991, 1992). Solow argued that:

1. We should interpret sustainable development as an obligation to leave to future generations the option or capacity to be as well off as we are. In order to achieve this objective, we must take into account the resources we use up and leave behind, in addition to the quality of the environment, both natural and man-made, including productive capacity and technological knowledge.
2. We should think about the substitutability of goods and services (cf. Repetto's point regarding no fixed asset base) and the need to leave behind a generalized capacity to create well-being.
3. We should choose robust policies applicable over a wide range of situations.
4. We should confront the issues of distributional equity, present and future.

From this perspective, Solow (1991, 1992) argued that sustainable development is therefore a matter of saving and investment, which implies the usual choice between current consumption and providing for the future. Policies to protect the environment contribute to sustainable development if they target current consumption and not investments in future capacity. Finally, returns to nonrenewable resource exploitation should be funneled into a wide variety of capital formation.

The approach to sustainable development in this article will be based on a combination of Repetto and Solow. The argument is that major patterns of utilization of the world ocean are not sustainable precisely because they emphasize current consumption and not future investment. Moreover, rates of current consumption are so high and their ecological impacts so severe and long-lasting that they threaten to leave future generations much worse off than we are. These strictures are aimed primarily at present patterns of utilization of the coastal ocean and the exploitation of living resources.

In order to achieve sustainable development in the world ocean, it is necessary to pass through Repetto's transitions and adopt the prescription that economic growth should emulate natural productivity. To get there is difficult because it involves fundamental changes in human conceptions of relationships to nature and in human behavior. These patterns of behavior have been deeply embedded in social structure since the origins of the Industrial Revolution in the early to mid-19th century. A major component of these transitions is education, enlightenment, and understanding of the significantly adverse effects of present patterns of behavior. But understanding is by itself an insufficient impetus for action because changing present patterns implies severe short-term societal costs and therefore distributional inequities and conflicts. In the space available, the choice is to scrutinize the implications of global population growth pressures, current patterns of utilization of the coastal ocean, the exploitation of marine fisheries, and the implications of global climate change.

The Population Time-Bomb and Its Implications

In 1991, Robert McNamara delivered a special lecture to the United Nations on population growth which graphically summarizes the problems we face. World population of a

Table 1
Growth of the world's population

Year	Total population	Years to add 1 billion
1,000,000 B.C.	a few thousand	
8,000 B.C.	8 million	
1 A.D.	300 million	
1800	1 billion	1 million
1930	2 billion	130
1960	3 billion	30
1975	4 billion	15
1987	5 billion	12
1998	6 billion	11

Source: Population Reference Bureau of Washington, D.C., based on United Nations and World Bank estimates. McNamara (1991).

billion people was not achieved until 1800, as shown in Table 1. This took over a million years but, because population growth is exponential, it took only 130 years to add the second billion, 30 years to add the third, and 15 years to add the fourth (McNamara, 1991).

As shown in Table 2, more than 90% of the increases in world population occur in the developing world, areas least able to support those levels of increases in societal demands. UN projections of world population growth to the year 2100 show a total population of 9.7 billion, with 8.4 billion concentrated in the developing world (McNamara, 1991).[2]

The World Bank, according to McNamara, its former director, anticipates eventual stabilization of world population in the range of 12.5 to 14 billion.[3] If the result is at the upper end of the range, 12.5 billion people will be concentrated in the developing world, as opposed to 4.2 billion in 1991. If we assume, therefore, that consumption will grow at 2% per year, a very conservative assumption, by the year 2100 it would be eight times

Table 2
Population and population growth rates: Past and current

	Population (in millions)			Growth rates: average annual		
Country	1950	1990	2000[1]	1950–1980	1980–1990	1990–2000
World	2,516.4	5,292.2	6,260.8	1.9	1.7	1.7
More developed	788.6	1,150.1	1,206.4	1.1	0.6	0.5
Less developed	1,678.4	4,070.6	4,978.3	2.3	2.1	2.0
Africa	221.0	639.3	862.7	2.6	3.0	3.0
Sub-Saharan	178.4	524.1	717.6	3.9	4.5	3.0

Source: McNamara (1991), based on UN data.

the 1991 rate. An 8-fold increase in consumption combined with a 2.6-fold increase in world population is equivalent to a 20-fold increase in consumption of physical resources, assuming business as usual (McNamara, 1991). It is difficult to imagine how this level of consumption can be sustained. There is simply no possibility of achieving sustainable development without drastic controls being imposed on rates of world population growth and on rates of consumption.

The Impacts of Population Growth on the State of the Marine Environment: Patterns of Utilization of the Coastal Ocean

In 1985, the United Nations estimated that, by the year 2000, about 75% of the world's population will live within 60 km of the coast (UNCED, Agenda 21, 1991–1992).[4] Whatever the precise proportion, we are talking about increasingly large numbers of people and, as world population increases, that density of concentration will only increase as well. The earth bears the scars of present patterns of settlement and agricultural and industrial activities. These scars include the following (GESAMP, 1990; UNESCO/COMAR, 1992):

1. habitat destruction as a result of urbanization, construction of harbors, industrial installations, development of tourist facilities, and mariculture;
2. major increases in contaminants transported by rivers and the atmosphere to the coastal ocean;
3. expansion in areas of eutrophication as a result of heavy loading of nutrients, particularly nitrates and phosphates, from sewage disposal and agricultural activities;
4. increasing microbial contamination of beaches with attendant human health effects;
5. increasing fouling of the sea by plastic litter;
6. an emergent build-up of chlorinated hydrocarbons in the Southern Hemisphere;
7. damming of rivers with net loss of sediments and freshwater, leading to declines of biological productivity in estuaries and areas near the coastal ocean.

The World Resources Institute (WRI, 1992) has republished some data from an article appearing in *Nature* in April 1991 which shows clearly the relationship between increases in population and increases in pollution in 42 major rivers (see Figure 1). The trend line is almost linear.

There are many examples of major and unintended adverse consequences to estuaries and wetlands as a result of industrial and agricultural activities on land. Three graphic examples (IPCC, 1990, V.II) are:

> (1) the accelerated retreat of two Nile subdeltas following construction of the Aswan High Dam and loss of the sardine fishery; (2) the rapid loss of land in the Mississippi River delta due to subsidence, river levees, canals, and navigation channels; and (3) the exposure of valuable agricultural land in Malaysia to ocean waves as a result of uncontrolled mangrove harvesting.

