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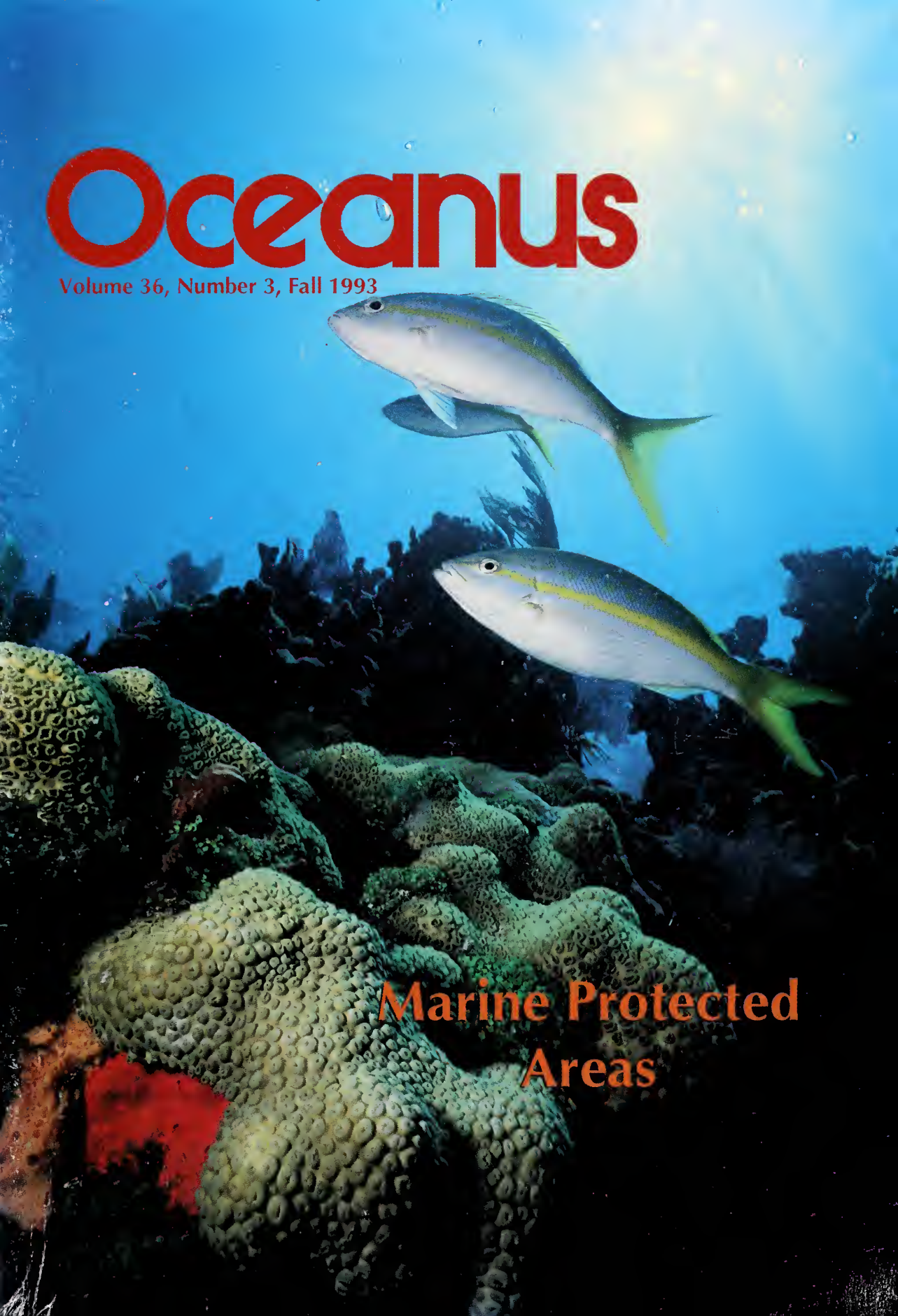

Marine Protected Areas

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On the Cover: Radiant light filters over yellowtail snapper as they swim toward clusters of polyp coral and star coral in Looe Marine Sanctuary, Florida Keys. Photo by Chris Huss.

