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Marine and Coastal Services at Risk: The Sleeping Dragon

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All we do is touched with ocean,
Yet we remain on the shores of what we know.
-Richard Wilbur, 1947

Introduction

It is a sad fact of human nature that we are moved to protect only what we value – sad because there is so much out there of great value that needs our protection, yet we often don't recognize its value, or the extent to which it is in danger of being lost. Such is the case for myriad ecological services provided by marine and coastal ecosystems. While many of these ecosystems are highly valued for the provision of goods: fisheries products, fuelwood, places to recreate – less well known is the extent to which marine ecosystem services of all kinds support the lives and well-being of humans the world over.

What are these services? Take the role of marshes and other coastal wetlands in buffering land and communities from storm events. Recent natural disasters have awakened us to the folly of destroying coastal habitats, whether they be coral reefs of Southeast Asia that were no longer there to be able to dampen the effect of the tsunami, or the tidal marshlands of Louisiana that were no longer able to absorb the storm surge and flooding associated with Hurricane Katrina. But we still struggle with the question, "How valuable are these habitats for the services they provide, and how does the cost of protection weigh against the benefits?"

People around the world value the oceans highly, though in ambiguous ways. For instance, polling indicates that some 80 percent of all Americans have a strong spiritual attachment to the sea, even among those who have never visited the shore nor seen the ocean. But ask someone, "What have the oceans done for you lately?" and few will be able to give an intelligible answer. For most of us are largely unaware of the enormous and crucial role marine ecosystems play in maintaining the biosphere and providing key goods and services to humanity. Nor are many of us aware of the degree to which these ecosystem services, and related human well-being, stand at risk. So although we may slowly be recognizing that marine ecosystems provide valuable services to humans, we seem unable to offer those ecosystems adequate protection – either because their benefits are not widely known, or not currently valued in markets, - or perhaps because the benefits accrue primarily to those groups which are already marginalized by society.

The true values of marine ecosystem services has now been made clearer by the completion of the *Millennium Ecosystem Assessment* (MA) – the first ever global assessment of ecosystem services and their connection to human well-being. The assessment represents the Herculean effort of over 1,300 researchers from 95 countries around the world, and the result is a stark scientific consensus on the extent to which humans have already compromised their well-being by destroying ecosystems and impairing delivery of these essential services.[1] The resulting documents have been published and will be available to the public in mid-January, 2006. And in a related publication released on December 9, 2005, the World Health Organization summarized the human health implications of the loss of ecosystem services.[2] What these assessments highlight about the role oceans play in providing services to humanity is startling – and the plausible futures postulated by them alarming.

Coastal and Marine Ecosystem Services

The world ocean provides a host of services through both its coastal ecosystems and offshore marine ecosystems. Coastal ecosystems are the most highly utilized, and most threatened, of these ecosystems. They include terrestrial ecosystems in the coastal plains and along shorelines, areas where fresh water and salt water mix, and nearshore coastal and open ocean marine areas on the continental shelves. Continental shelves account for at least 25% of global primary productivity, 90–95% of the world's marine fish catch, 80% of global carbonate production, 50% of global denitrification, and 90% of global sedimentary mineralization.[3] Services provided by coastal and marine ecosystems include shoreline stabilization, nutrient regulation, carbon sequestration, detoxification of polluted waters, and waste disposal; provisioning services such as supply of food, fuelwood, energy resources, and natural products; and amenity services such as tourism and recreation.[4] A summary of the services provided by various coastal habitats is provided in Table 1. These services are of high value not only to local communities living in a coastal zone (especially in developing countries), but also to national economies and global trade.[5]

Table 1. Summary of Ecosystem Services and their Relative Magnitude by Subtype

Services Direct & (indirect):	Estuaries & marshes	Mangroves	Lagoon& salt ponds	Intertidal	Kelp	Rock /shell reefs	Seagrass	Coral reefs
Food	●	●	•	●	•	●	•	●
Timber/ fuel	●	⬤	●					
Medicines, other	•	•	•		●			•
Biodiversity	●	●	●	⬤	●	⬤	●	⬤
Biological regulation	●	⬤	●	•		•		●
Freshwater Storage & Retention	•		•					
Biochemical	•	•			•			•
Nutrient cycling & fertility	●	●	●	•	•	•		●
Hydrological	•		•					
Atmospheric & climate regulation	●	●	●	•		•	•	●
Human disease control	●	●	●	●		•	•	•
Waste processing	⬤	⬤	●			•	●	•
Flood/storm protection	●	●	•	•	•	●	●	⬤
Erosion Control	●	⬤	•				•	•
Cultural & amenity	⬤	•	●	⬤	•	●	●	⬤
Recreational	⬤	•	•	⬤	•			⬤
Aesthetic	●	•	⬤	●				⬤