The problem of overharvesting of mangroves in the tropics is a problem that brings in its train serious secondary and tertiary effects, since estuaries receive up to 50% of

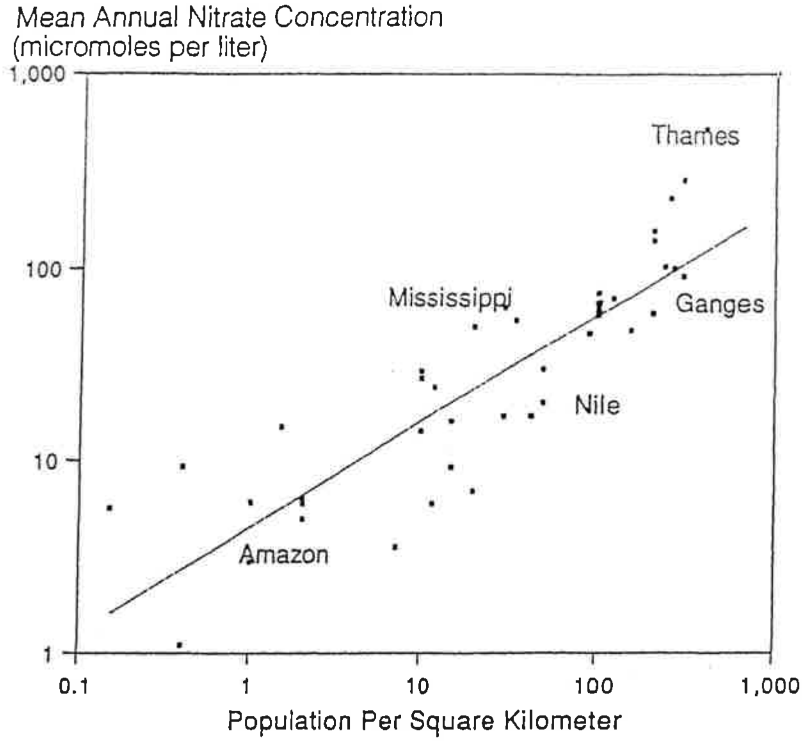


Figure 1. Increase in population and pollution in 42 major rivers. This figure was originally published in WRI (1992) and is reprinted here by permission.

organic matter from mangrove systems. However, in one audit (WRI, 1992), 31 countries had lost 76,939 km^2 of mangrove systems since preagricultural times, amounting in the aggregate to 56% of the area historically given over to mangroves. The largest losses in area were in Nigeria (12,200 km^2, or 50%) and Indonesia (21,011 km^2, or 45%).

Parsons (1992) has effectively summarized the impacts on the most productive coastal communities of human-induced, land-based pollution of the estuarine and coastal marine environment.

Salt marshes and mangrove areas are by far the most productive communities, followed by sea grass beds and, to a much lesser extent, mudflats. But these communities are precisely the ones most adversely affected by a wide range of human, land-based activities. The activities generating the widest scope of adverse impacts are production of pulp/paper and heavy metals, electricity generation, harbor and port activities, and sewage disposal.

Pulp and paper production generates primary contaminants via biological oxygen demand (BOD), suspended solids, and organics and secondary contaminants via nutrients, hydrocarbons, heavy metals, and organochlorines. Heavy industry generates primary contaminants via suspended solids, hydrocarbons, and heavy metals, and secondary contaminants via BOD and heat. Electricity generation produces only one primary contaminant, i.e., heat, but also suspended solids, hydrocarbons, and heavy metals as secondary contaminants. Harbor and port activities generate as primary contaminants BOD, suspended solids, hydrocarbons, and heavy metals, along with nutrients and pathogens as secondary contaminants. Finally, sewage generates the widest array of primary contaminants, including BOD, suspended solids, nutrients, pathogens, and organics, in addition to heavy metals and organochlorines as secondary contaminants.

The result is that everyday, practical human activities on land result in very heavy loading of the same primary and secondary contaminants in the coastal ocean, with river runoff being the primary pathway. It is therefore not surprising that the Group of Experts on the Scientific Aspects of Marine Pollution[5] (GESAMP, 1990) concluded its most recent review of the state of the marine environment by stating unequivocally that most marine pollution is derived mainly from land-based sources (44%) and the atmosphere (33%), as shown in Table 3.

Like mangrove systems in the tropics, wetlands (including salt marshes, sea grass communities, and mudflats) have the highest degree of natural productivity of all estuarine communities. They serve as nursery areas for a very large number of species that inhabit the coastal ocean. These communities are at risk not only from increased levels of pollution but also from a widespread practice of coastal reclamation for land use. According to the Organization of Economic Co-operation and Development (OECD), in 1991, Germany (Federal Republic) and the Netherlands had lost, respectively, about 52% and 50% of their wetlands between 1950 and 1980 (WRI, 1992). The comparable rates for Finland, the United States, and Sweden were 22%, 10%, and 5%, respectively.

In Asia, where land is scarce and the drive to economic development is intense, coastal reclamation is routinely resorted to as a means of creating bases for industrial development, whether they be centers of production or ports and harbors (Kim, 1991; Lim & Oh, 1991). These development projects are often not even subjected to benefit/cost evaluations beforehand and, if they are, the costs rarely include consideration of the environmental effects. Adverse environmental effects include loss of productivity and declining biological diversity as well.

Two other problems deserve mention as symptomatic of serious or potentially serious burdens on the coastal ocean. The first concerns what may be increasing incidents of toxic red tides involving organisms heretofore not implicated as carriers of these toxins (Culotta, 1992). We say "may be" because there is not general agreement that the flurry of recent reports since 1987 in fact represents a growing secular trend, and available data are insufficient to determine whether the unexpected carrier organisms have been so used in the past.

The usual carriers of red tide are dinoflagellates, which release toxins like brevetoxin

Table 3
Relative contribution of all potential pollutants
from various human activities entering the sea

Source	All potential pollutants (percent contribution)	
Offshore production	1	23%
Maritime transportation	12	
Dumping	10	
Runoff and land-based discharges	44	77%
Atmosphere	33	

Source: GESAMP, 1990.

affecting shellfish, or okadaic acid, which causes diarrhetic shellfish poisoning, or sai toxin, which causes paralytic shellfish poisoning. However, in 1987, there was a documented case of amnesic shellfish poisoning caused by domoic acid carried by a bloom of diatoms, which, until then, were not looked upon as carriers of toxicity. The major suspected pathway for the potentially increasing trend of red tides is the significant overloading of the coastal ocean with nutrients, usually nitrates and phosphates, via sewage disposal and agricultural runoff, in addition to the altered volume of freshwater input.