Undiscovered Diamonds for the Crown Jewels

Paul C. Pritchard

America's national parks have been called her crown jewels. Just as the national parks range from the majestic Statue of Liberty in New York Harbor to the world-renowned Grand Canyon in Arizona, the United States can boast marine resources with the same unrivaled diversity. From the coral reefs of the Florida Keys to the biologically rich waters of the Channel Islands, the 13 US marine sanctuaries offer glimpses of resources that have long been dramatically undervalued and under appreciated.

In 1972, exactly 100 years after establishing Yellowstone, the world's first national park, the US created the National Marine Sanctuaries Program. It provides protection of our coastal waters similar to that given Yellowstone a century before. Today the National Park System, managed by the National Park Service (a bureau of the US Department of Interior), includes more than 360 units and more than 80 million acres of mountains, seashores, battlefields, and other historic sites. During the two decades of its existence, however, the marine sanctuaries program (part of NOAA, the National Oceanic and Atmospheric Administration, under the Department of Commerce) has not enjoyed the same level of understanding or support.

Of the current 13 marine sanctuaries, 6 of them were designated within the last 6 years. The first marine sanctuary was established in 1975, three years after the program began. This sanctuary protects the sunken remains of the USS *Monitor*, an ironclad Civil War ship that was discovered 16 miles off the North Carolina coast in 1974 under 220 feet of water.

Following this first sanctuary designation, five more were named before the program faltered during the Reagan administration. Under Reagan, only one sanctuary was designated, and it had the dubious distinction of being the smallest in the program—Fagatele Bay in American Samoa, covering just 160

Courtesy - Pacific Whale Foundation

Protected by NOAA's Hawaiian Humpback sanctuary program, these "dual dorsals" belong to a pair of humpback whales cavorting off the coast of Lahaina, Hawaii.

acres. (Despite its diminutive size, it is nonetheless valuable for its protection of diverse coral reefs.)

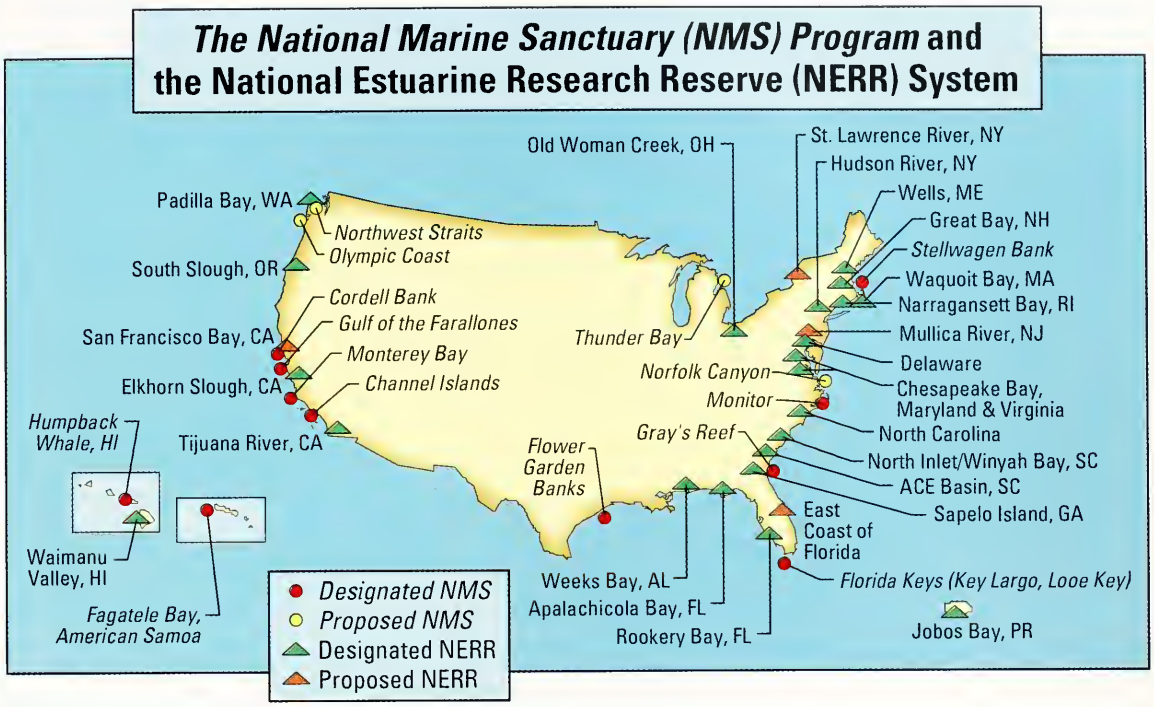
Under the Bush Administration, the marine sanctuaries program began to recover. Although, like the National Park Service, it is still underfunded, there are signs that the marine sanctuaries program can fulfill its potential for resource protection. In the last six years, the responsibilities of the marine sanctuaries program have doubled, but, as with the National Park Service, its budget has not kept pace. Three new areas that were nominated two decades ago recently joined the sanctuary list: Monterey Bay in California, Stellwagen Bank off Massachusetts, and the Hawaiian Humpback Sanctuary off Hawaii.

