animals for sampling, minimal wall effects. Temperature is regulated by exchange of heat through the walls. But they have various drawbacks. Not only is advection suppressed but vertical mixing decreases so that the outside physical conditions are not reproduced. The greatest disadvantage, however, is lack of adequate replication. There have been only three to six of these mesocosms available for any experiment and pairs did not often agree closely. Thus each tube represents an ecosystem on its own rather than a replicate of a larger community.

The need for experimental results at the community level represents an unresolved problem in biological oceanography. There are smaller-scale experiments continuing. Open mesh containers through which water and plankton pass can be a compromise for the study of small fish and fish larvae. It is now possible to mark a body of water with very sensitive tracers and follow the effects on plankton of the addition of nutrients, specifically iron, for several weeks. The concatenation of these results may have to depend on computer simulations.

See also

Copepods. Fish Larvae. Iron Fertilization. Population Dynamics Models.

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MARINE POLICY OVERVIEW

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Introduction

Marine policy is an academic field in which approaches from social science disciplines are applied to problems arising out of the human use of the oceans. Usually, human actions affecting ocean resources take place within an institutional context: laws establish a system of enforceable property rights, and goods and services are exchanged through markets. Most marine policy problems involve institutional imperfections or 'failures.' Governance failures include ill-defined property rights, the incomplete integration of the actions of public agencies operating under separate authorities, and wasteful 'rent seeking' on the part of stakeholders. Market imperfections include oil spills, nutrient runoffs leading to eutrophication in coastal seas, and overexploitation of commercial fish stocks, among others. Even in the absence of technically defined institutional failures, problems may arise when decisions allocating marine resources are perceived to be unfair.

Most marine policy issues are subsets of broader policy areas. Some examples are presented in **Table 1**. Marine policy can be distinguished from these more general policy areas because legal property rights in the ocean often differ from those found on land. One reason for this difference is the relatively high cost of monitoring and enforcing private property rights in a remote and sometimes hostile environment. Other reasons include the fugitive nature of biological resources and the ease with which nutrients and pollutants are dispersed by currents and other physical processes.

The existence of these characteristics argues for collective action (i.e., the exercise of public authority) as a means of optimizing human uses and managing conflicts among users. The nature of collective action covers a spectrum from a centralized system of government 'command and control' to the implementation of decentralized 'market-based approaches.' The goal of marine policy analysis is to identify alternative courses of action for addressing a problem of ocean resource use and to inform public and private decision makers about the likely consequences. Consequences include physical, ecological, economic, and distributional (equity) effects. In any particular situation, the universe of policy

Table 1 Some examples of overlaps of marine policy with general public policy areas

General policy area	*Marine policy focuses*
Environment	Ocean and climate change; macronutrient fluxes; eutrophication and hypoxia; treated and untreated sewage effluent; oil and hazardous material spills; industrial chemical and heavy metal effluents; thermal effluents from power plants
Natural resources	Commercial and recreational fisheries management; ocean minerals exploration and management; aquaculture regulation; conservation of protected species (mammals, birds, reptiles, fish, corals); ecosystem management; marine protected areas: conservation of biological diversity
Energy	Offshore oil and gas development; tidal power; ocean thermal energy conversion
Land use	Coastal zone management; planning; zoning uses; barrier beach protection
Waste management	Solid waste disposal; sewage sludge disposal; marine debris; nuclear waste disposal; incineration at sea
Transportation	Shipping and ports; underwater cables and pipelines; safety of life at sea; aids to navigation; international rights of passage; salvage; admiralty law
Defense	Zoned training and testing areas; atomic free zones; acoustic pollution; rights of passage for military vessels
Foreign policy	Legal geography; piracy; international trade in protected species; refugees; high seas fisheries; transboundary pollution
Emergency management	Weather prediction; hurricanes; coastal flood insurance; tsunamis; harmful algal blooms; search and rescue
Science policy	Funding for oceanographic research; technology transfer; basic versus applied research; large-scale science programs

alternatives is constrained by the environmental characteristics of the ocean, the range of feasible technological responses, financial resources, and, sometimes, institutional frameworks and processes.