Over the last decade it has become clear that ballast water in ships and ballast sediment serving world trade is a significant source of transport of algae and zooplankton which are exotic to the ecosystems into which they are introduced, and some of these introductions have had spectacularly adverse effects on the native communities (Kelly, 1992). This, for instance, has been the case with a ctenophore (type of jelly fish, *Mnemiopsis leidyi*) introduced into the Black Sea from the northeast coast of North America. This ctenophore is a particularly voracious organism that has devastated fisheries in the Black, Azov, and Marmara Seas, already overburdened with pollutants (GESAMP, 1993, 1997; Travis, 1993). Ballast water is also a pathway for the introduction of viruses or bacteria which then pose threats to local human, animal, and plant communities (International Maritime Organization [IMO], 1991)

The Exploitation of Living Resources

There is now a consensus that world fisheries, as presently conducted, are not sustainable biologically and are wantonly wasteful economically. Economists, to be sure, have been making this point since the publication of H. Scott Gordon's seminal paper, published two decades ago (Gordon, 1954). But a milestone was passed when the UN's Food and Agriculture Organization (FAO) officially declared that sustainable development of fisheries "cannot be achieved under open access regimes, whether these are within or outside EEZs" (FAO/Christy [SOFA], 1992; FAO/Dept. of Fisheries, 1992a).

The evidence for the conclusion is summarized in several tables and figures, only a few of which are presented below. The distribution of world catch as of 1990, the latest year for which official data were then available, is shown in Table 4. Of a total of 97.245 million metric tons (mmt), 14.444 mmt are produced from inland (freshwater) sources and 82.801 mmt derive from marine sources. Asia by itself produces 71% of all inland fisheries catches, and the Asian total is dominated by a single country, China. Only four regions produce 68% of the world total of marine fisheries: the Northwest Pacific (31%), the Southeast Pacific (17%), the Northeast Atlantic (11%), and the Western Central Pacific (9%).

But, if one looks at the rate of growth in global marine catch from 1948 to 1990, as shown in Figure 2, one begins to see cause for concern. The rate of growth from 1948 to 1970 was on the order of 6% per year, driven by the emergence of large, distant water commercial trawl fleets developed by Japan and the Soviet Union. Between 1970 and 1972, however, the world marine catch declined, reflecting the crash of the Peruvian anchovetta fishery from a high of 12 mmt down to about 2 mmt. Between 1972 and 1990, not only has the rate of growth declined to 2.3% per year, but 1990 saw the first decline in production since 1976, a drop of about 3% (FAO/Dept. of Fisheries, 1992a).

The troubling thing about this trend is that the increases in production achieved during the 1980s were based upon relatively few species, most of which were coastal

Table 4
The distribution of world catch for 1990 by major fishing areas

Areas	Inland fisheries	World catch in 1990 (tonnes)	
01	Africa	1,905	
02	North America	537	
03	South America	333	
04	Asia	10,197	(71%)
05	Europe (including former USSR)	1,448	
06	Oceania	24	
	Total inland	14,444	
	Marine fisheries		
21	Atlantic, northwest	3,221	
27	Atlantic, northeast	9,183	(11%)
31	Atlantic, western central	1,697	
34	Atlantic, eastern central	4,098	
41	Atlantic, southwest	2,029	
47	Atlantic, southeast	1,530	
37	Mediterranean and Black Sea	1,489	
51	Indian Ocean, western	3,376	
57	Indian Ocean, eastern	2,828	
61	Pacific, northwest	25,688	(31%)
67	Pacific, northeast	3,428	
71	Pacific, western central	7,311	(9%)
77	Pacific, eastern central	1,519	
81	Pacific, southwest	1,031	
87	Pacific, southeast	13,945	(17%)
88, 48, 58	Antarctic	428	
	Total marine	82,801	
	Grand total	97,245	

Note: Including aquaculture but excluding aquatic plants.
Source: FAO Yearbook Fishery Statistics: Catches and Landings 1990, Vol. 70 (FAO, 1992).

pelagics like Chilean Jack mackerel, Peruvian anchovetta, Japanese pilchard, and South American pilchard. In addition, one demersal species, Alaskan Pollock, also accounted for a significant share of the increase. However, coastal pelagics are subject to violent fluctuations on decadal timescales, so most of the increase in the world catch since 1976 has been achieved on a highly unstable base. Given the fact that we seem to have reached the limits of global marine productivity of conventional species, as predicted by FAO two decades ago, we simply cannot expect this level of production to be sustained.

The other troubling factor is that the instability of the resource base is not reflected in the size and rate of growth in the world fishing fleet. We have seen significant increases in fishing effort since 1976, accompanied by significant declines in production

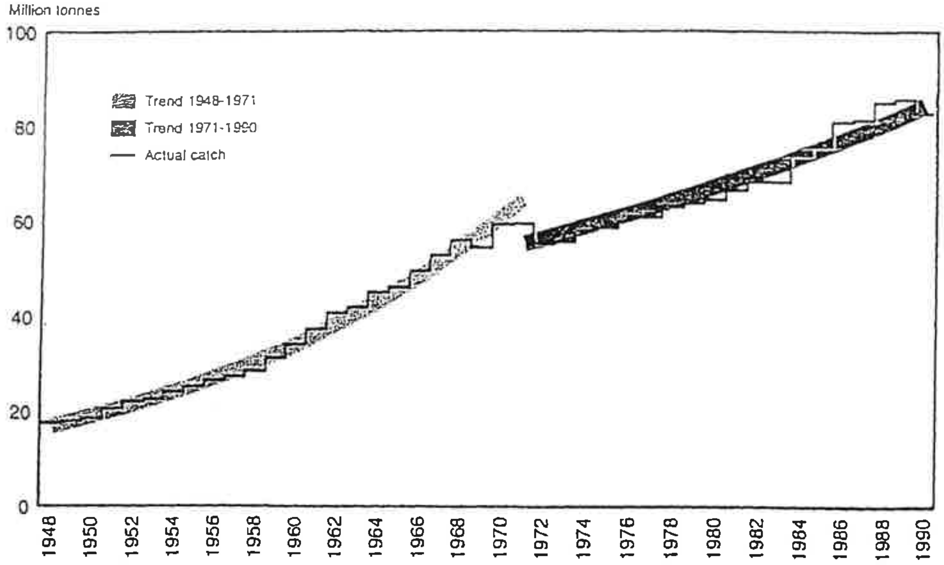


Figure 2. Growth in global marine catch, 1948–1990. FAO/Dept. of Fisheries (1992).

in the Northeast, Northwest, and Southeast Atlantic but increases in production in the Pacific and Indian Oceans (FAO/Dept. of Fisheries, 1992a).

Looked at in economic terms (FAO/Christy [SOFA], 1992), the world fleet is severely overcapitalized since, for an estimated annual value (all species) of U.S.$70 billion, the annual operating costs of the world fleet are estimated to amount to U.S.$85.7 billion. In addition, the present worth of the world fleet is estimated to be U.S.$159.6 billion, with a 1989 replacement value of U.S.$319 billion. Clearly, this level of imbalance between global productive capacity and resource base can be maintained only with the continued infusion of large national subsidies. There is also a vicious cycle at work here since, as demand continues to outstrip supply, the effect is rising real prices for fish and fish products, which in turn feeds the investment in fleets.