At one time, NOAA had suggested some 70 sites as candidates for marine sanctuaries. The agency no longer aspires to that goal, but perhaps the marine sanctuaries program will follow the same course as the National Park Service. When the marine sanctuaries program began, the 2.2 million square miles of ocean under US jurisdiction seemed to represent a vast and infinite resource, just as the American frontier was viewed as endless and inexhaustible during the 19th century. Only recently have we come to realize this is not so.

Although the marine sanctuaries program does not appear destined for increased funding any time soon, there are far more reasons than not to continue designating areas as part of this federal program. Even if no specific "resource protection" measures are taken, there are important and valuable psychological and emotional connections associated with sanctuaries. Designating an area a national park or monument elicits respect, as should naming a site a sanctuary.

In some cases, the impetus for setting areas aside as sanctuaries is to protect animals already receiving some degree of protection. For instance, Stellwagen Bank off Cape Cod National Seashore in Massachusetts is a prime feeding ground for migrating right, humpback, and fin whales—creatures already protected under the Marine Mammal Protection Act and the Endangered Species Act. Even so, designating an area a sanctuary provides a more

Divers inspect the sunken remains of the USS Monitor, *discovered 19 years ago off the North Carolina coast. A year after its discovery, the area surrounding* Monitor*'s gravesite was designated as the first US Marine Sanctuary.*



In the US there are currently 13 designated Marine Sanctuaries and 21 Estuarine Research Reserves.

integrated focus and puts everyone on notice that this area is considered a safe haven where people can come to watch and learn, but where animals or other resources may not be harmed.

While marine sanctuaries have often been compared with national parks, they are actually more akin to another type of national park unit called a preserve, where some harvesting practices are usually allowed. For example, whales are protected in Stellwagen Bank and coral are protected in the Florida Keys Marine Sanctuary but fish may be taken from either place. And while plants are protected in the southeastern Texas Big Thicket National Preserve, oil and gas drilling are allowed.

Perhaps as fin and shellfish are increasingly harvested from farms rather than from dwindling ocean populations, sanctuaries will become more like national parks. Although the marine sanctuaries program may not be perfect, it is one of the most effective ways we have to protect valuable marine resources. We now know the oceans are critical in the processes of cleansing the atmosphere, shaping and moderating the global climate, and nurturing the natural production of terrestrial and marine ecosystems. We also know that our ocean resources, like our national parks, are under siege from a variety of sources, including mining, oil spills, waste disposal, and silt that smothers marine habitats and historic artifacts.