Coastal communities derive great benefits from intact coastal ecosystems and the provisioning and regulating services they provide. For example, wetlands such as mangroves and coastal marshes maintain hydrological balances, contribute to freshwater recharge of aquifers, prevent erosion, regulate flooding, and buffer land from storms. Rock and coral reef habitats also buffer land from storms. With some 71% of the world's coastal population living within 50 kilometers of an estuary, 31% living within 50 kilometers of a coral reef system, 45% living within 50 kilometers of mangrove wetlands, and 49% living within 50 kilometers of sea grass ecosystems, it is apparent that these habitats and the ecosystem services they provide present many of the "pull" factors that resulted in initial settlement along a coast as well as subsequent migration to it.[6]

Dependence on coastal zones is increasing around the world, even as costs of rehabilitation and restoration of degraded coastal ecosystems is on the rise. Currently nearly 40% of the global population lives within the thin band of coastal area that is only 5% of the earth's terrestrial area. In part, this is because population growth is happening simultaneously with increased degradation of terrestrial areas (fallow agricultural lands, reduced availability of fresh water, desertification, and armed conflict all contributing to decreased suitability of inland areas for human use). Resident populations of humans in coastal areas are rising, but so are immigrant and tourist populations.[7] At the same time, wealth inequities that result in part from the tourism industry decrease access to coastal regions and resources for a growing number of humans.[8] Nonetheless, local communities and industries continue to exploit coastal resources of all kinds, including fisheries resources; timber, fuelwood, and construction materials; oil, natural gas, strategic minerals, sand, and other nonliving natural resources; and genetic resources. In addition, people increasingly use ocean areas for shipping, security zones, recreation, aquaculture, and even habitation. Coastal zones provide far-reaching and diverse job opportunities, and income generation and human well-being are currently higher on the coasts than inland.[9]

The Enormous Value of Coastal and Marine Systems

Coastal ecosystems are among the most productive in the world today, some rivaling even tropical rainforests in terms of their overall productivity of raw materials and goods used by humans.[10] As the following examples show, many coastal regions are valued through market activities that directly support humans—such as fishing, hunting, fuelwood and woodchip extraction, harvesting ornamental materials, and the extraction of medical resources.

Food

Matthew Wilson, a Lead Author in the Millennium Assessment's chapter on Coastal Systems and Coastal Communities, has summarized current understanding of coastal and marine ecosystem values, condensed in the following paragraphs.[11] Coastal systems generate a variety of seafood products such as fish, mussels, crustaceans, sea cucumbers, and seaweeds.[12] Many commercially important marine species, like salmon, shad, grouper, snapper, bluefish, striped bass, and invertebrates (such as shrimp, lobster, crabs, oysters, clams, mussels), use coastal nursery habitats. Capture fisheries in coastal waters alone account for $34 billion in yields annually.[13] Given this level of economic productivity, it is perhaps not surprising that overfishing and intensive aquaculture have caused serious ecological and social problems in coastal regions throughout the world.[14]

Valuation studies of food directly or indirectly supplied by coastal systems have predominantly focused on the economic value of fishery products.[15] Most often, the market price of seafood products is used as a proxy when calculating the value of ecosystem goods provided by coastal systems. For example, the annual market value of seafood supported by mangroves has been calculated to range from $750 to $16,750 (in 1999 dollars) per hectare.[16] High-value species are also harvested from coral reefs to meet live fish demand in restaurants, mainly in Asia.

Coastal areas also provide the foundation for the mariculture (marine aquaculture) industry, which uses coastal space or relies on wild stock to produce valuable fisheries products, from tiger prawns to bluefin tuna. Human reliance on farmed fish and shellfish is significant and growing. Global annual per capita consumption of seafood averages 16 kilograms, and one third of that supply currently comes from aquaculture.[17] Globally, aquaculture is the fastest-growing food-producing sector, with production rates doubling in weight and value from 1989 to 1998 18. Much of that growth has occurred in the shrimp and salmon farming industries. Yet in Thailand, for instance, the conversion of mangroves to shrimp aquaculture ponds reduced the total economic value of the intact mangroves by 70% in less than a decade.[19]

Genetic, Medicinal, and Ornamental Products

Besides food and raw materials, at least three other types of marketable goods are provided by coastal systems: genetic, medical, and ornamental resources. For example, coral reefs have been shown to be an exceptional reservoir of natural bioactive products, many of which exhibit structural features not found in terrestrial natural products.[20] The pharmaceutical industry has discovered several potentially useful substances among the seaweeds, sponges, mollusks, corals, sea cucumbers, and sea anemones of reefs. Furthermore, many coastal products are collected not only as food but also to sell as jewelry and souvenirs. Mother-of-pearl shells, giant clams, and red coral are collected and distributed as part of a worldwide curio trade.[21] The marine aquarium market is now a multimillion-dollar industry trading in live reef-dwelling fishes that are collected and shipped live from coral reef communities.