The design of corrective measures requires a more detailed look at the underlying dynamics. First, Figure 3 shows that 80% of the world marine catch is accounted for by only 20 states and that only six states, Japan, Russia, Peru, Chile, China, and the United States, account for 54% of the world marine catch. In the immediate future, therefore, by focusing on only 20 states, the world can seek sustainability for 80% of the world marine catch (FAO/Dept. of Fisheries, 1992b).

In the longer run, as Figure 4 shows, the task is more complicated since a significant number of developing countries have rapidly developed their catching capabilities since 1976.

With respect to catches on the high seas and within others' EEZs by nonlocal fleets, Russia had by far the largest at over 4 mmt in 1989; Japan was slowly declining at a little less than 2 mmt in 1989; and Poland, the Republic of Korea (ROK), Spain, and Taiwan hovered between .5 and 1 mmt, with ROK recently declining to that level and Taiwan recently increasing (FAO/Christy [SOFA], 1992).

The root cause of the overcapitalization problem is a failure to control access to resources and fishing effort effectively, which is a common feature of open access regimes whether they be within EEZs or outside. Therefore, the primary remedy for both

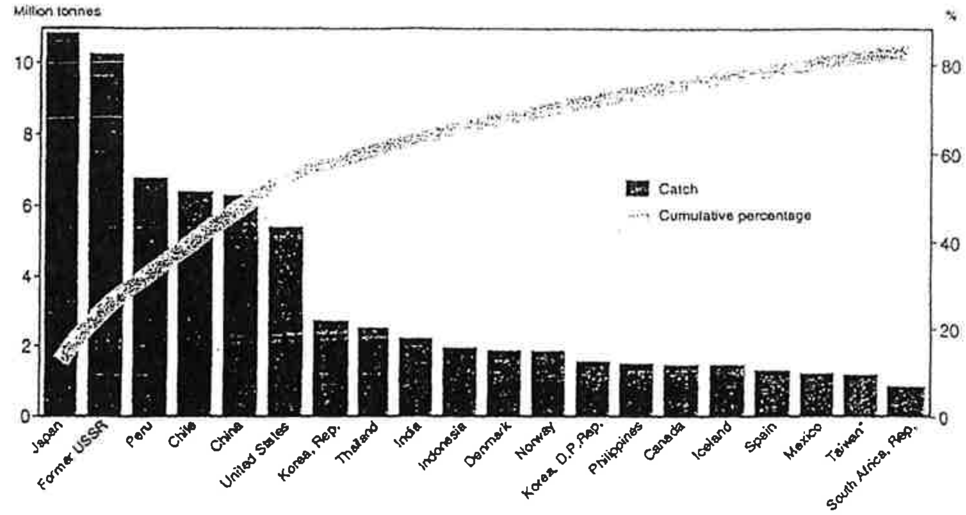


Figure 3. Catch by 20 major states and cumulative percentage of total marine catch in 1989. Reproduced in FAO/Christy [SOFA], 1992.

biological overfishing and economically wasteful resource exploitation is to be found in policies that serve to limit access and effort rather strictly. Such a wholesale shift cannot happen without a significant change in the way we perceive living resources and what is involved in their management.

As FAO/Christy (1992) pointed out, the necessary change is to move from management based on physical quantities (i.e., amount of catch) to management based on maximizing the net economic revenues from the exploitation of the resource.[6] Once this is done, a means of extracting the economic rents must be devised as well as a means of

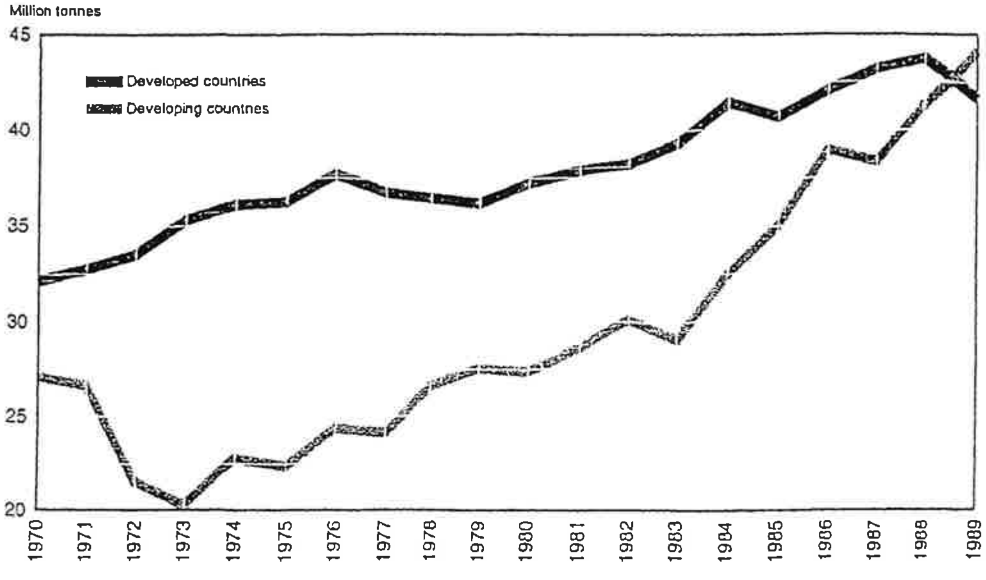


Figure 4. Total marine catch by developed and developing countries. Reproduced in FAO/Christy [SOFA], 1992.

distributing the benefits. The latter are defined as the economic rents minus the costs of administration, research, and enforcement. To a large extent Japan did so a long time ago and New Zealand has much more recently pioneered in this transition. Since there are dislocation costs involved, widespread adoption of significant change may be possible only at the point of major stock collapses, perhaps of the coastal pelagics. The pressure point is the national level and national systems of fisheries management, and the timescale is decadal.

The Implications of Global Climate Change

This is a very large topic indeed, and we do not have either the time or the space to treat it in detail. However, it must be included, since the predicted changes are quite significant and they are expected to occur over the same timescale as the other issues we have analyzed, i.e., from the late 1990s to 2050. Since the impacts of climate change on oceans, fisheries, and coasts were assessed in 1990 and 1995 by the Intergovernmental Panel on Climate Change (IPCC), we shall summarize the main relevant findings from these reports (Tsyban, 1990; Ittekkot, Jilan, & Miles, 1996; Bijlsma et al., 1996; Everett, Everett, & Titus, 1996) and some other relevant work, paying particular attention to the changing levels of confidence placed on the assessments between 1990 and 1995.

