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Woods Hole Oceanographic Institution

Marine Biological Diversity:

Report of a Meeting of the Marine Biological Diversity Working Group

Edited by

Mark E. Eiswerth

March 1990

Technical Report

Funding was provided by The Pew Charitable Trusts.

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Approved for Distribution:

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Marine Policy Center

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I. ABSTRACT

On August 3-4, 1989, the Marine Policy Center of Woods Hole Oceanographic Institution hosted the initial meeting of the Marine Biological Diversity Working Group. The formation of this working group was fostered as part of an ongoing program of research concerning the oceans and biological diversity. Participants in the working group include professionals from the fields of biology, ecology, economics, statistics, law, environmental management, and international assistance, all of whom have expressed an interest in issues surrounding the conservation of marine biological resources. The proposed goals of the working group are to initiate an ongoing interdisciplinary dialogue on the topic, to establish a mechanism for two-way transfer of theory and empirical results between natural and social science, and to serve as a resource for policymakers by providing authoritative and timely information on important issues. This report contains information about the working group and the motivations for its formation, a description of the format of the initial meeting, key points from each of the sessions, abstracts of research/issue briefings delivered at the meeting by participants, selected excerpts from group discussions, and an amended version of a draft working group statement that was introduced to the group for purposes of discussion. The appendices contain the agenda of the meeting, a list of the names and addresses of working group participants, and a list of key questions and issues submitted before the meeting by the working group.

II. THE MARINE BIOLOGICAL DIVERSITY WORKING GROUP

The Earth's endowment of biological diversity is a natural resource whose diminishment by human activities has received an increasing amount of attention by scientists, policy-makers and the public. Almost all this attention has been trained on the world's most biologically rich terrestrial ecosystems, in particular on rainforests in areas such as Brazil, Indonesia and tropical Africa. Clearly, an important factor which has focused attention in this way is the sheer number and tremendous variety of animals and plants which inhabit the world's rainforests. Another factor is the possibility of a link between rainforest destruction and adverse changes in global climate.

Though relatively little attention has been devoted to the dangers of a diminishing variety of life in marine habitats, it has long been known that the oceans play host to a large number of highly diverse living systems. High diversity in coral reefs, for example, motivated several efforts in the 1970s to determine the causal factors involved in the maintenance of diversity (e.g.: J.H. Connell, "Diversity in Tropical Rain Forests and Coral Reefs," *Science* **199**, 1302-1310 (1978); J.F. Grassle, "Variety in Coral Reef Communities," in *Biology and Geology of Coral Reefs*, Vol. II: Biology 1, Academic Press, Inc., New York (1973)). In deeper regions of the ocean, scientists have discovered that deep-sea ecosystems also can display a startling degree of biological diversity (e.g.: N. Maciolek, J.F. Grassle, B. Hecker, P.D. Boehm, B. Brown, B. Dade, W.G. Steinhauer, E. Baptiste, R.E. Ruff, R. Petrecca, "Final Report for the U.S. Dept. of Interior, Minerals Management Service OCS Study MMS 87-0050" (1987); R.R. Hessler and H.L. Sanders, "Faunal Diversity in the Deep-Sea," *Deep-Sea Res.* **14**, 65-78 (1967)). As with coral reefs, these findings have led to explanations regarding the determinants of high biological diversity (e.g.: J.F. Grassle, "Species Diversity in Deep-sea Communities," *Trends in Ecology and Evolution* **4**, 12-15 (1989)).

There is a growing awareness that threats to biological diversity in some marine ecosystems may be significant and increasing in severity. As a result of the most comprehensive study of such threats to date, The Oceanic Society recently completed what will prove to be a very useful report on biological diversity in the oceans (B.T. Miller and J.G. Catena, *Neptune's Ark: On the Nature and Protection of Biological Diversity in the Oceans*, Island Press, Washington, D.C. (In Press)). This report follows on the heels of E.O. Wilson's recent book on biodiversity, which includes one chapter devoted to diversity in marine ecosystems (G.C. Ray, "Ecological Diversity in Coastal Zones and Oceans," in E.O Wilson (ed.), *Biodiversity*, National Academy Press, Washington, D.C. (1988)). Notwithstanding the interest sparked by these reports, however, the awareness of threats to marine biological diversity is still very much in its infancy. While scientists perceive that serious biological impoverishment is a real possibility in several marine habitats, cognizance of these risks does not appear to have made its way to a significant subset of policymakers or the public. Certainly, attention to marine habitats has in no way begun to approach that given to the biological impoverishment of terrestrial ecosystems.

The perceived attention gap regarding the processes of and appropriate reactions to marine biological impoverishment represented a primary motivation for the formation of the Marine Biological Diversity Working Group. This group consists of professionals who are interested and involved in issues related to marine biological diversity. The interdisciplinary nature of the group reflects its belief that approaches to the problem of diminishing biological diversity should involve expertise and input from the fields of biology, ecology, economics, law, policy analysis, and environmental and resource management.

The proposed objectives of the Marine Biological Diversity Working Group are to initiate an ongoing interdisciplinary dialogue on the topic, to establish a mechanism for two-way transfer of theory and empirical results between natural and social science, and to serve as a resource for policymakers by providing authoritative and timely information on important issues. Examples of objectives that are important in meeting these goals are to determine the level(s) of diversity upon which resource managers should focus (e.g., species vs. ecological), to define clearly the ecological importance and sources of value of marine biological diversity, to identify those marine ecosystems that face the greatest risk of biological impoverishment, and to suggest practical conservation approaches to protect, replenish and shepherd this vital natural resource.

III. FORMAT OF THE MEETING

The August 1989 working group meeting consisted of seven distinct sessions, six of which were organized around featured presentations which dealt with specific topics (ranging from 20 to 45 minutes), and shorter research/issue briefings (10-15 minutes). The research/issue briefings allowed participants an opportunity to introduce themselves to the group and to discuss relevant research or program areas in which they have been involved.

The first session included introductory remarks, an overview of marine biological diversity, and a presentation concerning key policies, strategies and institutions. Subsequent sessions were structured loosely along thematic lines, and included discussion of economic issues, general biological considerations, diversity in specific marine habitats, law and policy, and consideration of marine diversity in international development and environmental management programs. The final session of the meeting was devoted to group discussion, including discussion of the working group statement and possible future activities of the group.

IV. KEY POINTS FROM MEETING SESSIONS

Key Points: Overview and Institutional Considerations

* Although fewer species appear to inhabit the ocean than the land, consideration solely of numbers of species can be a misleading indication of diversity. At higher taxonomic levels (e.g. the phylum level), marine ecosystems exhibit far greater diversity than terrestrial ecosystems. Because of this, many marine ecosystems also tend to exhibit a high degree of diversity in genetic material. In any case, biological diversity comes in other important forms beyond simply number of species.

* Based on samples taken from a deep ocean habitat off the New Jersey coast of the United States, deep-sea species diversity can be tremendously high. Furthermore, as compared to terrestrial ecosystems, there are a very large number of phyla represented in deep-water systems of the ocean.

* Too few samples have been taken to allow for an estimate of regional or global deep-sea diversity. A major obstacle to such an estimate is current lack of knowledge concerning the distribution of rare species.

* There currently are critical threats to marine biological diversity in near-shore areas such as coral reefs, mangroves, and seagrass beds. These habitats display the clearest, most obvious vulnerabilities to biological impoverishment as a result of human activities.

* Marine pollution, including eutrophication and sedimentation from coastal runoff, may outweigh harvesting, habitat destruction, species introductions, atmospheric effects, and climate change as a threat to biological diversity in the oceans.

* The coastal zones of the Earth contain many of the true "hot spots" of threatened biological diversity. While tropical rainforests are located a long distance from most of the Earth's inhabitants, many of the hot spots of marine biological impoverishment are "right outside our window."

* Ecological theory is shifting away from a focus on central tendencies in ecosystems and toward a concentration on ecotones or boundary conditions. Boundaries between ecosystems act as "membranes" for the transfer of nutrients, organisms, etc. The importance of biological interactions in ecotones should have a central place in discussions of marine biological diversity preservation.

* The tremendous deficiency of interactions between biologists and social scientists continues to be a critical hurdle in efforts to focus scholarship on the policy problems of biological impoverishment. Because of the interdisciplinary nature of the group, a key strength of the Working Group is its capability to address the **social science** and **policy** aspects of this topic.

Key Points: Economics

* Given scarce resources, it is necessary to make **choices** concerning the allocation of funding to possible programs of biological resource preservation. In making such choices, explicit consideration of the economic value of biological diversity can be helpful.

* Most previous work concerning the economics of biological diversity has focused on either the valuation of or optimal management strategies for a single species or single resource. While these approaches are important, it is crucial that we focus on the value of biological diversity **itself**, that is, the value of the distinctions and variety among the individual elements of natural systems.

* Different species of organisms that display strong similarities to one another often yield similar kinds of economic benefits for humans. This is true for a wide array of benefits, such as food production, marine recreation, the synthesis of medicines, research on basic biology, etc. Therefore, if society is interested in enjoying a broad class of benefits from marine life, then it is important to focus on the protection of a "stock" of marine plants and animals that displays great diversity, as opposed to a more homogeneous array of resources. This general guideline becomes more important as resources available for conservation programs become more scarce.

* Benefit/cost analysis represents a promising framework for the assessment of possible biological resource preservation programs. A major strength of this kind of analysis is that it can encourage policymakers to make explicit, rational choices concerning tradeoffs, when decisions regarding those tradeoffs would otherwise be made implicitly anyway. In assessing the benefits of biological diversity, however, it is very important to account for what economists refer to as "non-use values", such as the enjoyment of simply knowing that diversity exists.

* Uncertainty about the social benefits of biological resources and about future environmental conditions provides one strong rationale for the maintenance of biological diversity. Economic models illustrate that, with uncertainty, social benefits can be increased by the preservation of those elements of ecosystems that exhibit high diversity in structure and function.

* In some cases, additional information concerning the costs and benefits of marine biological resource preservation may only become available with the passage of time and in the event that preservation actually is carried out. Otherwise, the resource and information about it may be lost. There thus may be a special kind of benefit from preservation, which is the value of the scientific information that is generated by implementation of conservation programs.

* Some of the most apparent threats to marine biological diversity occur along the tropical coasts of developing nations. When marine reserves are established in such areas, local residents may experience

economic hardship and may react by increasing their economic activities at the edges of the areas, which can lead to degradation in the reserves themselves. The need to find ways to compensate for losses imposed on those dependent on the exploitation of marine resources thus is important in the formulation of conservation policies.

Key Points: General Biological Issues and Specific Habitats

* While scientists recognize different levels of biological diversity (e.g. ecosystem, species, genetic), a great deal of the discussion to date has dealt exclusively with diversity at the species level. For the purposes of designing resource management and conservation programs, however, it is exceptionally important to focus more heavily on the community, or ecosystem, level of diversity. An overemphasis on species could lead to ineffective approaches to conservation.