Tourism and Recreation

Recreational fishing is also a major industry in many parts of the world, and it primarily targets marine or anadromous fishes in coastal ecosystems. Coral reef–based recreational fisheries generate over $100 million annually.[22] The coastal zone also supplies nonmarket values associated with both recreational and commercial fisheries by providing some of the most productive habitat refugia in the world.[23] Eelgrass, salt marsh, and intertidal mud flats all provide a variety of services associated with their nursery functions.[24]

In addition to marketable goods and products, landscape features and ecological processes within the coastal zone also provide critical natural services that contribute to human well-being and have significant economic value.[25] As the data just cited suggest, much of what people value in the coastal zone—natural amenities (open spaces, attractive views), good beaches for recreation, high levels of water quality, protection from storm surges, and waste assimilation/nutrient cycling—is provided by key habitats within coastal systems.[26]

Spiritual and Aesthetic

Open space, proximity to clean water, and scenic vistas are often cited as a primary attractor of residents who own property and live within the coastal fringe.[27] These coastal values also underlie much of the world’s coastal and marine tourism. The link between tourist visits and the revenues from and condition of the coastal system has not been analyzed at the global level, but local case studies point to a strong correlation between value and condition. In the United States alone, reef ecosystems with their nursery habitats support millions of jobs and billions of dollars in tourism each year. In an even more specific example, a look at reef-based tourism state by state showed that such tourism generated over $1.2 billion in the Florida Keys, while in Hawaii, reefs generate some $360 million per year, with annual gross revenues generated from just one half-square-mile coral reef reserve exceeding $8.6 million.[28] As these reefs decline in biodiversity and ecosystem health, these nature-based tourism industries stand at risk.[29] In Jamaica and Barbados, for instance, destruction of coral reefs resulted in dramatic declines in visitation; loss of revenue streams subsequently led to social unrest and even further tourism declines.[30]

The seas and coasts are also of great spiritual importance to many people around the world, and such values are difficult to quantify. While the depth and breadth of these values are as diverse as the cultures that are found worldwide, there is the common theme of a cultural or spiritual connection. For example, the Baju peoples of Indonesia and the aboriginal people of the Torres Strait in Australia have a culture intimately connected to oceans, while many North Americans have similar strong ties to coastal systems.[31] Even systems on which we place low economic value today may be of importance tomorrow because they support species that may turn out to have pharmaceutical value or because they support species or habitat types that may become rare and endangered in the future. This gives them high option value (measured as an individual's willingness to pay to safeguard the option to use a natural resource in the future, when such use is not currently planned). And other non-use values are representative of the significance that humans attach to an environmental resource, despite the fact they may never use it.

These attempts at quantifying the many values of marine services are useful, but they cannot tell the whole story. A great many researchers, conservationists, philosophers, and sociologists resist the utilitarian approaches that attempt to attach economic values to natural systems. Instead, they would argue that natural systems are invaluable, and suggest that economic cost-benefit analyses will always favor habitat destruction for the purpose of economic development. This is especially true when the recipients of coastal and marine services are economically disadvantaged, or politically marginalized members of society, as is the case in many parts of the world. Certain services, such as planetary nutrient and atmospheric regulation, cannot be valued economically. Yet whether one takes a utilitarian or a more philosophical approach, we now more easily recognize that marine ecosystem services represent a significant portion of the total economic value of the coastal environment, and are critical to the functioning of earth's systems while at the same time contributing significantly to human well-being.

Why Aren't Coastal and Marine Ecosystem Services Better Protected?