In 1990 the major implications of global climate change for sustainable use of the world ocean appeared to relate primarily to:

1. the effects of increasing average global temperature on global thermohaline circulation and, therefore, on the "biological pump," or the ocean's capacity to sequester carbon;
2. the effects on biological productivity at the microlevel (plankton), particularly in polar areas;
3. the effects of increasing ultraviolet-B (UV-B) radiation on biological productivity at both the micro and macro (coral reefs) levels;
4. the effects of sea-level rise on fish habitat, particularly wetlands; and
5. the effects on fisheries.

Global thermohaline circulation and the "biological pump" are very important components of the planetary carbon cycle. Watson et al. (1990) pointed out that the largest natural exchange fluxes of carbon occur between the atmosphere and terrestrial biota, on the one hand, and the atmosphere and the surface layers of the ocean, on the other. However, these fluxes occur on different timescales. With respect to atmosphere/ocean interactions, the turnover time of CO_2 from the atmosphere to the surface layer of the ocean is about four years. This is a very short time compared with the turnover time from the ocean surface layer to the intermediate layers of the ocean below the thermocline, which occurs on the order of 50–200 years. But even that is a relatively short time compared to the turnover time of deep ocean basins, which is on the order of 1,000 years.

The exchange of CO_2 between the atmosphere and the ocean is via gas transfer controlled by the differences in the partial pressure of CO_2 (pCO_2) between the atmosphere and the ocean surface layers, and is heavily influenced by increasing windspeed and water temperature. The exchange of CO_2 between atmosphere and ocean is a two-way street but while the exchange from the atmosphere to ocean surface layer takes a very short time, exchange in the reverse direction, called thermocline ventilation, occurs on the order of 100 years. Considerable inertia is inherent in the system, and inertia always magnifies the latency of effects.

Now the partial pressure of CO_2 in the ocean surface layer, and therefore in the atmosphere as well, is very strongly influenced by biological processes at the micro (planktonic) level. These marine biota serve as the "biological pump" transporting organic carbon from the surface to deeper layers of the ocean via a slow but steady rain of detritus in very large amounts, estimated in 1990 to be on the order of 4 gigatons (billion metric tons) of carbon per year (4 GTC/yr.) (Watson et al., 1990). In turn, this downward movement of carbon is balanced by an equal upward transport from deeper waters. The biological pump therefore reduces pCO_2 in surface waters by very significant amounts. Note that in 1990 there was still a large sink in the global carbon budget unaccounted for on the order of 1.6 ± 2.0 GTC/yr., and there is controversy over the relative amounts taken up by the ocean as compared with terrestrial biota (Siegenthaler & Sarmiento, 1993; Quay, Tilbrook, & Wong, 1992). By 1995, significant conceptual advances had been made and two new components included, i.e., carbon uptake by Northern Hemisphere forest regrowth and a combination of CO_2 fertilization, nitrogen fertilization, and the climate effects of both, but the combined uncertainty was still very large, e.g., 1.8 ± 2.0 GTC/yr. (Schimel et al., 1996). However, Emerson et al. (1997) later showed that the flux of biologically produced organic carbon from the euphotic zone to the deep ocean in the subtropical region of the Pacific in the Northern Hemisphere is on the order of 2.0 mol Cm^{-2}/yr. This translates to about 5 to 6 GTC/yr. for the subtropical Pacific Ocean alone, much larger than the 1990 *global* IPCC estimate of 4 GTC/yr., and larger even than the current estimate of about 5 GTC/yr. based on sediment trap fluxes. Emerson et al. (1997) noted that current model-derived estimates of the global flux are around 10 to 11 GTC/yr. If these values are correct, then the subtropical oceans would account for more than half of the global uptake.

The problem all of the above presents for our concerns in this article is that increasing average global temperature can significantly change the role of the ocean in the global carbon cycle in a variety of ways (Watson et al., 1990):

1. As temperature increases, pCO_2 in ocean surface waters increases, thereby decreasing the net CO_2 uptake from the atmosphere.
2. Increasing temperature in the surface waters can decrease vertical mixing, and therefore the exchange of nutrients and the upward transport of dissolved organic carbon, as a result of increasing resistance of the thermocline, given the physics of heat transfer from the surface to deeper layers. Such a change could, in turn, trigger large changes in ocean circulation.
3. Were the net flux of carbon and other nutrients to be significantly disturbed, especially in the polar regions, then there could be significant changes in the distribution and species composition of marine ecosystems. Large changes in species composition can affect pCO_2 in ocean surface waters at the same time that increasing surface temperature can accelerate decomposition of dissolved organic carbon into CO_2, thereby adding to the atmospheric increase.

Beyond the issue of potential effects on marine primary productivity, there were other ecosystemic effects which gave rise to some concern about sustainable use of living resources, especially related to the large blooms of planktonic communities existing at the edges of ice shelves (Melillio et al., 1990). These communities are potentially at risk from the large influx of freshwater attendant upon ice sheet melting, but they are also actually at risk as a result of ozone depletion from chlorofluorocarbons (CFCs), another category of greenhouse gases.

For instance, Smith et al. (1992) demonstrated that as the stratospheric ozone (O_3) layer decreased by as much as 50% in the Austral spring, increased midultraviolet radiation, i.e., UV-B in the 280–320 nm band, reached the surface waters of the Southern Ocean. Increased UV-B radiation then inhibited photosynthesis as a result of altering the balance of spectrally dependent phytoplankton processes, including photoinhibition, photoreactivation, photoprotection, and photosynthesis. This inhibition, in turn, resulted in an estimated 6% to 12% reduction in primary productivity.

The interannual variability of primary production in the Antarctic Marginal Ice Zone (MIZ) is very large, and this variability generates significant effects for polar biota. Viewed in the context of a presumed ± 25% range of natural variability, the reduction of 6% to 12% in primary productivity would translate into a 2% to 4% loss to productivity in the MIZ. Smith et al. (1992) acknowledged, however, that the ecological consequences of this reduction in primary productivity were not clear.

Bacteria play an important role in the cycling of organic carbon in the ocean and, in the same direction as the findings by Smith et al. (1992), Herndl, Muller-Niklas, and Frick (1993) found that UV-B radiation penetrates more deeply into the water column than previously thought. They found that increased UV-B radiation suppressed bacterioplankton activity by 40% in the top 5 m of the coastal ocean and estimated that effects in the open ocean might be felt even beyond 10 m. Moreover, the bacterioplankton affected showed over time no ability to develop adaptive mechanisms against surface solar radiation. The aggregate effect of this result could therefore be a combination of both reduced bacterial activity and increased concentration of labile dissolved organic matter in the surface layers of the ocean.

Finally, Gleason and Wellington (1993) focused on the issue of whether the phenomenon of coral bleaching was an effect solely of increased water temperature or increased UV-B radiation in the 280–400 nm band. In a field experiment, they found that "irrespective of high water temperatures, short-term (three weeks) increases in ultra violet radiation of a magnitude possible under calm, clear water column conditions can readily induce bleaching in reef building corals."