* Different ecosystems respond differently to changes in the physical environment. For example, the response of terrestrial organisms to short-time-scale physical changes may differ dramatically from those of marine organisms, which have evolved in a markedly different setting. This illustrates one kind of "functional diversity" - diversity across ecosystems in terms of functional response to physical change.

* Evidence indicates that recent regional and local population extinctions of commercial sponges and eel grass in the Caribbean may have been related to positive thermal anomalies in sea surface and atmospheric temperatures.

* The New England-Canadian Maritime region displays significant zoogeographic complexity due to climatological and physiographic factors. Notable features include discontinuous distributions of species and outlier populations of species. It is these kinds of conditions that may produce patterns of significant and valuable genetic diversity.

* Recent research concerning fish reproductive cycles and spawning patterns may enhance efforts to protect and manage key spawning grounds for fish.

Key Points: Law and Resource Management

* In the United States, an array of federal laws potentially affects the biological diversity of marine ecosystems. These laws may be categorized into several subsets, each of which approaches environmental protection in a very different way: (1) Species protection, (2) Habitat protection, (3) Land use controls, (4) Pollution controls, (5) Off-site conservation, and (6) Federal funding incentives for state initiatives.

* Ocean policy in the United States has always been based on overlapping and sometimes conflicting laws and programs and the numerous agencies which administer them. U.S. ocean policy has never been fully integrated or comprehensive, despite efforts to achieve coordination through reorganization of federal agencies, the formation of special commissions and interagency entities, and other attempted programs and mechanisms.

* The argument can be made that international law now requires comprehensive research, planning and management for ocean resources. This requirement of employing the "ecosystem management model" is based largely on the history of nation-state practice and international agreements and resolutions. As part of customary international law, this approach is legally binding on U.S. federal and state governments.

* Cultural characteristics of nations are necessary considerations in the design and implementation of programs aimed at the protection of marine habitats. Preservation efforts that ignore these considerations clearly invite failure.

* The establishment of marine reserves or sanctuaries is a promising approach to the protection of marine biological diversity. There are, however, two practical drawbacks. First, the sanctuary approach is not effective in the face of transboundary pollution, for example, land-based pollution that may be transported into marine protected areas. Second, sanctuaries are not totally effective for cases in which targeted species spend part of their life-cycles outside the protected area.

V. SUBMITTED ABSTRACTS

OF PRESENTATIONS

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THE ECOSYSTEM MODEL -- MANDATE FOR A COMPREHENSIVE UNITED STATES OCEAN POLICY AND LAW OF THE SEA

In 1969, the Stratton Commission Report stated a "plan for national action" premised on a comprehensive ocean policy and program. Overlapping and conflicting laws and regulations and the lack of coordination among state, federal and local agencies hindered our ability to both protect the oceans and coasts and develop our ocean resources. To protect the environment and provide for "constructive management of the living resources of the sea," an "understanding of ecosystem dynamics" was essential.

The solution had to be "comprehensive systems" to regulate our coasts, to manage living and non-living resources and to monitor and predict environmental changes in the oceans. Ocean programs and policies had to be integrated and coordinated.

In my article, I compare the premises and recommendations of the Stratton Commission to America's present ocean policy and program. I suggest that there now exists a mechanism to provide for the establishment of a coordinated and integrated national ocean policy. That mechanism is the new international law requirement of comprehensive research, planning, and management for the oceans's space and resources. This "ecosystem model" is binding in domestic United States law and can be implemented under existing statutes and by existing government agencies.

The Article reviews the history of United States ocean policy. Over the last 20 years, there has been an extraordinary growth of federal and state marine-related programs. This rapid growth has, however, been haphazard. Laws and policies responded to different crises and varied constituency concerns. The management and policy framework is single-purpose oriented and often without consideration of the close interconnections between multiple offshore uses and resources.

These practices have led to criticism that we have "no ocean policy." Obviously, this is not accurate. We have many statutes that authorize numerous programs which are administered by numerous departments and agencies. The problem has been, and still is, that we have no "comprehensive" ocean policy.

Numerous attempts have been made to coordinate ocean policy, based on four strategies: (1) elevation of ocean issues and coordination to the highest levels of government; (2) reorganization of the federal government; (3) oversight by special committees, commissions, and interagency coordinating bodies; and (4) mandates for reports and coordination by special legislation. Each has had only limited success. The status of ocean policy today is still that of scattered laws, administered by scattered federal agencies, with minimal attention or integration.

There has been no coordinating theme to our marine-related programs, plans, and activities. There has been no theory or model that requires those in government and those conducting ocean activities to consider the collective, cumulative and sometimes conflicting impacts of the separate rules, policies, and actions that are focused on particular uses of the ocean.

Such a coordinating theme now exists. It is the **ecosystem management model.**

The article then describes the evolution of this comprehensive approach into a binding rule of international law. As a result of scientific consensus, scholarly writings, nation-state practice, and international agreements and resolutions, international law now requires an ecosystem-based integrated approach to ocean research, planning, management and policy. This mandate has been codified in the United Nations Convention on the Law of the Sea.

The ecosystem model must now be the basis of United States ocean policy. Customary international law is part of our domestic law, unless specifically overridden by domestic law. Thus, the model, requiring a comprehensive approach to ocean management and policy, is binding on federal and state government officials. In implementing the numerous federal and state laws and regulations applying to the coastal and ocean space, government officials must exercise their discretion, jointly if necessary, to reconcile their mandates with an integrated ecosystem model. Failure to do so is a violation of federal law and redressable in the courts.

The article concludes with illustrations of how that reconciliation can occur. Statutes must be interpreted to be consistent with the ecosystem model. Old coordinating mechanisms must be strengthened and new ones created. Interested citizens must be willing to seek judicial relief for insufficient administrative action. Funding must be made available, as necessary, to insure adequate planning and coordination of policy.

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THE ECONOMICS OF MARINE BIODIVERSITY

Most previous work on the economics of biological diversity has followed one of two lines. One of these is the analysis of "optimal extinction," that is, the conditions under which economic rationality might dictate driving a species to extinction or, alternatively, the conditions affecting investment in species preservation. The other dominant line of analysis has addressed the question of nonmarket valuation on species and related natural resources. While important for progress in valuing conservation of biodiversity, this approach is more concerned with the value of individual biotic elements or assemblages than with the value of the diversity among those elements.

Our work at Woods Hole is taking a somewhat different approach. It grows from the premise that scarcity of knowledge and other resources requires that choices be made and priorities established, either explicitly or implicitly, in conservation of the planet's endowment of biological diversity. This requirement for social choice, along with the view of biological diversity as a natural resource, raises the issue of the value of biological diversity per se, as distinct from the value of individual habitats, species and organisms. Thus we are applying the economic theory of diversifications, portfolio formation, and risk hedging to the question of biodiversity. Within that framework we intend to draw comparisons between terrestrial and marine biodiversity.

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CONSERVATION PROBLEMS PECULIAR TO MARINE ECOSYSTEMS AND THE MOBILIZATION OF A POLITICAL CONSTITUENCY

In animal communities, highest biological diversity is at the base of Eltonian pyramids among animals that are small. But on land these small animals are dependent on food chains that are based on very large plants; indeed, it is likely that most of the animal diversity in the richest of all ecosystem types, the tropical rain forests, is found in tiny herbivores of trees. The highest diversity of vertebrates is likewise concentrated in the smallest animals, those less than 20 cm long or 10 g weight. None of this high diversity in terrestrial animals is at risk from direct harvesting because harvesting animals of these size fractions is impracticable in terrestrial systems. Rather the risk on land comes from destruction of the plant base to the food chains. Plant diversity on land, however, is at peril from direct harvest. One of the consequences feared from the destruction of the Amazon rain forests is the loss of a significant part of the 80,000 species of vascular plants thought to live there. Preservation of biological diversity on land, therefore, is resolved into preserving terrestrial vegetation and habitats. Some large animals on land are in direct peril from harvesting; rhinoceros and elephants are obvious examples; but the total loss of diversity from harvesting animals on land is likely to be trivial compared with the loss from destruction of habitat.

Biological diversity in the oceans is differently distributed. Most ocean plant diversity is in plants of microscopic size, the populations of which are immense. The plants are not at risk from harvesting. Most marine plants are probably not at risk at all because even the most catastrophic pollution events are of constricted area compared with the size of ocean water masses. And diversity in the animals of the open oceans has a relationship to the Eltonian pyramids that is quite different to the relationships found on land. The diversity of free living open-ocean herbivores probably does not approach the relative diversity of small herbivores on land, because of the difficulty of partitioning the limited diversity of small plants on which ocean diversity is based. But a significant portion of the diversity of free living ocean herbivores is, unlike on land, in size fractions susceptible to harvest. Harvest of animals only a few centimeters long or a few grams in weight is not only possible in the oceans, but relatively easy. Animals high on the Eltonian pyramids in the oceans are likewise all easy to harvest. In principle, advancing technology puts most of the animal diversity of the open oceans at risk directly from harvest, a pattern quite different from the pattern of risks on land.

A second portion of herbivore or primary carnivore diversity in the oceans is provided by the planktonic larvae of benthic organisms. These are at risk from two processes: harvesting of the adult organisms and destruction of habitats of the adult organisms. Because the total habitat for many benthic animals is restricted to coastlines, they are particularly vulnerable both to harvest and to habitat destruction by reduction of water quality.

Conservation of biological diversity in the oceans, therefore, imposes different tasks than does conservation of diversity on land. A large part of the task will involve direct control of the harvesting of animals that have commercial value. This will become ever more urgent as the technology of harvest improves. Experience of terrestrial conservationists of similar problems of control of commercially valuable animal stocks, though informative, is trivial compared with the scale of the undertaking that will be necessary in the oceans. A smaller part of the marine task is the preservation of coastal habitats. Despite the fact that these habitats are more vulnerable to pollution than are terrestrial habitats, they have the advantage that people cannot live on them, suggesting that pressures for their destruction are typically less than pressures on fertile terrestrial habitats.

The political constituency whose support is needed in order to effectively control harvest of the oceans and to preserve near-shore habitat is the middle class in oceanic nations, together with the medial that form the attitudes of that class. Recent experience in terrestrial conservation illustrates this. Despite many years of agitation by first world conservationists, the destruction of the Amazon forests continued to accelerate, with the government of Brazil dismissing protests from outside and encouraging the clearing of the Amazon as a matter of national policy. A change has at last come, however, because the Brazilian middle class, with its views reflected in, and molded by, the Brazilian media, has started to call for the preservation of the Amazon rain forests. The change is both sudden and remarkable and has led to a major candidate for the Brazilian presidency at the next election adopting a "save the Amazon" issue in his appeal to the voters. The message for the conservation of biological diversity in the oceans is that conservationists must explain accurately what is being lost so that educated, middle-class people can understand the self-denial of immediate gain that is needed to prevent this loss.