Coastal and marine ecosystems present a complex web of goods and services, perhaps more so than any other major ecosystem type. Clearly individuals and communities value the coast, as burgeoning population growth and resource use in coastal areas attest. But there is not a clear understanding of the extent to which intact ecosystem services, particularly when taken individually, support human well-being and economies. These values are only just coming into view, and are not widely known. Too often we realize the importance of ecological services only in the wake of calamities, once the ecosystems providing them have been degraded or destroyed.[32]

Inadequate conservation of marine ecosystems and their services has its roots in both science and sociology. Our scientific understanding of marine ecosystem function lags behind that of terrestrial ecology, and policy makers are uncomfortable with the uncertainties. We are only beginning to recognize and quantify linkages between various sorts of marine habitats, such as the link between intact mangrove and diverse and productive coral reefs many kilometers away.[33] At the same time, our understanding of thresholds for stress in various ecosystems remains thin, though we are starting to take stock of the existence of such thresholds, and direct research towards identifying more of them.

At the same time, the "tragedy of the commons" problem in marine environments is not an insignificant one. The common pool resource nature of fish and other resources, and the open access to ocean space, fuels conceptions about unalienable rights and privileges that are difficult to overcome.[34] Many sectors of many societies feel they have a right to use, and even damage, coastal and marine ecosystems, because those ecosystems "belong to them". In such a sociological climate, cheating the system of regulation is often overlooked, or even worn as a badge of honor. In addition, coastal and particularly offshore areas are difficult to monitor. Surveillance under the water or far out to sea is prohibitively costly, and modern technology has only presented a few viable tools to address these problems. Yet paradoxically, technology has provided users with ever-expanding access to resources.[35]

Conventional management of ocean areas is inadequate, and innovative mechanisms that utilize free market co-management principles or have yet to be broadly applied.[36] Few national, state, or local government entities have access to the information needed to shape policy on market design, and there is little political will to try unconventional approaches in which local communities or the private sector share responsibility for management. Similarly, there is a glaring lack of institutional support and insurance for collecting payments for protection of ecosystem services from the private sector. Another fundamental barrier is that coastal management and conservation professionals are not naturally aggregated, lacking global or even regional associations. Information about ecosystem service markets is scarce and the capacity to assess and develop markets is limited. Progress is hampered by lack of understanding and political support form key stakeholders. While the United States, Canada, the European countries, and Australia have long been considered pioneers in coastal management, their general approach is very much command /control, with few incentives for users to practice good stewardship and direct needed energies towards safeguarding not only goods but also these valuable services.

Coastal and Marine Systems and Their Services Into the Future

Heterogeneous coastal ecosystems are naturally dynamic, but in many cases they are now undergoing more rapid change than at any time in their history.[37] These transformations have been physical, as in the dredging of waterways, infilling of wetlands and construction of ports, resorts and housing developments, and they have been biological, as in the declining stocks of marine organisms and spread of invasive species. The dynamics of sediment transport and erosion deposition have been altered by land and freshwater use in watersheds; the resulting changes in hydrology have greatly altered coastal dynamics. Overexploitation has not only reduced supplies of resources, but also dramatically altered the structure and function of many marine ecosystems. These impacts, together with chronic degradation resulting from land-based and marine pollution, have caused significant ecological changes and an overall decline in many ecosystem services.