With respect to the potential impacts of sea level rise on habitat for living resources, particularly wetlands, Tsyban et al. (1990) showed that rising sea level would generate pervasive effects for marine ecosystems and coastal zones. These effects would include:

1 inundation and displacement of wetlands and lowlands,
2. erosion of shorelines,
3. exacerbation of coastal storm flooding,
4. increasing salinity in estuaries and threatening freshwater aquifers,
5. altering tidal ranges in rivers and bays,
6. altering sediment deposition patterns, and
7. decreasing the amount of light penetrating the water column in the coastal ocean.

The importance of wetlands and estuaries for the living resources of the world ocean is great since two-thirds of fish caught for human consumption depend on these areas for at least part of their lifecycle (Tsyban et al., 1990). Most wetland loss would be due to inundation, but increasing water temperature would also have an adverse impact on coastal marine ecosystems since, as temperature increases, the quantity of dissolved oxygen in the water decreases. At the same time, for wetlands, the fact of sea-level rise is not as important as its rate of speed. Wetlands can migrate if the rate of sea-level rise is sufficiently slow, and the existence of wetlands is also important for a variety of sea birds and terrestrial animals.

These changes were all seen to be fairly direct consequences of increasing global surface temperature as a result of increasing concentrations of CO_2 and other greenhouse gases in the atmosphere. What these changes meant for fisheries per se was very hard to say because the impacts were expected to be indirect, "mediated by changes in both physical processes in the oceans and by production of smaller organisms that serve as fish food" (Francis & Sibley, 1991).

Francis and Sibley (1991) also pointed out that different species of fish inhabit particular hydrodynamic structures and that there are crucial relationships between these structures and species' responses that we do not understand. Moreover, there is enormous uncertainty about the sequence of energy transfers from plankton to fish, and the biological effects of environmental changes even for adults are not uniform over wide areas.

Substantial uncertainty was also generated by the following factors:

1. changes in current patterns and mixing as a result of alterations in wind fields;
2. primary effects of changes in the water column on juveniles from the egg and larval stages;
3. increased potential for survival as a result of decreased latitudinal and seasonal sea ice extent;
4. weakening and shifts in the distribution of storm tracks and turbulence;
5. decrease in temperate zones and increase in high altitude zones in net precipitation and runoff; and
6. the occurrence of species substitution as a result of climate-induced ecological changes.

All of this uncertainty is compounded by the coarse resolution in the General Circulation Models (GCMs) currently in use and our widespread ignorance about the biological effects of low-frequency alterations impacting large areas of the world ocean.

By 1995 there remained substantial uncertainty about the precise effects of increasing sea surface temperatures (SSTs) on the biological pump and therefore on global thermohaline circulation. There was high confidence that the most pervasive effects of global climate change on human uses of the ocean would emerge via impacts on biotic resources, but it was not possible to be very specific about how SSTs would be redistributed globally and how this redistribution would produce changes in biodiversity and the distribution and abundance of species (Ittekkot, Jilan, & Miles, 1996).

Expectations about sea-level rise as a function of thermal expansion of the ocean remained firm, although the anticipated magnitude was decreased about 25%, to 50 cm from the present to 2100, under the IPCC best estimate scenario (IPCC, 1996). A new expectation added by the 1995 assessment was that changes in the magnitude and temporal pattern of pollutant loading in the coastal ocean would occur as a result of changes in precipitation and runoff, and increased coral bleaching as a result of a 2°C rise in average global atmospheric temperature was confirmed (Ittekkot, Jilan, & Miles, 1996).

With respect to impacts on coastal zones, IPCC acknowledged that already intense development and utilization of the world's coasts by humans had significantly stressed these locations and reduced their resilience (Bijlsma et al., 1996). This reduction was accompanied by limits on their capacity to adapt to change and a significant increase in the hazard potential to humans. While the rate, magnitude, and direction of sea-level changes would vary significantly across regions, the current estimate of average global sea-level rise is still two to five times higher than the experience in the last 100 years (Bijlsma et al., 1996). Sea-level rise was also expected to have negative impacts on tourism, freshwater supply and quality, fisheries, and aquaculture via impacts on habitat (wetlands), human settlements, financial services, and human health (Bijlsma et al., 1996). Protection of low-lying island states and coastal states with large deltaic areas would prove to be extremely costly.

By 1995 the likely impacts of global climate change on oceanic fisheries had not become much clearer. While dislocations in distribution and abundance of species was likely, particularly near ecosystem boundaries, there was no evidence in either direction to assess the likely impacts on total production. Species composition could change, but total yield was likely to stay about the same (Everett et al., 1996). In descending order of significance the fisheries assessment group offered the following ranking of major impacts with a medium level of confidence in their prediction:

- freshwater fisheries in small rivers and lakes, in regions with larger temperature and precipitation change;
- fisheries within EEZs, particularly where access-regulation mechanisms artificially reduce the mobility of fishing groups and fleets and their capacity to adjust fluctuations in stock distribution and abundance;
- fisheries in large rivers and lakes;
- fisheries in estuaries, particularly where there are species without migration or spawn dispersal paths or in estuaries impacted by sea-level rise or decreased river flow;
- high-seas fisheries.

It is evident that significant progress has not been made in the detailed understanding of the impacts of global climate change on marine ecosystems between 1990 and 1995. The reasons for this are to be found in the poor resolution of the GCMs combined with the lack of detailed information relative to local winds and sunlight. Clearly, therefore, major advances will come only from localized regional studies that make use of still-to-be-developed mesoscale climate models linked to downscaled versions of the GCMs.