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RISK AVERSION AS A MOTIVATION FOR CONSERVING BIOLOGICAL DIVERSITY

In recent attempts to discuss the "value of biological diversity," economists have tended to focus on efforts to attach economic values to individual species. This tendency stands quite at odds, however, with the ongoing efforts of natural scientists to define different types of biological diversity and to identify those types that might be most important (e.g. ecological diversity, genetic diversity, functional diversity, and diversity at the genus or family level). To explore the economic benefits of the above kinds of biological diversity in and of themselves, it is useful to consider the problem of a decision-maker who wishes to invest a finite quantity of funds in the preservation of various biological resources. At the simplest level, three characteristics of the economic problem are apparent. First, the decision-maker perceives that, for any given group of ecosystems, there exists a collection of species. Second, there is potential value to humans associated with each of these species. Third, there is uncertainty concerning the magnitudes of those values.

Though there clearly are important differences between living biological resources and financial assets (such as stocks and securities), such a decision-maker's problem is similar in some very key ways to that of an individual who wishes to invest funds in one or more financial assets. Interestingly, for reasons well-known by economists, a financial investor will <u>not</u> choose to invest in a collection of assets that are similar to each other in the ways that they respond to future changes in market conditions. Instead, an individual should invest in an array of assets that displays great <u>diversity</u> among individual assets.

Why is such diversification a good thing for the investor? It is desirable because, given uncertainty about the future and aversion to risk, benefits are increased by investing in financial assets whose expected returns are negatively correlated across possible future conditions. That is, the investor's risk of losing big is lowered, no matter what the future turns out to be.

Furthermore, despite key differences between biological resources and financial assets, it can be shown that there are similar gains to be made by purposefully focusing conservation efforts on a diverse array of living organisms and ecosystems. In the face of uncertainty regarding the future of the environment and the ways in which humans will interact with it, the maintenance of biological diversity can yield real benefits for society.

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WHO'S MINDING THE SHORE? A SURVEY OF FEDERAL LAWS AFFECTING MARINE BIOLOGICAL DIVERSITY

Marine biological diversity is threatened by habitat destruction, pollution and overexploitation. Federal legislation has been enacted which ameliorates certain of these threats, but none specifically seeks to preserve the variety of marine life in its infinite combinations. Federal laws directly or indirectly affecting marine biodiversity in U.S. waters can be classified into six categories: species protection; habitat protection; land use controls; pollution controls; offsite conservation; and funding incentives.

This Survey discusses, in non-legal terminology, the reasons for each statute's enactment, the act's powers, who is responsible for enforcement, and how the act helps or hinders preservation of marine life. The conclusion of this Survey is that federal legislation to date has been too species specific. While legislation protecting a single species is commendable, it does not address the problem of conserving the ecosystems and habitats which support the sea's inhabitants.

Direct predation (hunting or fishing) does threaten some marine animals, but pollution and destruction of habitat from land-based activities (dredging, waste disposal, etc.) are a far greater threat to most species and ecosystems. Therefore, this Survey recommends that new legislation be enacted which will allow marine authorities to preserve marine ecosystems through comprehensive/holistic regulation of marine and land-based activities. But until then, better coordination of existing legislation -- by linking land use with water quality and habitat protection -- would help preserve marine environmental quality and diversity.

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Three important elements that are involved in the maintenance of marine biological diversity are (1) temporal and spatial patterns of disturbance, (2) temporal and spatial patterns of resources, and (3) dispersal ability of taxa. In general, diversity is maintained by small-scale biogenic disturbance and patchy supplies of food. Most scientists would agree that a change in the diversity of an ecosystem is the most sensitive measure of a change in that ecosystem. However, whether that measure of change is relevant to the particular ecosystem function that one might be interested in is a more problematic question.

Shallow coral reefs and mangroves may be the best examples of marine biological diversity "hotspots" in the sense that they are highly complicated and diverse systems and many of them are quite vulnerable to anthropogenic disturbances. In addition, deep-sea species diversity can be exceptionally high, though at present we do not have good data on temporal change in the deep sea or on the effects of human activities on relative species abundance in deep-water habitats. An important feature of deep-sea environments is that, relative to the terrestrial environment, they often contain species from a multitude of different phyla. For example, in 21-square-meter samples taken from deep water off the New Jersey coast, 800 species and 171 families were found to be represented. Unfortunately, too few samples are available to make an estimate of regional or global deep-sea diversity. There particularly is a lack of knowledge concerning the distribution of rare species, which are very important in the deep sea as they also are in coral reefs and rain forests.

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MARINE BIODIVERSITY: COMMUNITIES OF THE LAND-OCEAN INTERFACE, WITH EMPHASIS ON THE STRESSED CORALGAL (CORAL) REEF SYSTEM

Along the latitudinal stretches of continental coasts an extensive changing array of marine habitats occurs: kelp forests, rockweed beds, mud flats, salt marshes, mangrove swamps, seagrass beds, coralgal (coral) reefs. Unlike those of the open ocean the communities of these shore habitats are generally macrophyte based. Many of these regions are highly productive with, for example, coralgal reefs comparing favorably with tropical rain forests. Diversity within, as well as between these latitudinal regions determines the nature and abundance of top predators associated with the food webs. Many of these predators are commercially important.

The ecological and presently perceived economic importance of these very different communities varies considerably. Diversity of coastal habitats is enhanced by the three-dimensionality of the primary producers. In marked contrast the essentially structureless nature of the microscopic primary producers of the open ocean provides little niche diversification. Most of the coastal regions serve as rich nursery grounds for the ocean's harvestable resources. Some may be significant exporters of nutrients and energy to adjacent ocean regions, and play an important role in the availability and cycling of nutrients such as nitrogen. They also provide a physical buffer zone, protecting the coastline from the fullest impact of ocean storm energy.

Coastal regions have become increasingly stressed in recent decades by the demands both of burgeoning human populations and the increased quality of life. Coralgal reefs, with their high species diversity and productivity, their intricate patterns of food webs and nutrient cycling, and their haunting beauty are especially threatened. This system is the subject of my subsequent comments.

Modern coralgal reefs are intricate systems that depend on algae, corals, symbiotic relationships, light and suitable temperatures for their success. Significantly these highly diverse and productive regime systems are often surrounded by ocean waters where biomass is exceedingly low, where they are like solitary jewels. Not surprisingly, we do not have the full catalogue of their rich and varied biota. But what may be more important: we are ignorant of many aspects of how this rich and productive reef system works: for example of pathways of nutrient cycling within the reef and with adjacent ocean regions, or of taxonomy and physiology of symbiotic relationships between photosynthesizers and animals. Symbiosis promotes most of the framework and some of the sand production essential to the building and renewal of natural tropical reefs.

Coralgal reefs as we presently know them are in danger. Too many are being overfished (fish, turtles, shellfish...), overharvested (corals, shells, aquarium fish, building materials...), and used as building sites. Some appear to be suffering from the effluent of development and affluence: fertilization and pollution by nutrients from runoff, sewers, industrial wastes, etc..

Modern framework reefs can and possibly are being replaced by other types of reef systems (e.g. algal reefs); they are but a stage in a long geological history of reef systems. But the loss of the modern massive scleractinian structure by the destruction and death of corals can be far-reaching. Reduction of framework and of the associated 3-dimensionality leads to extensive loss of species and communities. Ultimately the diversity of fish is affected, and the economic value of their harvest. At danger too is one of the most beautiful natural creations of our planet, the modern coralgal reef.

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BENEFITS AND COSTS OF SPECIES PRESERVATION

Preservation of species and biodiversity is directly related to protection of species' habitats. Typically, policy makers have to decide whether to protect a particular species' habitat or let a development project or industrial activities destroy that habitat. Regulatory agencies designate marine sanctuary areas to protect species' habitats. Preservation of marine biodiversity is usually discussed for a group of species and their habitats, instead of focusing on one particular species.

There are two questions I would like to discuss. First, what is the value of species and biodiversity. Secondly, how we should treat uncertainty of benefits from preserving species. As an economist, I think benefits of preserving species should be measured from consumers' valuation. Observations of fascinating species by scuba diving, at aquariums, or from pictures are probably the most visible benefits. People may value the fact that numerous species exist and they are contributing to scientific discoveries. These benefits may be classified as direct benefits. Indirect benefits are difficult to measure. While consumers may not value species directly, they value tangible benefits derived from preserving species. Certain species may be crucial to sustain an ecosystem and keep desirable levels of environmental amenities valued by people, or they may contribute to discoveries of new medicine or biomedical technologies. The difficulty of measuring indirect benefits is to establish the linkage between species and tangible products or environmental amenities valued by consumers.

Possible ecological risk from extinction of species has been widely discussed. Biodiversity may significantly contribute to sustainability of an ecosystem and the pool of genetic information which may become valuable later. Decisions about which species should be preserved have to be made under uncertainty about their benefits. Some may prefer a risk neutral treatment. Others may advocate to minimize the worst possible outcome. Decisions should be made with the recognition of associated costs. Lower risk can be attained by keeping more species. However, the cost of doing so becomes higher.

New information about benefits from species may be obtained by waiting and conducting more research. However, we still have to make decisions at a given point of time with imperfect information. In this case, an attempt to collect the best "scientific guess" from researchers about possible benefits of preserving species may be worthwhile. This benefit information should be updated regularly as new researches are completed.

It is important to recognize that preserving species and biodiversity is not free. If a particular development project is threatening a species' habitat, possible benefits provided by this project are in turn a part of the cost of keeping the habitat intact. Calculation of benefits is not easy. However, an attempt should be made for quantifying costs and benefits of preserving species. A policy action affecting biodiversity should be subject to a cost-benefit analysis with the understanding of the degree of uncertainty involved.

Is a marine habitat with 100 species more valuable than a terrestrial habitat with 10 species? Is a California condor more important than a sea turtle? What is the "adequate" level of protection for a coral reef or marine sanctuary area? It seems to be necessary to compare costs and benefits of available policy options in order to make objective decisions.

Policy actions usually create two groups of people: losers and winners. It is rare a regulatory decision makes somebody better off without making anybody else worse off. Cost-benefit analysis criteria for deciding policy actions imply winners can compensate losers and we are still better off as a whole. It is not certain whether such compensation actually takes place. However, a cost-benefit analysis at least indicates whether a proposed regulation has a "potential" for overall welfare gain.