History of the Field

The emergence of marine policy as a distinct field of research dates back only about 40 years, coincident with rapid increases in ocean uses, the maturation of oceanography as a scientific field of study, and the rise of environmentalism. A number of journals specializing in public policy topics concerning the oceans, estuaries, and the coastal zone began publication in the early 1970s. Among these journals are: *Coastal Management*, *Marine Policy*, *Marine Policy Reports*, *Marine Resource Economics*, *Maritime Law and Commerce*, *Maritime Policy and Management*, *Ocean Development and International Law*, and *Ocean and Shoreline Management*. More recent additions to this list include: the *International Journal of Marine and Coastal Law* and the *Ocean and Coastal Law Journal*. Many marine policy problems predate this period, such as those relating to national security, international boundary determinations, resource exploitation, and shipping. In earlier periods, however, marine policy was not easily distinguishable from other, more general policy areas.

The negotiations on the third United Nations Convention on the Law of the Sea (UNCLOS) (1970–1982) may have spurred the development of the field, as many academic institutions in the West established programs in marine policy in the early 1970s. For example, the Marine Policy Center (then the Marine Policy and Ocean Management program) was established in 1972 at the Woods Hole Oceanographic Institution by Paul Fye, who was then director of the Institution. At that time, one main purpose of the Center was to follow and analyze the potential international regulation of marine scientific research, a focus of debate at the UNCLOS negotiations. Two institutions, the Law of the Sea Institute (1966 to present) and the Center for Ocean Law and Policy at the University of Virginia (1976 to present), have published on a continuous basis the proceedings of their annual meetings on international law of the sea issues. Since 1978, the International Ocean Institute, located jointly at the University of Malta and Dalhousie University, has published an annual *Ocean Yearbook* that features scholarly articles on marine policy topics, compiles descriptive statistics of ocean uses and legal geography, and summarizes the activities of marine policy research centers worldwide.

Social Science Disciplines

Marine policy is often described as a multidisciplinary field. Although academic degrees are issued in the United States and Europe in the field of marine policy or 'marine affairs,' progress in understanding marine policy problems typically occurs within the confines of more traditional social science disciplines. Alternative points of view may arise from the application of methods from different disciplines to a specific policy problem.

The social sciences are divided into a number of well-established disciplines. Some of these disciplines are listed in **Table 2**, along with examples of recent research topics to which they have been

Table 2 Social science disciplines and some examples of research foci

Discipline	*Some example research foci*
Cultural anthropology	Analysis of the effects of fisheries management on fishing communities; underwater archaeology research
Economics	Development of bioeconomic models of fisheries; estimating the net benefits of fisheries regulation; valuation of the nonmarket benefits of coastal and marine recreation; measurement of damages from marine pollution; evaluation of the net benefits of alternative policy instruments for controlling marine pollution
Geography	Mapping and analysis of demographic, resource, and economic data using geographic information systems
History	History of oceanography as a science; characterization of laws, social norms, and customs from earlier societies
Law	Analysis of legal institutions governing the use of marine resources; interpretation of common and statutory law with respect to ocean resource use
Philosophy	Identification and interpretation of the principles of environmental ethics as they apply to marine resource uses and conservation
Planning	Forecasting coastal and marine resource uses; demographic trends in the coastal zone; zoning the marine environment; marine protected areas; control of land use in the coastal zone
Political science	Analyzing common property institutions; characterizing the effectiveness of international environmental institutions; international regime formation
Sociology	Effects of fisheries management on fishing communities; importance of institutions in control of resource use

applied. Notably, considerable overlap may exist in the disciplinary coverage of certain topics, such as fisheries management.

Ocean Resources and Uses

The uses of the ocean for transportation, as a source of protein, and as a sink for wastes are among its oldest. In ancient times, the supply of ocean space and fish were thought to be virtually without limit. Modern humans have demonstrated that some uses of the ocean can preclude other uses, underscoring the existence of limits to the supply of space and resources, and giving rise to the potential for conflicts across uses. Since its modern development in the 1930s, oceanographic research has made significant strides in characterizing the distribution of ocean resources, although substantial uncertainties persist.