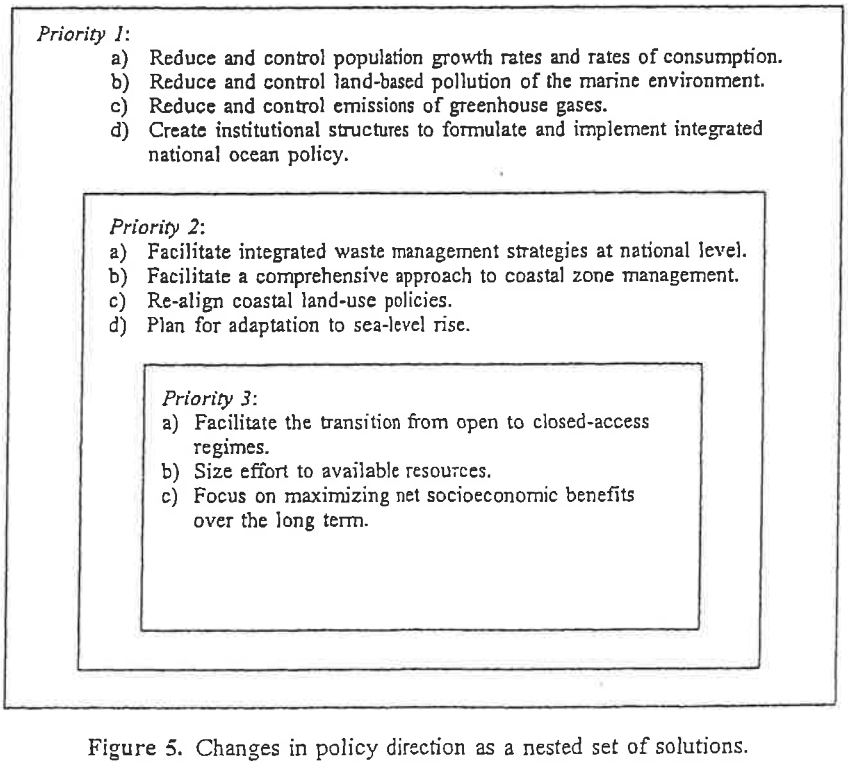
Conclusion

This article began by responding to the question: "What today are the crucial elements of the concept of ocean governance?" These explorations began with a three-dimensional concept of ocean governance involving norms, institutional arrangements, and policies. Having surveyed the suite of fundamental norms developed by UNCLOS III for the oceans, the question was posed whether they sufficed to meet the challenges expected in the 21st century. The answer was in the negative, and the corrective prescription focused on the soft law concept of "sustainability." The next step was to consider how this concept could be elaborated and made more operationally specific to meet the challenges which are fairly clear. The answer was found in a suite of problems and policies that constitute the heart of the article. Several clusters of policy changes have been offered in the course of this argument as a means of shifting human use of the world ocean toward the conditions for sustainable development. All of them are major. They range from placing drastic controls on rates of population growth and on rates of consumption of natural resources to systematic, comprehensive policy development to achieve protection of the marine environment; from harmonizing national legislation and institutional structures to control marine pollution to developing a tightly linked set of policies to minimize land-based pollution and to protect the coastal environment; from controlling access to fisheries and sizing amount of effort to the availability of resources to stabilizing and reducing the emissions of greenhouse gases.

The policies that have been recommended in this article in response to the problems identified are substantially linked with each other. This linkage merely mirrors the interconnectedness of the problems themselves, so that corrective action taken in one area will generate effects in other areas. Because policies do and will have cross-cutting effects, they need to be considered as a whole, i.e., as a nested set of solutions to interlinked problems that are evolving on different time and space scales, as shown in Figure 5.

In this nested set of solutions, from a global perspective, those policies that will have the widest range of effects are given the highest priority and are therefore placed in the outermost box. These policies would include those that serve to: (a) reduce and control population growth rates and rates of consumption; (b) reduce and control land-based pollution of the marine environment; (c) reduce and control emissions of CO_2, CFCs, and other greenhouse gases; and (d) create institutional structures to formulate and implement national ocean policy.

Those policies that have an intermediate range of effects will be given second priority and are placed in the middle box. These policies would include those concerned with facilitating integrated waste management strategies at the national level and with



Priority 1:

a) Reduce and control population growth rates and rates of consumption.
b) Reduce and control land-based pollution of the marine environment.
c) Reduce and control emissions of greenhouse gases.
d) Create institutional structures to formulate and implement integrated national ocean policy.

Priority 2:

a) Facilitate integrated waste management strategies at national level.
b) Facilitate a comprehensive approach to coastal zone management.
c) Re-align coastal land-use policies.
d) Plan for adaptation to sea-level rise.

Priority 3:

a) Facilitate the transition from open to closed-access regimes.
b) Size effort to available resources.
c) Focus on maximizing net socioeconomic benefits over the long term.

Figure 5. Changes in policy direction as a nested set of solutions.

a comprehensive approach to coastal zone management. The latter, also at the national level, would seek to: (a) interweave marine environmental protection policies into development of the coastal zone, both land and water; (b) realign coastal land-use policies in accordance with the objectives stipulated above and engage in systematic planning to adapt to sea-level rise.

Those policies with the narrowest focus would be placed in the innermost box. The primary recommended focus would be managing the transition from open-access fishery regimes, both within EEZs as well as on the high seas, to closed-access regimes. There would be heavy emphasis on reducing and controlling overcapitalization in fleet and therefore control of fishing effort. Preference would be given to policies that change the rules of the game so that the system operates largely on incentives rather than on command. Experiments with stakeholder management systems are definitely warranted (Christy, 1996). Such a shift would result in both a change in the nature of surveillance and enforcement and a decline in total transaction costs. Total effort would be scaled to the capacity of the stocks, although it would not be assumed that any particular configuration of species in the catches would be indefinitely sustainable.

In order to arrive at sustainable development of the world ocean, particularly of coastal zones and marine fisheries, this nested suite of policies must be pursued simultaneously. Policies that are derived from this perspective would seek to target the widespread inefficiencies in and counterproductiveness of current patterns of consumption and could therefore facilitate investment in sustainable options. We follow here Solow's (1991) advice: (a) that we look at sustainable development in terms of saving and investment and as a choice between current consumption and providing for the future; (b) that we target current consumption and not investments in the future; and (c) that returns to nonrenewable resources be funneled into a wide variety of capital formation (e.g., human resources, new types of technologies, including pollution control and monitoring technologies, and infrastructure).

One of the causes of haphazard ocean development is the prevalence of haphazard, overly fragmented national ocean policy decision processes. Therefore, it is not possible to move significantly down the road toward sustainable development of the ocean without at the same time building the capacity to formulate and implement integrated national ocean policy (Miles, 1989, 1992). No other way exists of making informed decisions that seek to achieve a sensible balance between industrial development and environmental protection and that seek to accommodate conflicting multiple uses of the same ocean space.

Achieving and maintaining a balance between development and environmental protection means continued investment in scientific research. Many crucial components of ocean dynamics are still unknown and the need for site-specific knowledge is also great. The results of research must be used to inform the determination of objectives based on short-term and long-term considerations. We should always ask not only "what do we want?" but also "what should we want given our biogeophysical conditions?" Perhaps in that way we can avoid the many embarrassing examples of inappropriate (for the time, place, and context) ocean development that are evident in the world ocean at large. And a central component of integrated national ocean policy, particularly as it relates to environmental protection, is risk assessment. Risk assessment is multidimensional since policies must be able to assess and respond to risks to ecosystems, human health, and economic well-being.

There must be harmonization between targets, national legislation, and the policies pursued by different agencies in order to achieve the kinds of impacts on the problems described and assessed in this article. Integrated performance is simultaneously the most cost-effective and efficient performance. As such, it promises a "bigger bang for a buck." Integrated performance does not mean doing away with the traditional marine sectors. One needs the sectors for specialization and for operational management. It does mean developing the institutional structure and capacity to overlay the focus of the sectors with a national focus that demands balanced development according to systematically derived national goals. This perspective lends itself to a search for a balance between horizontal and vertical integration in the policy system to which all users and interested parties should have access.