PETER F. LARSEN
BIGELOW LABORATORY FOR OCEAN SCIENCES

THE DISTRIBUTION OF BENTHIC MARINE INVERTEBRATES IN THE NEW ENGLAND-CANADIAN MARITIME REGION AND ITS RELEVANCE TO THE CONSERVATION OF MARINE BIOLOGICAL DIVERSITY

The region of New England and the Canadian Maritime Provinces is zoogeographically complex due to present temperature regimes as well as historical, climatological and physiographic developments. Traditionally, Cape Cod has been considered a thermal barrier separating the warm-temperate or Virginian zoogeographic zone from the cold temperate or boreal zone. In recent years, several investigators have given increased attention to describing the fauna of the region, determining the evolutionary origins of the fauna, and examining the smaller scale zonation patterns. Many aspects of these investigations are of interest in a discussion of the conservation of marine biological diversity.

The Gulf of Maine region is extremely rich in terms of numbers of benthic invertebrate species and individuals. For example, 1500 species of benthic invertebrates have been identified from Passamaquoddy Bay and a one year study of the Sheepscot Estuary, Maine encountered 450 species. By comparison, only 750 species have been found in the marine and estuarine waters of Virginia. The species colonizing the region are of several zoogeographic affinities. The cool, deep and/or tidally well-mixed waters allow for the maintenance of subarctic species; many warm temperate or Virginian (transhatteran) species reach their northern limit in this region and a large percentage of the species are of boreal origin. Many boreal species are amphi-Atlantic in their distribution but a significant proportion are endemic to the northwest Atlantic. Of particular interest is the fact that these species of diverse origin are not distributed over a smooth south-north gradient between southern New England and Labrador, as might be expected. Instead, they exhibit disjunct and discontinuous distribution. The cold water species are found in the far north and in the deep and eastern portions of the Gulf of Maine while the warm water species are found in the southern Gulf of St. Lawrence, in southern New England and in isolated pockets in the Gulf of Maine and Bay of Fundy. This pattern undoubtedly results in outlier populations having limited gene flow with the main population centers of the species. Changing environmental conditions have resulted in local extinctions of some of these populations in historical times, but could not these populations also offer genetic strains better adapted to future climatic changes?

The complex zoogeographic nature of the New England-Maritime region manifests several complexities. Understanding these complexities may offer insights useful in addressing conservation of marine biological diversity on a larger scale.

BRUCE LEIGHTY
WORLD WILDLIFE FUND

CONSERVATION OF BIOLOGICAL DIVERSITY PROGRAM

World Wildlife Fund (WWF) is the lead organization in a joint venture with the WRI Center for International Development and Environment (WRI/CIDE) and The Nature Conservancy (TNC) to implement a U.S. Agency for International Development (AID) centrally-funded Conservation of Biological Diversity Project. Established through a cooperative agreement between AID and WWF, the project has a dual mission to conserve biological diversity and to promote sustainable economic development in developing countries through better conservation and use of biological resources. The project will work to improve and focus AID's efforts for the conservation of biological diversity through collaboration with AID Missions and Bureaus, government institutions, and NGOs in AID-assisted countries.

The project has five major components: (1) technical assistance for AID missions and bureaus, host country institutions, local PVOs and the U.S. Peace Corps, (2) a small research grants program to address specific research issues relevant to AID's conservation activities worldwide, (3) training focused on improving the capacity of recipient countries to conserve biological diversity, including training for local scientists in identifying research priorities and preparing competitive proposals, (4) an information and evaluation network on the conservation activities of AID and other U.S. institutions, and (5) pilot demonstration projects funded largely by AID Mission and regional Bureaus.

The Conservation of Biological Diversity Project will focus on both terrestrial and marine biodiversity in selected developing countries.

PHILLIP S. LOBEL
BIOLOGY DEPARTMENT, WOODS HOLE OCEANOGRAPHIC INSTITUTION

PATTERNS OF FISH REPRODUCTION AND DIVERSITY

Tropical fishes in coastal marine habitats (e.g. coral reefs) form part of a highly diverse community. The key question is "what historical events and/or environmental circumstances are responsible for or associated with the evolution of marine fish species?" The solution must consider how natural selection affects (1) the composition of shore fish communities, and (2) biogeographic distributions. An important aspect of marine fish life history is that the majority of species produce planktonic eggs and have a pelagic larval phase of several weeks duration. Thus, a fundamental premise is that the numbers and diversity of fish species found on a reef results, in large part, from the interaction of the (1) timing of reproduction, (2) duration of the pelagic larval phase and swimming ability, and (3) the variable flow of ocean currents.

Existing methods and proven technologies already provide the capability for estimating larval lifetimes and relative swimming abilities (by means of otolith ring-counts and anatomical analyses of the muscular-skeletal system) and for defining the physical flow field of deep ocean waters (by using physical oceanographic instrumentation and quasi-geographic models of the flow field). However, until now, it has not been possible to accurately qualify the temporal and spatial variability of fish reproduction. Existing methods involve intrusive sampling and do not adequately resolve variability in time and space scales.

I recently discovered that certain fishes produce distinct sonic signatures while actually spawning and releasing gametes. This discovery provides the opportunity to apply passive acoustic tracking technology originally developed for the Navy to the study of fish biology. The results of this scientific research will provide not only a detailed understanding of fish reproductive cycles but will also define spawning locations. The protection and management of fish spawning grounds is an important application of this research.

A second implication of this research to the biodiversity issue concerns the recognition and definition of fish species. Preliminary data will be presented which suggests that one fish previously thought to be a genetically diverse single species may be, in fact, several incipient species at the first stage of evolutionary divergence based upon sexual selection and reproduction isolation.

BOYCE THORNE MILLER
OCEANIC SOCIETY

MARINE BIOLOGICAL DIVERSITY: SCIENCE TO POLICY

There is little question as to the significance of the oceans and marine biochemistry to the maintenance of our planet's geochemical cycles. Nevertheless, the diversity of ocean life is rarely used as an indicator of environmental conditions in marine ecosystems or of the effectiveness of programs to protect marine environments. We need to not only institute programs specifically designed to protect biological diversity, but also to recognize the intrinsic role of that diversity in all ocean management efforts. We must begin to incorporate biological diversity studies into environmental assessments and into the adaptive management of marine ecosystems.

Biological diversity, as it has been presented to policy and law makers, is broken down into several categories. The three most commonly recognized are species diversity, genetic diversity (referring to the genetic variation within populations of the same species) and ecological diversity (referring to the variety of ecosystems). Other categories which ought to be more widely recognized are functional diversity (the variety of biological functions within an ecosystem) and taxonomic diversity at levels higher than species.

Terrestrial and marine systems differ in the following respects important to a consideration of biological diversity and related policy/management issues:

- There are more species on land (although the final score is not in yet);
- There are more higher taxa in the sea;
- Therefore, the genetic differences between species are greater;

- A greater diversity of life functions and more complex food webs can be found in marine environments;

- Individual species are more widely distributed in the oceans because of the fluid matrix which facilitates dispersal of spores and juvenile forms;

- Therefore, endemism is apparently rare in the oceans; and

- However, genetically distinct populations can be identified; and

- The dispersal of juveniles means that the young are often dissociated and live in different ecosystems from the adults that bore them, so the survival of a species may require that more than one environment be protected.

That chemical pollution in marine environments threatens biological diversity is, we believe, irrefutable. It is also causing impoverishment of marine ecosystems by weakening the genetic and physiological condition of populations of marine species. In this weakened state, populations, communities and ecosystems are more vulnerable to new environmental perturbations such as global warming.

Biological diversity has not been well assessed in many marine ecosystems and consequently protective programs are not widespread. The most common approach to protecting marine biological diversity is through protected areas such as marine sanctuaries and wildlife refuges. Protected marine areas are most common on coasts (many wetlands are protected under one program or another, for instance) and to a limited extent in shallow coastal waters. There is a need to broadly expand the marine sanctuaries programs and to consider deeper communities for inclusion. However, the limitations of the protected area approach to preserving species diversity in the marine environment should be recognized. First, no marine sanctuary can protect a community from pollution carried in from other areas on ocean currents. Secondly, a marine sanctuary or refuge only protects the individuals which remain fixed within the sanctuary boundaries throughout their life cycles. Marine protected areas cannot just mimic their terrestrial counterparts; the unique properties of marine ecosystems must be taken into account.

There is a need for new approaches to the protection of marine biodiversity. At least part of the answer may lie in the innovative implementation of a global policy of sustainable development in a world where money buys environmental protection as well as products.

JOHN C. OGDEN
DIRECTOR, FLORIDA INSTITUTE OF OCEANOGRAPHY

The wide scientific and political concern directed at the issue of world biological diversity arose from the dramatic and documented increase in loss of species associated with tropical deforestation. In the many recent workshops and discussions of biological diversity, the high diversity marine environments, such as coral reefs and the deep sea, have received little attention. While contemporary species extinctions are rare or unreported in these environments, because of increasing habitat damage and loss, a major component of biological diversity is at crisis proportions along tropical coasts in primarily third world nations. Population extinctions and subsequent loss of genetic diversity may also be epidemic. Ironically, deforestation, the primary cause of loss of biological diversity on land, is also a leading cause of habitat destruction in shallow tropical seas through runoff of forest soils and nutrients.

There is disturbing evidence that habitat degradation in the ocean may be more widespread than previously thought. Sublethal stresses may spread over wide areas, increasing susceptibility of populations to disease. Recent examples include the mass mortality of the sea urchin Diadema antillarum in the Caribbean in 1983-84, the world-wide loss of acroporid corals, and the deaths of dolphins on the East coast of the U.S. in 1987. While the interconnectedness of the ocean may spread stresses widely, the dispersal capabilities of marine larvae may result in the relatively rapid recovery following stress. In the marine environment we may have the time to act before a crisis is reached.

As on land, the conservation of marine biological diversity lies at the uneasy and contentious meeting ground of science, society and politics. Scientific progress in the documentation and understanding of marine biological diversity must be accompanied by social action. Declines in species-rich marine environments are the result of exploitation of resources, in most cases by an indigenous human society with immediate economic or food needs and no alternatives. Banning exploitation of marine resources from marine parks and preserves will not prove to be completely effective in the conservation of biological diversity as little or no relief is provided for human needs and thus pressure on adjacent resources may increase. In the long run intensive exploitation to the edge of a marine park or preserve will result in its destruction.

Within scientifically defined sub-regions of the world's oceans, or "large marine ecosystems," a combined scientific assessment and sustained monitoring of biological diversity over appropriate time and geographic scales and political action must be combined in an overall strategy. Clear demonstrations of the economic and social advantages of alternatives to exploitive practices are needed as well as the political will to invest in the alternatives to provide immediate social benefits. Successful demonstrations may be exported from one sensitive region to another.

G. CARLETON RAY
DEPARTMENT OF ENVIRONMENTAL SCIENCES, UNIVERSITY OF VIRGINIA

The brief paper from Biology International will be distributed at the meeting. It emphasizes the role of biodiversity in the structure and function of ecosystems and has led to continued discussions within the International Union of Biological Sciences (IUBS) .