A broad range of ocean uses can be mapped into a small set of ocean resources. These resources include ocean space, living resources and their habitats, nonliving resources, and energy. **Table 3** lists the most prominent uses of the ocean along with a summary of typical marine policy issues that arise as a consequence of institutional imperfections.

Institutional Frameworks

Marine resources, their utilization, and ocean space are all managed through a myriad of legal instruments. These instruments exist at all levels of governance, including those policies directed at local or subnational concerns, and those designed to address issues of national, regional, or global importance. A seventeenth century *laissez-faire* concept of 'freedom of the seas' was based upon the premise that the ocean was infinite, its resources inexhaustible, its degradation impossible. These assumptions have proved to be both unrealistic and detrimental. It is now widely acknowledged that complete freedom of the seas would lead to resource waste and exploitation, economic inefficiency, and increased conflict among users.

Enclosure of Ocean Space

From a pragmatic perspective, the management of ocean space involves methods of enclosure. Theoretically, the enclosure of ocean space can be derived from both national and international management regimes. In practice, it has been accomplished through the seaward extension of national jurisdictions by establishing zones of authority and use (e.g., the territorial sea and exclusive economic zone; *see* **Law of the Sea**). The primary thrust has been toward the expansion of sovereignty over ocean space previously considered open-access. Although large-scale ocean enclosures have led to reductions in international conflicts over resource use within the proscribed enclosure, such conflicts continue to persist among domestic users and over resources (e.g., straddling fish stocks) that transgress enclosure boundaries.

Global Institutions

International cooperation to address marine and coastal concerns has been codified through several formal commitments. In international affairs, this institutionalization usually takes the form of

Table 3 Ocean uses and some leading policy issues

Use	*Some leading policy issues*
Commercial fishing	Overharvesting due to inappropriate management measures; overcapacity due to government subsidization; shifts to fishing lower trophic levels; impacts on habitat, species diversity, ecological functions, protected species; loss of gear; human safety risks
Recreational fishing	Overharvesting due to inappropriate management measures
Aquaculture	Macronutrient pollution; spread of disease; escaped fish; interactions with protected species; loss of gear
Shipping	Cabotage laws; cartelization; infrastructure investments, including harbor dredging; piracy; oil and hazardous material spills; marine debris; transport of invasive species; interactions with protected species; acoustic pollution; safety of life at sea
Channel dredging	Disposal of contaminated material; government subsidization
Ocean dumping	Radioactive waste disposal; chemical waste disposal; transport of pollutants from disposal sites
Minerals	Oil spills; benthic disturbances; habitat impacts; acoustic pollution; commercial and recreational fishery impacts
Recreation	Loss of ecosystems and habitat to other uses; impacts of global climate change; impacts of recreation on protected species, coral reefs; recreational boating safety
Defense	Weapons tests; acoustic tests; runoff of pollutants from military sites; oil and hazardous waste spills; marine debris
Coastal development	Erosion; industrial runoff; habitat loss; limits to public access
Agriculture	Macronutrient and pesticide runoffs; hypoxia; hypothesized links to harmful algal blooms

Table 4 Prominent global agreements and organizations for ocean management

Year	*Institution*	*Description*
1992	UNCED (United Nations Conference on Environment and Development)	International 'soft law' that helped to set the context for several international agreements targeting the interdependence of global environmental protection, sustainable development, and social equity. Most prominent for ocean management was Chapter 17 of Agenda 21 that stresses both the importance of oceans and coasts in the global life support system and the positive opportunity for sustainable development that ocean and coastal areas represent
1982	UNCLOS (United Nations Convention on the Law of the Sea)	An overarching framework convention that provides both a foundation for global ocean law, and a means for individual States to direct specific coastal and marine activities
1973	MARPOL (International Convention for the Prevention of Pollution from Ships)	The first comprehensive global convention that prevents or limits the type and amount of vessel-source pollution including oil, garbage, noxious liquid substances, sewage and plastics.
1972	London Convention	Established the first global standards to govern the dumping of wastes into the ocean, including specific mandates as to what materials may be legally dumped through a permit system.
1971	Ramsar Convention	Requires national initiatives by each signatory to conserve wetlands as regulators of water regimes and as habitats of distinctive ecosystems of global importance
1958	IMO (International Maritime Organization)	Facilitates international cooperation on matters of safety and environmental protection in maritime navigation and shipping. Its principal environmental responsibilities are to prevent marine oil pollution, provide remedies when prevention fails, and to assist the development of jurisdictional powers to prescribe and enforce pollution control standards through intergovernmental cooperation
1946	IWC (International Whaling Commission)	Regulates, but does not preclude, the global sustainable taking of whales through a system of quotas designed to prevent their overexploitation and possible extinction. Various management procedures and moratoria (including stout opposition to the moratoria by some commercial whaling nations) have provided an institutional framework but not a cessation of stock depletion