It should be admitted that the suite of nested policies suggested here to achieve sustainable development of the world ocean and its resources is not easy to implement. We return in effect to Repetto's (1986) transitions. The recommended solutions are complex and difficult because the problems that confront us are complex and difficult. Note, too, that, on the basis of the evidence to date, the international system is constrained in its responses by both national sovereignty and the dynamics of collective action problems where each player prefers to be a free rider and have others bear the cost of change. Consequently, the international system does not respond effectively to environmental problems except under two conditions: (a) disaster and (b) consensus that disaster on a significant scale is highly probable in the short run.

Therefore, the propensity of the international system to face up to transitions as pervasive as the ones identified by Repetto (1986) will be very dependent on the rate of environmental change and the immediacy of perceived effects. But, given the inertia generated by present patterns of consumption and development and their distributional consequences, moves in the direction of Repetto's transitions for the world ocean will be significantly distorted by:

1. conflicts of interest between countries,
2. distributional conflicts within countries, and
3. the general inadequacy of current institutional arrangements, i.e., fragmentation at subnational and national levels reinforced by the dynamics of bureaucracy.

One might inquire here whether, given this list of shortcomings, the argument should be based on an assumption that the nation-state system will continue into the indefinite future. My response to such a question is that whether we like it or not, all available evidence indicates that the nation-state system will continue as the critical locus of action in the international system, albeit constrained by fluctuating levels of regional political integration, ethnic conflict which tears at the fabric of some existing states from below, and the undoubted political significance of nonstate actors like multinational organizations and a variety of other international nongovernmental interest groups. These conflicting and messy trends merely serve to complicate the collective action problems served up by human degradation of the natural environment and to constrain the feasibility of potential solutions.

Policies that seek to create win–win conditions for all parties would have the greatest chance of success. In addition, national authorities that are tasked with ocean management responsibilities should give the highest priority in the next three to five decades to land-based pollution of the marine environment and integrated coastal zone management, because these are the foci of our most severe problems in the short to medium term. The potential of significantly changing fundamental ocean dynamics through continued concentration of greenhouse gases is our greatest long-term potential problem since the planet seems to have two stable equilibria, glacial and interglacial, and the paleoclimate evidence currently available shows discontinuous "flipping" between the two to be far more prevalent in the historical record than slow, continuous, monotonic changes.

The variation in timescale presents us with a difficult policy problem in itself. Both the land-based pollution and the global climate change problems have their origin in present patterns of human industrial development over the course of the last 140 years. Seeking to change such deeply ingrained patterns of behavior is no easy matter, especially since trying to maintain a change in course over 30 to 50 years is a more than Herculean task.

Lee (1993) frankly confronted this issue by acknowledging that:

> Paths to sustainability cannot be found at the human individual or species level. If there is a better path, it must be found and built by human institutions. . . . It must be based on long-term social learning to deal with uncertain threats to well-being and to sustain cures for enough time to make a difference.

Lee offered a strictly defined approach to "adaptive management" as a mechanism to facilitate social learning. By adaptive management, he meant treating economic uses of nature as experiments characterized by taking uncertainty seriously; being explicit about one's expectations and using measurement techniques to assess effects; collecting and analyzing information so that expectations can be compared with reality; and transforming the comparison into learning via error correction and changes in action and plans.

Note that Lee's (1993) definition of adaptive management merges with what Argyris and Schon (1978) called single-loop and double-loop learning. Single-loop learning is characterized essentially by trial and error (i.e., error detection and correction without a basic change in course), whereas double-loop learning is characterized by learning how to learn, in which basic objectives and directions can be called into question. These same characteristics can be found in May's (1992) distinction between instrumental and social learning.

The difficulty with moving organizations, governments, and indeed whole societies in the direction of double-loop learning is that learning is inhibited by ideological and distributional conflicts, institutional inadequacies, and a host of other conditions, so one has to ask under what conditions a system will be movable in the desired direction. But, once the question is asked, May's (1992) analysis shows graphically the indeterminacy of political effects, since the same conditions can act as both obstacles and supports to social learning on different issues.

Lee, in an earlier article with Fluharty (Fluharty & Lee, 1988), admitted that the conditions which facilitate the adoption of adaptive management are quite steep. Two particularly demanding ones are, first, that costs for planning, experimental design, and baseline measurement must be incurred at the beginning and, since the timescale of measurement must be appropriate for biological systems, there must be a sustained commitment to this course of action. These costs therefore tend to be large. Second, these timescales of experiment typically exceed most terms of office or agency assignments.

Halbert (1993) showed that even explicitly defined adaptive management strategies can, over time, experience significant conflict generated by competing expectations of what the experiment entailed and threats to persistence as a result of built-in conflicts of interest among the various players. Over time, therefore, the experiment can be corrupted by the task of staying alive amidst significant conflict so that it evolves into something quite different from a strict definition of adaptive management.

The point to be made here is that policies to reverse course and to set us on the path of sustainable development of the ocean (or any other dimension of the planet) are incomplete without attention to the kind of institutional design that will sustain them over the timescales required. Since, as Lee (1993) demonstrated, fragmented jurisdictions are impediments to learning and to the design and implementation of ecosystemically effective policies, I have stressed the need for simultaneously moving toward the capacity at the national level to make integrated ocean policy. This need is reinforced by Lee's argument that remedial actions cross jurisdictional boundaries and require coordinated implementation for long periods of time. How we design institutions to facilitate sustainable development at every level—subnational, national, regional (international), and global—is therefore a critical issue about which we have not yet thought sufficiently.

Notes

1. These deficiencies are not limited to *marine* pollution but apply to freshwater resources as well. For these reasons, J. Karr argued for clearly defined biological endpoints to be chosen as the overall goals. See J. R. Karr (1994).

2. However, more recent (1992) UN projections provide a range extending from 7.8 billion people to 12.5 billion by 2050 (Cohen, 1995).

3. Note that most projections of population growth rates characteristically underestimate the levels actually achieved.

4. This estimate has recently been challenged (Cohen et al., 1997) and recalculated to show that in 1994, 37% of the world population lived within 100 km of a coastline and 44% within 150 km of a coastline.

5. In 1993, GESAMP decided to retain its acronym but to change its name to the Group of Experts on the Scientific Aspects of Marine Environmental Protection.

6. Technically, in such a shift, the management objective would be to maximize the net revenue product. In many societies such an objective may be regarded as being too narrow. In that event, the objective could be broadened to maximizing the net socioeconomic benefits over the long term.

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