In addition, the Scientific Committee on Protection of the Environment (SCOPE) has had a major project on ecotones, having to do with ecosystem boundaries and how they may be determined by examination of gradients, including human-originated ones. A meeting of IUBS-SCOPE on these subjects last month led to a report, not yet in my hands, on research initiatives related to these subjects.

HOWARD L. SANDERS
BIOLOGY DEPARTMENT, WOODS HOLE OCEANOGRAPHIC INSTITUTION

MARINE BENTHIC DIVERSITY

Much of the confusion relating to how the diversification process is brought about can be explained by two tenuously related phenomena or pathways that have been invoked, observed and documented from nature as inducers of species enrichment.

One pathway has been termed Long-Term, Equilibrium or Evolutionary Diversity. The increase in diversity is the product of past biological interactions in relatively stable, benign and predictable environments. The time scale is geologic - at least thousands of years. Only over such a time span can new species be generated. Diversity increment is slow, the result of speciation and/or a low rate of immigration into the environment. This pathway to elevated diversity is well within the mainstream of Darwinian precepts.

The alternate pathway has been termed Short-Term, Non-Equilibrium or Transient Diversity. Here, diversity increase is induced by physical, chemical or biological perturbations of low predictability. The resulting biological undersaturation allows more species to temporally occupy the habitat until population sizes build up to densities where the co-occurring species must interact as space, food or other resources become limiting, resulting in turn, in the winnowing out or reduction of species. The effects are local and the time span realized is short, well within the ecological time scale of days, weeks, months, or, at most, a few years. This mode of diversification is primarily manifested in highly stressed communities. The increase in diversity is rapid and is brought about by settlement of planktonic larvae of benthic species and by immigration of post-larval and adult benthic species from the immediately surrounding areas.

Stresses or disturbance inhibit, constrain or reverse the process of diversification at the evolutionary time scale. Such perturbations are equally evident in some of the tropical, shallow-water, level-bottom benthic habitats as they are in the shallow-water seafloor at higher latitudes. These stresses and disturbances are naturally induced or products of man's activities (pollution) or combinations of both.

Low diversity and pronounced numerical dominance are faunal characteristics typical of a wide range of stressed or impacted marine environments. They include among others:

(i) ephemeral habitats such as the deep-sea hydrothermal vent systems that have been examined;

(ii) shallow-water habitats in middle latitude. In Buzzards Bay, Massachusetts, the benthic assemblages during most years are exposed to summer temperature maxima of 22-23^{o} C and winter minima of -1.3^{o} C;

(iii) shelf depths that experience periods of strong and sustained winds over a long enough fetch of water and of sufficient duration to generate waves large enough to reach the seafloor and wash out the benthic fauna;

(iv) the seafloor beneath 4600 to 5000 meters of water in the Northwest Atlantic where aperiodic deep-sea storms dramatically accelerate the currents in contact with the sediment to speeds recorded as high as 70 to 75 centimeters per second that resuspend the surface sediment and create turbidity concentrations in the bottom water that exceed any turbidity measurement taken in the World Ocean, be it an estuary, on the shelf or beneath the deep sea;

(v) oxygen depletion through organic overloading in bays, basins and even open continental shelves markedly impacts and sometimes eradicates the benthic fauna. This very widespread phenomenon is typical of upwelling systems. It also appears along the west coast of India at shelf depths during periods of strong southwest monsoonal winds and is present during elevated temperatures of summer in numerous Japanese bays and other embayments in middle latitudes elsewhere in the world and is often a feature of many fjords with shallow sill depths. It occurs both in the deeper parts of the Baltic Sea and many of its shallower embayments.

A quest for structural pattern change at different levels of diversity may well be insightful in understanding the conditions in nature that enhance or diminish diversity. A simple, straightforward analysis can be employed whereby (i) individual or combined replicate samples obtained across a spatially broad gradient of environment change or (ii) a set of samples collected from habitats that historically have been exposed to or impacted by a spectrum of stress conditions ranging from near absence to near maximum can be directly compared. Species are sequentially ranked from most to least abundant along the horizontal x-axis or abscissa while the corresponding percent composition that each species contributes to the sample or combined replicate samples is plotted vertically in parallel to the y-axis.

Figure One compares the endpoint histograms of an onshore to offshore boreal latitude transect from shallow inshore depths to the seafloor beneath the deep sea. The inshore benthic Station 35 located under 14 m of water in Buzzards Bay, Massachusetts, U.S.A. experiences extremely wide amplitudes of seasonal change in water temperature that does drop as low as -1.3^{o} C during many winters in February and usually reaches as high as 22-23^{0} in early August. Wind conditions are sufficiently strong during much of the year to generate waves of adequate size to reach the seafloor and put the surficial sediment into suspension at this relatively shallow site. At the opposite end of the transect is Benthic Station 8 on the deep-ocean floor beneath a water column of 2090 meters. As in nearly all of the vast reaches of the deep sea, the temperature, salinity and oxygen values of the immediate overlying flow of water that moves past Station 8 along the 2100 meter depth contour are remarkably constant. Indeed, each of these hydrographic features are so unvarying and conservative at any given sampling site in the great depths of the World Ocean that they are used by physical oceanographers to characterize and define the different water masses.

Not unexpectedly, histograms generated for these two stations are decidedly different. The inshore station histogram (heavy-lined) shows pronounced numerical dominance by its most abundant species. The rank 1 species comprises 48.36% and the second-ranked species forms 13.07% of the total fauna. In sharp contrast, the two most abundant species in the Station 8 histogram comprise 6.06% and 4.85% of total fauna. A mere 1.13 ranks account for 50% of the total fauna at Station 35 (heavy vertical line) while the initial 19.44 ranks are required to achieve half of the total fauna at Station 8 (fine vertical line). The percent composition values are greater only in the first four ranks of the Station 35 series. However, the cumulative non-overlap differential or excess in percent composition of Station 35 over Station 8 for the initial four ranks is a large 52.91%.

Since this comparison is made on a percent composition basis of species ranked by abundance at each of the two stations, the dramatically large percent-composition differential accumulated over the first four ranks by Station 35 preceding the fulcral or changeover point between ranks 4 and 5 must be counterbalanced by an equal 52.91% non-overlap or differential accumulated at Station 8 from two sources. One source is the 113 sequential rankings that are subsequent to the fulcral changeover point where the Station 8 percent composition values are higher at every ranking. All of the 117 species obtained at Station 35 have now been utilized. The other source is the cumulative percentages of the remaining 108 species present at the rare species end of the rank order at Station 8 where each species comprises a very small percentage of the total fauna.

If the histograms generated for the two stations in the comparison were identical and the total number of species present at each station were the same, the cumulative percent differential between the two stations would be zero. In the Station 8 - Station 35 comparison, the cumulative non-overlap percent differential is very large, 52.91% for each station, a reflection of the markedly different structure of the histograms generated from the two stations.

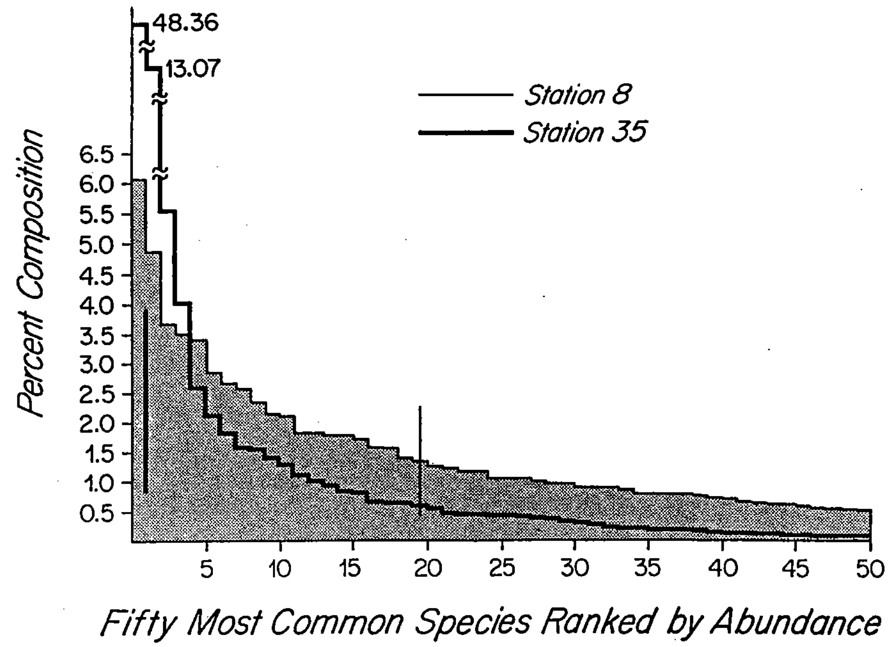

FIGURE ONE

Between these two end points exemplified by shallow-water Station 35 and deep-sea Station 8, there is a gradually changing continuum of intermediary histograms.

When the histograms composed of the species percentage generated from single samples or combined samples of two compared stations demonstrate a significant measure of similarity or coincidence, then the percent departures between the paired species members of each of the ranks will range from minuscule to small. Concomitantly, there will be frequent rather than a single fulcral changeover point, the number of rankings that account for 50% of the fauna in each of the two stations will be nearly the same, and the combined cumulative percent differential - a measure of the histogram structural difference between the two stations - will be small, less than 15.0%. This suite of conditions is most likely to be realized in the species-rich, diverse benthic fauna of the deep sea.

RUDOLPH SCHELTEMA
BIOLOGY DEPARTMENT, WOODS HOLE OCEANOGRAPHIC INSTITUTION

Biogeography is the study of the spatial and temporal distribution of organisms. Whereas historical biogeography is concerned mostly with large scale patterns of geographical distribution whose origins may have been determined in the distant geologic past, geographical ecology deals principally with the immediate processes that determine contemporary spatial relationships. In searching for patterns of distribution historical biogeographers often seek congruence in the spatial disposition of widely unrelated animal and plant genera or families by means of cladistic analysis. If congruence is found, this is cited as evidence that a single historical incident must have affected all the disparate taxa alike to produce the observed distributional pattern. The usual explanation is vicariance, the partitioning of wide-spread species (or entire fauna) through the formation of barriers by some kind of geologic circumstance such a (1) the formation and widening of deep-ocean basins, e.g., the Atlantic since the middle Mesozoic: (2) the closing of seaways (e.g., the Panamanian Isthmus or Tethys Seaway during the Early Tertiary) or (3) the movement of lithospheric plates or "terranes" (as in the Pacific), resulting in the observed disjunct distribution of taxa, each with their own endemic species, which have evolved as a consequence of geographic speciation. Many historical biogeographers consider an "alternative" to vicariance, namely dispersal, as unlikely and argue that such explanations depend upon ad hoc assumptions for each individual taxon and do not provide a general explanation for the pattern encountered. However, most historical biogeographic hypotheses are based upon non-marine environments where dispersal differs markedly and must frequently be regarded as largely random within the constraints of an appropriate environment.