a treaty or customary practice, although certain important intergovernmental organizations also exist. On the global level, both broadly based and issue-specific treaties that affect a majority of national interests have been developed. **Table 4** describes some prominent examples of these agreements.

The proclivity of most States to cooperate in world affairs also extends to regional arrangements. Many coastal and ocean resources transcend political boundaries and thus do not conform to jurisdictional constraints. Therefore, several regional agreements address concerns that extend beyond national jurisdictions to the interests of neighboring

Table 5 Important regional institutions for coastal and ocean management

Institution	*Description*
UNEP (United Nations Environment Program) Oceans and Coastal Areas Program	Designed to address coastal and marine environmental problems (e.g., marine pollution, fisheries conservation and development, species protection) and socioeconomic issues such as tourism common to those nations that share a communal body of water. At present, over 100 hundred States participate in twelve regional oceans and coastal area programs
Large Marine Ecosystems (LME)	This concept has been proposed but it does not presently constitute a legal institution. An LME is a large region of ocean space, generally over 200 000 km^2 (77 000 square miles) and situated typically within exclusive economic zones, that have unique bathymetry, hydrology, and productivity and encompass a regional functional ecological unit. Managing this comprehensive ecosystem for both the protection of biological diversity and sustainable uses requires broad regional cooperation between States
Man and the Biosphere Program	The United Nations Educational, Scientific, and Cultural Organization's (UNESCO) Man and the Biosphere Program is an international program of concerted scientific cooperation among countries directed towards finding practical solutions to environmental problems. A major function is the establishment of protected areas (including several marine and coastal reserves) of ecological significance
Cartagena Convention	The Cartegena Convention addresses the myriad of environmental concerns (including marine oil spills) associated with the cultural, economic and political differences exhibited throughout the wider Caribbean. As a supplement, the protocol establishes protected areas to conserve and maintain species and ecosystems, and promotes the sustainable management and use of flora and fauna to prevent their endangerment
ICCAT (International Convention for the Conservation of Atlantic Tunas)	Primary goal is the conservation of tuna-like fishes and billfishes throughout the Atlantic Ocean and adjacent seas. Member nations must conduct most research, carry out analyses, and enforce ICCAT recommendations for their own nationals
Antarctic Treaty System	Composed of the 1972 Convention on the Conservation of Antarctic Seals; the 1980 Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR); the 1988 Convention on the Regulation of Antarctic Mineral Resource Activities (CRAMRA); and the 1991 Protocol on Environmental Protection; the Antarctic Treaty System (ATS) seeks to bring institutional order to the activities of those States claiming sovereignty over Antarctic territory, or those interested in resource exploitation
The Great Lakes Program	A comprehensive management regime for the protection and management of the Great Lakes established through the cooperation of the federal governments of the United States and Canada, eight US states, the Canadian province of Ontario, and many local and regional organizations. Targeted issues include nonpoint source pollution, water levels, navigation, recreational activities, and fishing.

states. Table 5 provides several illustrations of regional institutional governance.

National Institutions

Virtually all coastal nations have enacted domestic marine policies and laws to legitimize their claims to ocean resources and space. Despite the inefficiencies of fragmented policy administrations and a general lack of public input and future planning, the resulting governance regimes have brought order to the management of various ocean uses. These legislative actions have often been taken as a reaction to real or perceived threats to the health of the ocean or the overexploitation of resources. Often, these laws are designed to work in conjunction with regional and international treaties, but sometimes they do not. The US Marine Mammal Protection Act is one example of a national institution that aims to conserve specific marine resources but which has come into sharp conflict with international trade law.