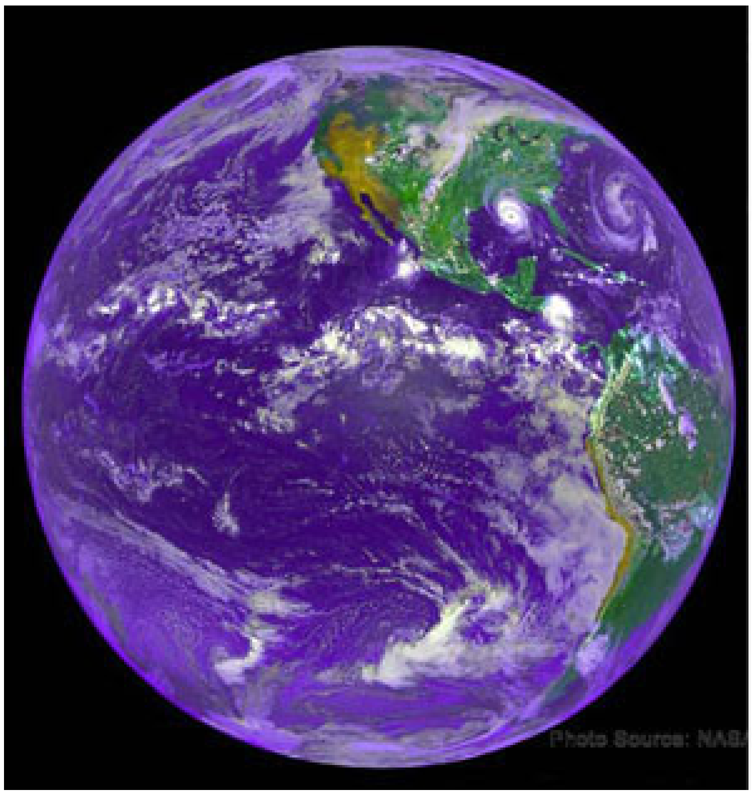
Despite their value to humans, coastal systems and the services they provide are becoming increasingly vulnerable. Degradation is a severe problem, since pressures within coastal zones are growing and because coastal zones are the downstream recipients of negative impacts of land use. Freshwater diversion from estuaries has meant significant losses of water and sediment delivery to fish nursery areas and fishing grounds – in the last 50 years there has been an average thirty percent decrease worldwide, with regional variations.[38] Coastal areas have been deemed the most highly chemically altered ecosystems in the world, given that the global average for nitrogen loading has doubled, with resulting eutrophication driving largely irreversible changes to coastal ecosystems.[39] Nearly half of the global population living in regional seas areas have no access to sanitation and thus face decreasing ecosystem services and increasing risks of disease. The global economic costs related to pollution of coastal waters are $16 billion annually, much of it due to human health impacts.[40] Mining and other industries cause heavy metal and other toxic pollution. Harmful algal blooms and other pathogens affecting the health of both humans and marine organisms are on the rise, in part because of decreased water quality. Over-exploitation of fisheries affects the majority of commercially fished stocks in both coastal and offshore waters, and is taxing the ability of oceans to provide food for growing numbers of people. Aquaculture, seen by some as a remedy to overfishing, is driving rampant destruction and degradation of some of the ecologically most critical habitats of the world. Add to this mix the problem of alien species and it is easy to see how very threatened these ecosystems have become.[41]

Coastal areas are physically vulnerable: many areas are now experiencing increasing flooding, accelerated erosion and seawater intrusion into freshwater. These changes are only expected to be exacerbated by climate change in the future. Coral reefs and atolls, salt marshes, mangrove forests and seagrasses will likely continue to be impacted by future sea-level rise, warming oceans and changes in storm frequency and intensity.[42] These ecosystems that are at greatest risk also support the largest coastal populations; thus collective human well-being is significantly at risk from ecosystem degradation and loss of services.

Globally, coastal and marine systems will continue to be altered, over-exploited, degraded and destroyed as competing demands for freshwater, marine resources, industry and living space increase.[43] In some cases these changes are unsustainable, even into the near term future. For instance, despite the value of coastal areas to support the tourism industry, coastal tourism development will likely continue to use coastal habitats for waste disposal, degrading these areas and rendering them useless in providing the very ecosystem services that attract tourists. Additional construction of dams will damage estuaries and reduce fisheries yields, even as freshwater diversion is meant to increase food supply. Fisheries will continue to be over-exploited as perverse subsidies drive further over-capitalization and as fisheries management remains largely unsuccessful at controlling destructive fisheries, by-catch, and impacts on whole ecosystems.[44] Regulating services such as carbon sequestration will continue to be adversely affected by global warming, ozone depletion, and the changes in ocean circulation brought about by a whole host of climate change impacts. Finally, given the fact that many degraded coastal systems and offshore fisheries are near thresholds for healthy functioning, and that coastal systems are simultaneously vulnerable to major impacts from sea level rise, erosion and storm events, coastal populations are in danger of having their relatively high levels of human well-being severely compromised.

Recent natural disasters provide a striking reminder of how very risky it is for us to degrade ecosystems that provide us with essential, though usually greatly undervalued, ecosystem services. Ministers of environment, finance, tourism, and internal and foreign affairs, would do well to heed the information presented in the Millennium Assessment, as would the private sector and civic society. The slow and largely unnoticed decline of marine ecosystem services may well be a sleeping dragon – one can only hope that we will learn to pay attention before it awakens in earnest.

Yet despite the sobering nature of what we are coming to find out about the importance of coastal and marine ecosystems services and how they stand at risk from myriad human impacts, this is a time of hope. Armed with information we can tackle the sleeping dragon before it wreaks havoc on the planet. Perhaps history will record the turn of the millennium as the dawn of a new era, when we no longer remain on the shores of what we know,[45] but rather set out to sea armed with the knowledge that if we take responsibility for the three-quarters of the planet that is marine and act as stewards rather than its plunderers, we will continue to reap the benefits of productive and healthy marine and coastal ecosystems for many years to come.



"Angels and ministers of grace defend us
…we fools of nature, so horridly to shake our disposition…"
- William Shakespeare, Hamlet, 1622

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