Among the shoal-water benthic invertebrates (especially in tropical regions) most major groups include in their life history a planktonic larval stage. Such larvae are passively advected by ocean currents, sometimes over great distances along "corridors of dispersal" and markedly unrelated taxa represented by various larvae will necessarily be dispersed at approximately the same rate along the same route by the same currents. Consequently, larvae of all taxa are transported in a similar fashion to the same general destinations. Random dispersion by eddy diffusion can be largely ignored on a biogeographically relevant scale of hundreds to many thousands of kilometers. The only distinction between species with regard to dispersal lies in (a) time of reproduction in relation to seasonal changes in surface currents (e.g., the equatorial countercurrents) and (b) variation in their potential maximum length of planktonic life and the ability to delay settlement and metamorphosis.

Present research in the tropical Pacific on long-distance dispersal by teleplanic larvae provides a plausible hypothesis for (1) how shoal-water benthic species cross barriers such as deep-ocean basins; (2) how some forms among the attenuated Indo-Pacific fauna become very widely distributed half-way around the world from east Africa to the easternmost Polynesian Islands; (3) how newly formed central Pacific oceanic islands become initially colonized; (4) why there is an increased endemism on tropical islands from west to east across the Pacific (explicable by the different capacities for dispersal by various species); and (5) how gene flow can maintain the genetic integrity of far-ranging contemporary Indo-Pacific species and why tropical Pacific Islands are populated by so many widely ranging Indo-Pacific species rather than by endemic species of widely distributed genera and conversely among taxa lacking a larval stage (e.g., pericarid Crustacea). Fossil evidence from mollusks shows that long-distance veliger larvae occurred well into the Mesozoic and probably earlier and that their effect is not restricted only to the recent Holocene. What one may ask has all this to do with practical affairs?

The scale at which human intervention is now possible can readily bring on profound changes in the distribution of marine organisms, equivalent to natural processes over millions of years. For example, the sea level canal, proposed during the 1970s to cross Central America, arguably could have altered or even reversed, in only a few years, natural processes that were the result of 3 million years. It became obvious that with the present state of knowledge the biological outcome would be largely unpredictable. In an address to the National Academy of Science, John F. Kennedy remarked, "In the past the problem of conservation has been mainly the problem of inadvertent human destruction of natural resources. But science today has the powers for the first time in history to undertake experiments with premeditation which can irreversibly alter our biological and physical environments on a global scale. The problem is difficult because it is hard to know in advance whether cumulative effects of a particular experiment will help or harm mankind..." (New York Times, 23 October 1963; see I. Rubinoff, "Central American sea-level canal: possible biological effects," Science **161**, 857-861 (1968)).

ANDREW R. SOLOW
MARINE POLICY CENTER, WOODS HOLE OCEANOGRAPHIC INSTITUTION

DIVERSIFICATION WITHOUT RISK AVERSION

In standard economic models of portfolio selection, diversification arises from risk aversion. This paper proposes a model for selecting a portfolio of species under which diversification (i.e., a preference for genetic diversity) arises even in risk neutral situations. The key difference between the two models is that earnings from the sale of financial assets are additive, while benefits derived from species may not be.

JOHN H. STEELE
MARINE POLICY CENTER, WOODS HOLE OCEANOGRAPHIC INSTITUTION

FUNCTIONAL DIVERSITY

Scientists recently have discussed three distinct types of biological diversity: genetic, species and ecological diversity. In this presentation, however, I will describe what may be referred to as functional diversity. By this I mean diversity across ecosystems in the way in which those systems respond to changing physical environments. In particular, much can be learned by comparing the different responses of marine and terrestrial systems. In relation to marine ecosystems, three conclusions can be made:

(1) As a result of changes in physical environments, we observe very large "switches" in marine communities that can last for several decades.

(2) Such switches have occurred without human involvement but may be increased in frequency or amplitude by our actions.

(3) Explanations can be given for particular populations of organisms in terms of the effects of physical processes during early life stages, but this does not explain the observed changes at the community level.

These conclusions differ greatly from the usual views of terrestrial changes. The focus in studies of terrestrial systems is generally on the community interactions as the explanation for changing patterns in observations of species compositions. The effects of fluctuations in the physical environment are usually treated as noise. But this depends very much on the time scales involved. The relatively large daily, seasonal and interannual variability of the atmosphere compared with the ocean has resulted in the evolution of terrestrial adaptations that can eliminate or smooth out their consequences. The coupling with large-scale trends is observed at time-scales of centuries to millennia. Within the ocean it appears that the responses are found at decadal periods and may be responsive to variations in ocean dynamics. At the population level this is explained by a much closer interaction between the reproductive processes and the particular patterns of ocean currents and mixing. Many marine systems are very responsive to relatively rapid changes in their overall environment but in consequence are also adaptable in an ecological sense.

VANCE P. VICENTE
U.S. FISH & WILDLIFE, PUERTO RICO

RECENT SEA SURFACE TEMPERATURE CHANGES AND THEIR EFFECT ON REGIONAL DIVERSITY

Long term changes in the distributional patterns of commercial sponges (Spongia spp. and Hippospongia spp.) within the West Indian Region indicates that: 1) commercial sponges had a widespread distribution throughout the whole West Indian Region and were ubiquitous in very shallow water until about the first half of the present century; 2) they were fished commercially not only in the traditional northern Caribbean sites (Florida, Gulf of Mexico, Bahamas) but also in the Greater (e. g. Hispaniola, Jamaica) and Lesser Antilles; and 3) they became extinct throughout most of the Lesser Antillean Region (e.g. Puerto Rico, Vieques, St. Thomas) sometime during the first half of this century. Mortalities of spongiids within the Antilles were found to differ from other marine mortalities reported in that: 1) species disappeared from a large region; 2) species vanished from different habitats and depths; and 3) natural populations never recovered. Species richness distributional patterns suggest that commercial sponge genera (Spongia and Hippospongia) had their center of origin in cooler, northern latitudes. These sponges might have spread from these centers towards tropical West Indian islands when climatic conditions were cooler in the region, and then became extinct by direct or indirect effects of registered positive thermal anomalies in sea surface and atmospheric temperatures between 1900-50. Similarly, outbreaks of Labyrinthula which have caused widespread as well as local extinctions of eel grass (Zostera marina) have also been related to positive thermal anomalies by other authors.

MIRANDA WECKER
COUNCIL ON OCEAN LAW

The recent conclusion of the second meeting of experts on the development of a protocol on specially protected areas and wildlife (SPAW) for the Caribbean region offers fresh lessons concerning the evolution of multilateral efforts to protect resources. The objectives articulated in the SPAW protocol go right to the heart of protection of biological diversity in the Third World. The controversies encountered say a great deal about the obstacles ahead in developing strategies acceptable to countries with vastly different institutional capabilities and socio-cultural expectations. I will review the results of the Caribbean SPAW meeting highlighting a number of tentative conclusions and personal observations drawn from the experience. Among the impressions I want to describe are the following:

1. the predominance of cultural and social dimensions of the issues over scientific and technical aspects or "Environmental Imperialism versus Shortsighted Self-determination";

2. the gulf in expectations with regard to the pace of change which can be expected or "Hup to versus Manana";

3. the reluctance of diplomats to attempt innovative approaches to problems which defeats the very rationale for regionalism or "Leaving it to the Lawyers";

4. the impact of First World NGOs in stymieing the development of international law or "The Ideal as the Enemy of the Good."

GEORGE M. WOODWELL
WOODS HOLE RESEARCH CENTER

IMPORTANT ISSUES IN THE CONSERVATION OF MARINE LIFE

Two issues dominate: toxification and destructive harvests.

Despite the size of the oceans, the cumulative effects of the overt disposal of wastes, and the inadvertent contamination of the oceans through aerial transport of toxins is producing a series of irreversible transitions in the chemistry of the oceans. The assumption that these changes will not affect biotic systems is naive. The best data exist for the chlorinated hydrocarbons, but there is reason to examine a wide range of toxins.

Destructive harvesting includes the over-exploitations of fisheries stocks and whales as well as virtually every other product of the seas.

Explicit efforts are appropriate to avoid dumping in marine systems, to avoid further contamination of coastal waters, and to reduce aerial transport of toxins.

VI. EXCERPTS FROM GROUP DISCUSSIONS

A. OVERVIEW AND BIOLOGY SESSIONS

Selected Comments

Fred Grassle (Overview session): "... I think that there's an interest in what's been called global change, and I think that scientists are a lot more concerned about that than they have been in the past... One of the things about the deep sea is that, if change comes, it won't be because of sludge dumping or some local effect. It will be the sort of thing where a pollutant is being distributed over most of the ocean, and where you have the potential for change over large areas. The possibility of those [changes] makes me uncomfortable about saying that the deep sea is not a problem."

Fred Grassle (Overview session): "But the other thing that should be talked about is the fact that the average person does care about diverse systems... a lot of the questions about why do we care about diversity are a bit irrelevant, and the fact is that it's a characteristic of people that we do care. And so, I think our goal in that circumstance is to discuss what this means for managers."

John Ogden (Session on general biological issues): "We have a pretty good idea of where the marine diversity hotspots are: the Caribbean and the Indo-West Pacific, particularly the Philippines and Indonesia. We know that there's a decline taking place. We have a good idea of some of the causes. Interestingly, deforestation as a major cause of species loss on land is intimately linked to species loss in the sea through runoff, sediments and excessive nutrients..."

John Ogden (Session on general biological issues): "We need a global strategy with sub-regions defined biologically and physically as large marine ecosystems. Within these sub-regions scientific data may feed directly into management strategies. Where management directly impacts subsistence activities such as fishing and deforestation, there must be an economic strategy that provides compensation and alternative employment for those whose lives are impacted."

Carleton Ray (Concluding discussion session): "I think that one of the things that we come across is the levels of organization that we look at... we've been talking about biodiversity, and in talking with several people around here, I think we have to emphasize... what level it is that we want to look at. Is it the community, is it species richness?... my own vote very strongly goes to the community level..."

Vance Vicente (Concluding discussion session): "...I've talked to several scientists here about this paper published by Robert Ricklefs [R.E. Ricklefs, "Community Diversity: Relative Roles of Local and Regional Processes," *Science* **235**, 167-171 (1987)], and he wrote a very good paper... in which he shows how local diversity is strongly a function of regional diversity, so therefore... we really have to expand our scale of conservation. For example, preserving a few reefs in order to conserve local coral diversity is not enough..."