Institutional Integration

In general, most laws governing the use of ocean space and resources are sectoral and issue-specific. Examples include legislation pertaining to fisheries management, offshore oil and gas development, and coastal mineral extraction. The primary concern is that as ocean space, particularly coastal waters, becomes the subject of increasingly intense and diversified uses, the activities of one user group will frequently affect the interests of others. A goal of institutional integration is to discover ways in which all uses can be optimized or, at least, coexist without rancor. The hope is that integration can reduce conflicts between uses. The integration of marine policies, sometimes through the implementation of so-called multiple-use management regimes, works to eliminate the inefficiency of single-sector regulatory schemes and is believed to mirror more closely the dynamic complexity of the ocean system. For example, some marine protected areas exhibiting

high degrees of marine biological diversity are zoned also for human uses such as tourism within a multiple-use management system.

The primary purposes of integration are to ensure that links among issues are not neglected in the creation and implementation of public policies and to internalize the external costs that normally accompany the misuse of open-access resources. Integration also emphasizes responsiveness to the legitimate needs of current users while exercising stewardship responsibility on behalf of future generations. Unfortunately, a number of obstacles to the integration of marine policies remain, including incomplete scientific information, boundary disputes, lack of political will, fractionalization of government efforts, and the existence of short-term ocean management programs that may not be optimal for solving persistent problems.

Integrated Coastal Zone Management

A prime illustration of the movement toward policy integration is found in the management of the coastal zone and its resources. Integrated coastal zone management (ICZM) is a process that attempts to resolve coastal conflicts, promote the sustainability of resources, and enhance economic benefits to coastal communities. Despite some reservations as to the practicality of the concept, ICZM is designed to overcome the traditional sectoral approach to managing coastal uses by accommodating all sectors within the context of a larger planning scheme. Management tools including zoning, special area planning, land acquisition and mitigation, easements, and coastal permitting are employed to implement an ICZM program. Evolving ICZM efforts are ongoing in such diverse nations as the United Kingdom, Thailand, South Korea, and Tanzania.

Analytical Approaches

Approaches to the analysis of marine policy issues are diverse, ranging from highly quantitative models to qualitative and descriptive techniques. Whether mathematical or descriptive, these approaches are unified by the presentation of policy options and the comparison, using disciplinary criteria, of alternative courses of action. Economic and political science models tend to be more quantitative, whereas models from other social science disciplines tend to be less mathematically oriented. All social science applications to marine policy problems may test hypotheses, employing rigorous statistical methods for the analysis of empirical data. These methods include the standard regression techniques as well as modern nonparametric, time series, and limited dependent variable techniques. Different analytical approaches in marine policy can be complementary, and they are commonly informed by oceanographic research findings and theory.

Economic Analysis

The economic theory focusing on the management of marine resources provides the most common example of the application of a quantitative approach. Neoclassical economics emphasizes the selection of a course of action that optimizes the welfare of society through the supply and consumption of goods and services. In the marine environment, natural resources, such as fish, marine mammals, coral reefs, or entire ecosystems, represent these goods and services, and the dynamics of the ecosystem, including its response to human exploitations, provides a natural constraint to welfare optimization.

A basic model, developed in the 1950s, seeks to maximize welfare in the form of producer surplus (profits, broadly defined) in a fishing fleet of identical vessels from the harvest of a single fish stock. Numerous extensions of the basic model include the addition of other ecologically related species, the incorporation of uncertainty, the investigation of nonlinear dynamics, the consideration of a nonuniform distribution of fish stocks, the analysis of consumer surplus, the introduction of competing fleets or nations (game theory), and so forth. The model has become an important tool in the analysis of the economic and biological effects of the implementation of conservation and management measures in a fishery, such as marine reserves or individual transferable quotas. Given significant uncertainty and lags in the response of the marine ecosystem to human perturbations, fisheries economists and scientists now think in terms of managing a fishery adaptively by observing how the system responds to variations in the level of fishing pressure.

The economic optimization model has been utilized most commonly in the analysis of fishery management questions. Other, related applications include those in the areas of marine pollution, the environmental risks of offshore oil and gas development, shipping infrastructure, ocean dumping, and marine aquaculture.

Economic analysis is also directed at estimating the willingness of members of society to pay for goods and services that are not traded on established markets. Several approaches have been used to value these so-called 'nonmarket' commodities, some of which have generated considerable controversy. Nonmarket goods for which demand has been estimated include beach visits, water quality,

marine mammals, marine protected areas, and coral reefs, among others. The purpose of estimating nonmarket values is to allow a comparison in common units of the economic values of market and nonmarket commodities when deciding on the net benefits of alternative courses of action.

Organizational Studies

Social organization and cultural norms are institutional forms that may shape the feasible set of policy alternatives for any particular marine policy issue. Researchers in disciplines such as geography, sociology, history, and cultural anthropology, among others, focus their research efforts on broad- and fine-scale characterizations and mappings of social organization. Their studies include understanding the development of resource-based communities and enclaves and the ways in which coastal and marine resources are used and conserved. Through induction, empirical studies lead to theories of the natural emergence of organizational principles for the management of marine resources, including collective choice arrangements, enclosures, property right definition and enforcement, and modes of conflict resolution. One such theory that appears in the fisheries context involves the concept of co-management, through which management responsibilities and functions are shared, according to specified rules, between the owners of the resource, or their agents, and those who are involved in its exploitation.

Legal Studies

During the last 30 years, the body of law governing the human uses of the ocean has expanded and diversified at a rapid pace. At both national and international levels, virtually all uses of the sea are now regulated in some fashion. Ocean law is a dynamic institution that responds to changing ecological parameters, economic conditions, and technological and scientific advances. Legal analysts track the changing nature of the law, interpret the way in which legal institutions affect the allocation of marine resources, and characterize the actual and potential impacts of these institutions on human behavior.

One could easily argue that the courts, legislative bodies, and executive agencies with responsibility for ocean management rely on legal analysis to a much larger extent than other types of marine policy analysis. Methods of legal analysis can be characterized generally as descriptive and interpretive, relying upon: the practice of nations; the content of treaties, statutes, and rules; the interpretations of courts; and uncodified societal norms. Legal analysis may be further characterized as subjective, in the nature of advocating a particular policy to benefit the interests of one or more agencies or stakeholders.

Institutional Effectiveness

In the field of international political relations and in domestic policy reviews, analysts attempt to understand the extent to which an institution is effective at attaining agreed-upon goals. For example, the degree to which an institution, such as an international agreement to control land-based marine pollution, is effective at improving the quality of the marine environment would be based upon observed changes in environmental quality measures over time. In contrast with economic analysis, studies of institutional effectiveness put forth no normative standards, such as the optimization of social welfare. The goals are determined by the participants (stakeholders, national legislatures, legations) who establish the institution. If the goal is attained, then, holding constant other motivations, such as political power, changes in economic conditions, or external influences, it is assumed that the institution has been effective in motivating its participants to take action.

Lesson-Drawing

Another useful analytical approach is known as 'lesson-drawing.' As a form of comparative political analysis, lesson-drawing focuses on the set of circumstances through which marine policies observed to be effective in one jurisdiction are potentially transferable to another. Confronted with a common problem or consistent behaviors, policy makers may be able to learn from how their counterparts elsewhere respond, and conclude that the implementation of policies in other places may be of use in their own circumstances. Lesson-drawing is particularly useful in nations that share some commonalities such as resource availability or cultural norms. The methodology involves an initial search for similar contexts and policies in other jurisdictions, the development of a conceptual model of the application of the policy, a comparison of practices across jurisdictions, and a prediction or forecast of success after the lesson has been drawn and the policy approach adopted.

Notably, the search for and discovery of lessons does not imply that there must be a common application. Realistically, one cannot expect that policies can be successfully transferred without considering the idiosyncratic characteristics of

jurisdictions that may allow the policy to be effective in one place but not in another. For example, in the case of preserving marine biodiversity by zoning, there is no generic type of marine protected area that is capable of meeting every situation. The nature of a reserve, its design, and its regulatory framework all depend on the primary objectives it seeks to achieve. These identified objectives will influence the size, shape, and other design constraints of the protected area, and its implementation.