Fred Grassle (Concluding discussion session): "Just a comment on the terminology, first of all I agree with what Carleton said and I agree with what Vance said, but I think that there is a general consensus that we need to think of the species diversity problem in the context of what has been variously called ecosystems, ecological diversity, communities, regional diversity, or habitat diversity. Species diversity *per se* is simply a measure of some of these larger units that we're concerned about, and if we take a species-by-species approach to the problem, again, going back to the problem of the point of view of advocacy, we've lost the case."

Responses and Questions

Following the Overview session:

John Ogden to Fred Grassle: "Fred, in Jim's [Broadus] terms at the beginning, we're brought together in response to what's going on in terrestrial biological diversity and a sense of crisis... I know you're going to have to guess, but is there a crisis in marine environments?"

Fred Grassle: "I think there is something of a crisis in coral reefs, and in mangroves, marshes, and coastal wetlands. These are places where we see impacts first... We don't know much about the deeper end [of the oceans], and I worry a bit about that. I think we've got to say that it's not a crisis situation, but I feel very uncomfortable with saying that - with certainty - when we're not measuring change in the deep sea at all - and [when] it's such an enormous surface area."

Daniel Cheever to Fred Grassle: "If you were willing to hazard a guess as to whether there's a crisis, can you hazard another guess as to the cause, I mean something to do with human beings, industry, what is it?"

Fred Grassle: "It's the fact that everyone wants to live on the coastline. It's habitat modification by people. It is also that the ocean does not have a strong constituency, the way land areas do."

V. Kerry Smith: "[I have] a reaction to the fact that people value diversity. This comes a little bit closer to my disciplinary turf. People value diversity and they value a lot of things, and there are a lot of very, very difficult choices, just from an environmental perspective, that have to be made. So the issue is twofold: one, understanding the relative values for different components of the environment. And the second is, frankly, learning to communicate with people what the consequences are of different changes, whether they are by policy or by default, that impact on species diversity, so that we have a better chance of understanding how they would value those changes. That's really exceptionally important; if we can't explain beyond a very simple level what diversity is, it's going to be very hard to explain what it might mean to them, why they might be concerned about an increase or decrease in diversity."

Following John Ogden's presentation:

Carleton Ray: "... [I agree with you that] monitoring is a fundamental part of research and whether or not it works is a problem... the NSF is very resistant internally to monitoring. LTER [Long-Term Ecological Research] sites are trying to battle that trend, and I don't know what the solution is or which way it's going to go but I think it's going to take an act of Congress [to facilitate long-term monitoring]..."

John Ogden: "Well, I don't really know what it's going to take but it isn't working, it especially isn't working in ecosystems beyond ankle-deep in seawater... Do we need more examples of the fact that long-term data are interesting? I don't know how many people here today have mentioned Joseph Connell and his work... at least in part his whole seminal ecological theory [on] the importance of disturbance is based on a set of photoquadrats taken at Heron Island for no real purpose when he started out... patterns show up in monitoring data that are critical in our understanding of underlying ecological processes."

During concluding discussion session:

Fred Grassle to Boyce Thorne Miller: "As a practical matter, you mentioned earlier that you found the words 'ecological diversity' useful in talking about it. Do you think that that's better than 'biological diversity?'"

Boyce Thorne Miller: "Well, I think that because the framework seems to have already been set up, the legal framework, and that was set up by the Office of Technology Assessment, which wrote a report on biological diversity and defined it as genetic, species, and ecological diversity. So... that will be the definition that we deal with... However, even using that definition, the legislation so far has focused very strongly on species diversity, and I think we can use those other two categories..."

Fred Grassle: "I certainly like the emphasis on all three categories."

B. THE ECONOMICS OF DIVERSITY CONSERVATION

Excerpts from remarks by V. Kerry Smith

o **Smith** (On estimating the benefits of preservation):

"...every decision implies a monetary value, whether we're willing to impose them or not, by default, because if we choose to do something or choose to do nothing, there is an implicit value that is associated with that choice. We either were not willing to spend the resources to save the species, or we were willing to spend the resources, the additional cost, to save the species. Implicitly, then, the species was either worth or not worth the amount that we chose to spend or not spend. So, we might just as well introduce the dollar values at the outset, and that's what I see as the moral of Yoshi's [Kaoru]... example of the endangered species story. By failing to incorporate the analysis, by failing to have a structured policy and [instead] allowing politics to take over, we ignore another important source of information - society's values. So, the moral of having a [marine biological diversity working] group like this thrash out the issues and start to think about the interactions... [is that it may be possible to] avoid that on a larger scale."

o **Smith** (On the importance of "non-use" benefits of biological diversity):

"When we get into benefit measurement, do we measure benefits that consumers realize because of direct use of the resource?... Or do we also identify the fact that people might have values for things even when they never use them, quite aside from the fact that they would be thinking that at some time in the future they might need the resource?... [that] at some time in the future the species might generate something that had a medical value?

"[An individual may feel that]: 'maybe I don't care whether the species has a medical value, maybe I just care that an ecosystem be preserved'... In order to be able to find out what those values are, we have to learn how to communicate with [individuals], we have to be able to explain to them what biodiversity means and what a policy means that would change the diversity... Non-use values do exist,... and they are quantitatively important, relative to use values, but they can't be measured in ordinary ways. Economists can measure them, but not through market transactions. The D.C. District Court of Appeals just reaffirmed that on July 14 in evaluating the Department of Interior's rules for natural resource damage assessments, that non-use values are tremendously important..."

o **Smith** (On scientific and economic uncertainty):

"...there is a vast amount of uncertainty in the [conservation] decision process, both from the scientific perspective and certainly from the perspective that economists will ultimately have to deal with in making a connection between biodiversity and how people might value it.

[Therefore] we can't work in the comfortable world that a large amount of the benefit/cost analysis...has worked in, assuming certainty... The minute we say that, we then have to face a distinction that economists and others have raised between what's called *ex ante* analysis and *ex post* analysis. In advance, before the outcomes [of conservation decisions] are known, we are not sure of what will happen, therefore we can only calculate as analysts what will happen in either expected value terms, as Mark [Eisworth] described it, and we can talk about expected monetary returns, or we can talk about expected levels of well-being...

"As time goes by, we can expect to learn more, and that information has to somehow be reflected in decisions we make today to the extent those decisions are irreversible."

Other Selected Comments

Jan Post (session on international development and the environment): "As more countries get more and more developed, I think... values like the enjoyment of a biodiverse environment are increasing very rapidly, and the large political momentum which the global biodiversity preservation movement has gained has not been based on economic calculations... I'm not saying that economics is not important in this, but the perceived value of this is gaining momentum rapidly and I think even more so in Europe than maybe in the United States... I understand and agree with the arguments of the necessity to make choices, but I disagree with the question, 'Can we afford to keep [preserve] everything?' The question is, 'Can we afford to lose all this?'"

James Broadus (Concluding discussion session): "... practical choices about the allocation of resources are going to be encountered, whether you like it or not, and we can't just simply say that it's wrong or somehow mischievous to try to attach economic values to the consequences of those choices. Because somebody is going to be called on to divvy up the resources, and that somebody is going to want to know what the payback, in whatever terms, what the payoff, is going to be for the investment that is thereby made."

VII. AMENDED DRAFT WORKING GROUP STATEMENT*

o Biological diversity is a vital natural resource for the human future.

o There currently exist critical threats to marine ecosystems, most notably in near-shore habitats such as coral reefs, mangroves and seagrass beds. Land-based marine pollution and the over-exploitation of fisheries stocks are two important causes of stressed marine environments.

o Because of different spatial and temporal features, conservation approaches that work well on land could fail in the more open systems of the ocean. Attempts to establish marine reserves, for example, need to incorporate information concerning the ranges occupied by organisms at various stages of the life cycle. Comparative analysis of the characteristics of terrestrial and marine ecosystems can identify specific challenges, as well as opportunities, for the protection of marine biological diversity.

o Substantive communication between natural scientists, social scientists and policy makers is difficult, but vital, for effective conservation of marine biological diversity.

o There currently is a need for the adequate training and funding of natural scientists, particularly systematists and biogeographers, so that the quantity and quality of scientific information available to marine protection decision-makers can be enhanced.

o Potential future programs of marine conservation must pass through the political arena, and therefore their success will be determined in part by the calculus of perceived net gains for society and for those who represent interested constituencies. It therefore is important for social scientists to examine the social benefits and economic costs of alternative approaches to protecting marine ecosystems.

o Effective conservation of the Earth's endowment of biological diversity requires inevitable **choices** in the allocation of scarce resources to conservation efforts. Given competing demands for limited resources, a policy conceived without regard to costs and benefits could lead to a diffusion of resources away from the most productive conservation efforts.

o In analyses of the economic importance of marine biological diversity, it must be recognized that only a subset of the economic value of diversity is reflected in market prices. The prices of various kinds of seafood are easily observable, but there are no market prices for swimming in, or even reading about, healthy and diverse marine ecosystems. Economists therefore resort to other techniques, such as directly surveying consumers or observing their willingness to pay for related goods and services.

o Attempts to preserve biological diversity in the Third World can affect their standard of living along with that of more developed countries. These effects may often run in opposite directions. Conservation planning for biological diversity must take account of these sometimes divergent needs and interests.

* Note: This statement is an amended version of that which was drafted by staff of the Marine Policy Center and presented to the Working Group for discussion on August 3-4. In amending the original statement, we have attempted to reflect the comments and suggestions which were made during the meeting. This statement should by no means, however, be interpreted as a consensus statement of the Working Group.

VIII. APPENDICES

APPENDIX A: WORKING GROUP MEETING AGENDA

Marine Biological Diversity Working Group Meeting
Sponsored by the Marine Policy Center
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
August 2 - 4, 1989

<u>Wednesday, August 2</u>

5:00-7:30PM	Reception **Clark 507**

<u>Thursday, August 3: Clark 507</u>

8:30AM	Coffee/Danish
9:00	Welcome and Introduction James Broadus Director, Marine Policy Center, WHOI
9:20	Marine Biological Diversity: An Overview Fred Grassle Dept. of Biology, WHOI
9:55	Policies, Strategies and Institutions G. Carleton Ray Dept. of Environmental Sciences, Univ. of Virginia
10:30-10:45	Coffee Break
10:45	The Economics of Diversity Conservation: Limited Resources and the Need for Choice Mark Eiswerth and James Broadus Marine Policy Center, WHOI
11:05	Yoshiaki Kaoru Marine Policy Center, WHOI V. Kerry Smith Dept. of Economics and Business, North Carolina State University Andrew Solow Marine Policy Center, WHOI (25 minutes reserved for discussion)

12:00-1:00PM	Luncheon **Clark 507 Foyer**
1:15PM	Comparison of Marine and Terrestrial Ecosystems John Steele WHOI
1:40	Howard Sanders Dept. of Biology, WHOI
	John Ogden Director, Florida Institute of Oceanography
	Phil Lobel Dept. of Biology, WHOI
	Rudolph Scheltema Dept. of Biology, WHOI
	George Woodwell Woods Hole Research Center
	(45 minutes reserved for discussion)
3:15-3:30	Coffee Break
3:30	Tropical Marine Ecosystems During Peaks of Climatic Changes: Continuity or Crisis? Vance Vicente Center for Energy and Environment Research, University of Puerto Rico
4:00	Tundi Agardy Marine Policy Center, WHOI
	Peter Larsen Bigelow Laboratory
	Llewellya Hillis Dept. of Zoology, Ohio State University
	(30 minutes reserved for discussion)
5:00-6:00PM	Cocktail Reception **Fenno House**
6:00-	Clambake **Fenno House**

Friday, August 4: Clark 507

8:30AM	Coffee/Danish
9:00	Who's Minding the Shore?: A Survey of Federal Legislation Affecting Marine Biological Diversity Kristina Gjerde Marine Policy Center, WHOI
9:30	Miranda Wecker Council on Ocean Law Boyce Thorne Miller The Oceanic Society Martin Belsky Dean, Albany Law School (30 minutes reserved for discussion)
10:30-10:45	Coffee Break
10:45	Bruce Leighty World Wildlife Fund Jan Post World Bank (45 minutes reserved for discussion)
12:00-1:00PM	Luncheon Clark 507 Foyer
1:00-3:00PM	Planning Session

APPENDIX B: LIST OF WORKING GROUP PARTICIPANTS

Marine Biological Diversity Working Group Meeting
August 2-4, 1989
Clark 507

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APPENDIX C: LIST OF QUESTIONS/ISSUES SUBMITTED BY PARTICIPANTS *

How do scales (time and space) of ecosystems and human activities relate, relative to the conservation and management of biodiversity?

How may ecological and economic theory be coordinated? That is, how can biodiversity be optimized from both viewpoints?

How may incentives for public involvement be developed?

An environmental "classification " has been called for; what would this look like for coastal-marine systems and how could it be developed and used?

What are the best parameters to be used for definition of ecosystems and ecological gradients (ecotones) that would best elucidate ecosystem properties relative to socio-economic activities?

What is the distribution of rare species?

Do species count in the function of ecosystems? If we replace a diverse community with a community dominated by a few species, do we change the role of that system in biogeochemical cycles?

Is species diversity the most sensitive measure of system change?

What is the value of biological diversity *per se* as a resource (and as distinct from the values of the individual elements of the biosphere)?

What guidance can be provided by the results of scientific research for making choices in the conservation of biodiversity?

In terms of urgency and magnitude of damage, are there marine counterparts to tropical deforestation?

How do the patterns and sources of value of marine biodiversity differ from terrestrial biodiversity?

Marine plants and animals yield benefits to society in a variety of ways. However, for many biological resources there exists significant uncertainty concerning benefits. In a world with a multitude of social needs, how can decision-makers determine the appropriate level of conservation effort for a resource that *may* (with low probability) yield benefits? What approach should be taken towards incorporating uncertainty into conservation policy?

It is vitally important to take conservation costs into account when devising strategies of diversity maintenance. In some cases, relative costs could influence tough choices relating to the allocation of funding. How can scientific information concerning the response of organisms to environmental conditions be used as input to cost analyses?

What role might economic incentive mechanisms play in the development of diversity conservation schemes?

How may appropriate incentives be established for situations in which cooperative actions among governments are necessary to conserve biological diversity?

Value of species needs to be measured from benefits consumers derive from them or consumers' "willingness to pay" for preserving species. Are consumers aware of benefits from species?

Is it possible to undertake a cost-benefit analysis for species preservation? What is the value of research on species?

Extinction of species may adversely affect sustainability of an ecosystem. Valuable genetic information may be lost. What is the risk of such adverse outcomes? What level of risk is acceptable?

A regulatory action for preserving species is likely to create both losers and winners. Should winners compensate losers? Is it possible to administer such a compensation plan?

How can we deal with the shortage of scientists who are trained in taxonomy?

How should marine reserves be created? For example, how large do they need to be?

What role does diversity play in determining ecosystem resiliency? What is the status of marine biological diversity in the world?

Given the clustering of species-rich areas, may they be assigned to regional seas or "large marine ecosystems" in which coordinated research and political action is possible?

What are potential scientific and political actions that might be proposed for each of these areas which will result in conservation of marine biological diversity?

Within each region, what are the scientific and political entities that will be most effective in formulating and implementing a strategy to conserve biological diversity?

Where do fishes spawn and what spawning areas are critical for high larval survival rates?

What recruitment areas are most important for larval settlement?

How should we quantify fish recruitment and spawning?

How should the spatial and temporal boundaries of populations, species and communities be defined? How should the definitions influence the direction of research?

How does knowledge of historical biogeographic and geographical ecology contribute to the understanding of biological diversity in space and time?

Is it possible to predict the effect of major human projects, such as the construction of the Suez Canal - or a Central American sea-level canal on the marine fauna? What practical consequences are there to fisheries?

What are the dangers of introducing species into a new region? How are species introduced into new regions? (Accident or design?)

What is known of "rare" species in ecological communities and what role do they play? What proportion of species are "rare" relative to "common" species? Do rare species make any difference?

In particular case studies, what are the main factors responsible for maintaining local or regional marine biological diversity?

How important are local and regional marine biological diversity to the economy and welfare of Latin American countries?

In what proportions do anthropogenic factors and natural processes contribute to present day local extinctions of marine species?

How will the existing warming trends affect present day marine biological reserves?

Does biodiversity, expressed in conventional terms as an index of the species richness of an area, constitute the most important grounds for preserving or protecting an area?
If so, what about areas which have a high number of species but low productivity (low abundances of each species)? And what of extremely high productivity areas of low diversity?

Species diversity in most marine areas is relatively low when compared to terrestrial areas. Diversity at higher levels of taxa, however, is very high. The same can be said for habitat diversity (depending on what measure is used to index habitat diversity). Does this mean that efforts to preserve global biodiversity should concentrate on land ecosystems and overlook marine systems, or should some compensation be made for difference in scale?

There is much movement afoot to catalog all existing species before they disappear into the vast terminal void that is extinction. Given that funds and time are limited, are we wise to take such an approach or should we be focusing on keeping ecosystems intact, worrying about the number of species they contain later?

All of life is inexorably linked, although for simplicity's sake these linkages are often overlooked. In discussing the merits of the preservation of diversity, and in talking about how to go about it, should more mention be made of the way that a species contributes to the maintenance of the ecosystem (more on the topic of homeostasis)?

What percentage of a species' genetic variability is contained within the core population?

What is the likely role of outlier populations during periods of climatic change?

How much habitat space is needed to maintain a species' genetic diversity?

How is the need to preserve biological diversity effectively communicated to the general public, management agencies, etc.? How are management plans developed, initiated and enforced?

On what scale is marine biological diversity being addressed, i.e. the maintenance of evolutionary centers for the spin-off of future species or the maintenance of contemporary marine communities?

Are benthic marine algae important to the ocean system? What is the extent of their contribution to ocean economy compared to the contributions of the wetlands flora, seagrasses and phytoplankton?

What are the differences in the species diversity, productivity, and functioning within their communities between tropical, temperate and polar benthic algal communities?

What are the effects of changing sea levels and global radiation on benthic algae and wetlands vegetation?

Symbiotic relations between algal and animal systems are an important aspect of the highly productive coralgal reef systems. How diverse are these symbiotic relationships? And how are they affected by stressed reef environments (sea levels, light, nutrient loading)?

How can we integrate the scientific ecosystem model into our ocean policy and programs so as to provide for conservation of marine biological diversity?

How much research is necessary to determine the conservation needs of marine areas before appropriate programmatic responses can be given to protect ecosystems?

How successful has the Endangered Species Act been in protecting marine biological diversity - should new legislation, specifically focusing on marine species, be developed?

How successful have our laws - particularly our regulatory laws - been in protecting marine biological diversity?

Where will the money for protecting species and habitat and for investing in sustainable forms of development come from?

How can nations be coaxed into complying with their specific international commitments and widely accepted international standards? In what ways can international environmental laws be made more effective, particularly in the implementation stages?

How can First World governments and the environmental community promote environmental objectives and at the same time display greater sensitivity to the Third World's right to cultural self-determination and its own scheme of priorities?

In what specific ways can international institutions be strengthened and made more efficient so that they can garner more respect and nations will see that it is in their interest to support such institutions?

A common approach to the biodiversity problem is to "zooify" endangered species and habitats, cordon them off in the strictest possible protectionist manner. But the world is a dynamic ever-changing place, and protectionism only works when reserves are large enough to allow the natural functioning and evolution of the system to continue. In a world of booming population growth and plummeting areas of wilderness, opportunities for such an approach are less and less likely to succeed. Is controlled use, based on adequate knowledge of ecosystem functioning and the connectivity between systems, fast becoming the best way to preserve diversity?

Loss of biological diversity is a global problem requiring local and regional solutions. Whether dealing with the diversity crisis on land or in the sea, should we work towards global or national treaties, or merely practice global consciousness raising, while working on microscale or mesoscale solutions?

*Note: These questions were submitted by participants prior to the August 1989 meeting, with the objective being the preliminary identification of important topics and issues for discussion and research. The questions above have been arranged by participant, in the order in which presentations occurred during the meeting. Since most of the issues raised are interrelated, no attempt has been made to organize the questions by topic or academic discipline.

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16. Abstract (Limit: 200 words)

On August 3 – 4, 1989, the Marine Policy Center of Woods Hole Oceanographic Institution hosted the initial meeting of the Marine Biological Diversity Working Group. The formation of this working group was fostered as part of an ongoing program of research concerning the oceans and biological diversity. Participants in the working group include professionals from the fields of biology, ecology, economics, statistics, law, environmental management, and international assistance, all of whom have expressed an interest in issues surrounding the conservation of marine biological resources. The proposed goals of the working group are to initiate an ongoing interdisciplinary dialogue on the topic, to establish a mechanism for two-way transfer of theory and empirical results between natural and social science, and to serve as a resource for policymakers by providing authoritative and timely information on important issues. This report contains information about the working group and the motivations for its formation, a description of the format of the initial meeting, key points from each of the sessions, abstracts of research/issue briefings delivered at the meeting by participants, selected excerpts from group discussions, and an amended version of a draft working group statement that was introduced to the group for purposes of discussion. The appendices contain the agenda of the meeting, a list of the names and addresses of working group participants, and a list of key questions and issues submitted before the meeting by the working group.

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3. conservation
4. marine policy
5. marine ecosystems
6. biological resources
7. marine biological resources

b. Identifiers/Open-Ended Terms

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