Future Prospects

Marine policy will continue to grow in importance as human populations place increasing pressure on coastal space, ocean resources, and marine ecosystems. These pressures, driven by such forces as population growth, human migration to coastal areas, and expanding demand for both living and nonliving resources, will disrupt ecosystems, lead to genetic losses, and exacerbate user conflicts. As many of these problems involve institutional failures, in the future, historical customs and institutions will need to be re-examined. Solutions involving the establishment of new (or clarification of existing) property rights and their enforcement, utilizing technologies that lower the costs of monitoring and enforcing such rights, will undoubtedly come to the fore.

Policy choices affecting the allocation of ocean resources lead to questions of effectiveness, or the ability of institutions to meet agreed-upon goals. Despite the steady advance of marine science and technology, policy makers must face choices across options with a high degree of uncertainty. In the face of uncertainty, policy analyses can be neither comprehensive nor fully conclusive, leading policy makers to turn increasingly toward precautionary approaches. Substantial alterations to the current institutional framework supporting coastal and ocean activities are necessitated by the shift to a precautionary approach, including a movement away from sectoral management and toward the greater integration of policies.

See also

Coastal Topography, Human Impact on. Diversity of Marine Species. Fishery Management. Fishery Management, Human Dimension. International Organizations. Large Marine Ecosystems. Law of the Sea. Mariculture, Environmental, Economic and Social Impacts of. Marine Protected Areas. Oil Pollution. Pollution Control. Tidal Energy. Wave Energy.

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MARINE PROTECTED AREAS

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Introduction

Marine protected areas (MPAs) are a regulatory tool for conserving the natural or cultural resources of the ocean and for managing human uses through zoning. MPAs may also be referred to as marine parks, sanctuaries, reserves, or closures; the latter two terms are used most commonly in the context of fisheries management.

Definition

At a conceptual level, zoning in the ocean involves the spatial segregation of a marine area in which certain uses are regulated or prohibited. This general definition might apply to any marine area in which a set of human uses are given preference over others. For example, by law the US President may set aside hydrocarbon deposits on the US outer Continental Shelf as 'petroleum reserves.' However, the typical use of the term 'protected' implies that a primary focus of an MPA is on the conservation of either individual species and their habitats or ecological systems and functions through the regulation of 'extractive' or potentially polluting commercial uses, such as fishery harvests, waste disposal, and mineral development, among others.

MPAs are frequently considered to be a fishery management measure, but they may be used for other purposes as well. For instance, in 1975, the first US national marine sanctuary was created around the wreck of the *U.S.S. Monitor*, a civil war vessel, located off the coast of North Carolina. The sanctuary was established to prevent commercial 'treasure' salvage and looting of the shipwreck, to regulate recreational diving, and to promote archaeological studies. In the discussion below, we focus on the use of MPAs in the field of fishery management because this use represents one of the most relevant and interesting examples.

Size

Although there is no discernible size limitation, the issue of geographic scale may be another defining characteristic of MPAs. On the tidelands of US coastal states, for example, the 'public trust doctrine' gives preference in the common law to transitory public uses, typically navigation, fishing, and hunting, over permanent private uses, such as constructing a dock. Yet the tidelands, which are quite extensive, are not referred to as an MPA. Some fishery closures can be quite large, and we would classify these as one type of MPA. The Great Barrier Reef Marine Park in Australia is the largest MPA in the world, measuring 344 million km^2. Most of the world's existing MPAs are much smaller, however, and focused on unique ocean features or sites, such as coral reefs or underwater banks. The World Bank estimates the median size of a sample of about one thousand of the world's MPAs to be 15 840 km^2 (**Figure 1**).

Number

Worldwide, MPAs have become a popular form of ocean management, and their use has expanded exponentially since they were first introduced in the late nineteenth century (**Figure 2**). The trend in the establishment of MPAs follows on the heels of a more general trend in the regulation of ocean uses, as an MPA represents merely a form of governance distinguishable geographically by type or severity of regulation. Regulation of the ocean has become