Failure to support natural, historic, and cultural resources through the marine sanctuaries program would be akin to disinterestedly watching the Statue of Liberty sold as salvage or the Colorado River dammed to fill the Grand Canyon. Losing our marine resources would be devastating to our national—and global—heritage.

Paul Pritchard has served US lands and seas, first with the National Oceanic and Atmospheric Administration in the formative days of the Coastal Zone Management Program and later with the National Park Service. Since 1980, he has been president of the private, nonprofit National Parks and Conservation Association, which has grown from 23,000 to 350,000 members, reflecting, he says, "possibly his leadership, but also the realities of the politics of Washington."

Integrated Management of Coastal Areas and Marine Sanctuaries

A New Paradigm

Charles N. Ehler and Daniel J. Basta

The world we have created today as a result of our thinking thus far has problems which cannot be solved by thinking the way we thought when we created them.

—Albert Einstein

The goal of integrated coastal management is to produce the optimal mix of products and services from a coastal ecosystem over time.

Most coastal areas of the US—and the world—face urgent, increasingly severe problems of rapidly growing human populations, deteriorating environmental quality, loss of critical habitats, diminishing levels of fish and shellfish populations, reduced biodiversity, and increased risk from natural hazards. Several characteristics are common to the management of coastal areas:

- Increasing conflicts among economic development, environmental protection, and natural resource (including marine sanctuary) management objectives.
- Growing numbers of coastal resource users and increasing conflicts among them.
- Multiple-agency authorities and jurisdictions, and little or no coordination between levels of government and across agencies within the same level of government.
- Limited or inadequate financial and human resources for management activities.
- Incomplete data, information, and understanding of coastal problems.
- Public and political expectations that coastal problems have immediate solutions.

These problems challenge virtually all institutions responsible for managing coastal areas—public agencies at various levels, the private sector, and the academic community. An integrated, highly participatory management approach (one that involves all of those facing these challenges) is beginning to replace the traditional segmented approach of each institution concentrating on only a part of the coastal picture. There is also growing recognition that ecological systems, which can suffer severely from human activity, underpin economic systems.

Unfortunately, most institutions continue to tackle coastal management problems in a disjointed manner. Almost all decisions about coastal-resource use continue to be made on a single-sector, single-use, or single-resource basis. Some process is needed to determine the desirable mix of products and services (such as food, energy, and habitat) that coastal areas can provide at any particular time and over time, who should produce and pay for them, who should benefit, and by how much. That process is *integrated coastal management.*

What Is "Integrated Coastal Management?"

"Management" is a set of related activities carried out to achieve desired objectives. Coastal management and marine sanctuary management require diverse activities such as planning, assessing, implementing, enforcing, monitoring, evaluating, and educating. To be effective, these activities should be integrated and performed continuously. They should also have information feedback, for example, from monitoring to planning and assessment to operations, built into the continuous management process. The goal of integrated coastal management is to produce the optimal mix of products and services from a coastal ecosystem over time, with "optimal" being the mix that results in maximum social benefit. The political process usually defines the mix. Since the interests and priorities of society change over time, so does the mix.

Stephen R. Gittings

This Mobil oil platform in Galveston, Texas, easily visible from the Flower Gardens Marine Sanctuary, is an example of how commercial and environmental needs can converge on a marine area. Scientists from the sanctuary regularly use the platform in their work.

In the context of coastal and sanctuary management, "integration" has at least five possible pathways:

- across the management of regional economic sectors, such as agriculture, industry, energy, and recreation;
- among agencies responsible for coastal management activities such as natural-resource, environmental-protection, economic-development, and land-use departments;
- among authorities and resources of federal, state, regional, and local institutions;
- within the management tasks themselves; and
- across the disciplines of management, including science, engineering and technology, economics, political science, and law.

Both coastal management and sanctuary management focus on multiple-use area management, rather than specific-resource (such as fish) management, or specific-use (such as marine recreation) management. The management area might be a set of coastal counties within a state, or one or more coastal watersheds, or an entire coastal ecosystem such as the Florida Keys. Within that area, human activities and interactions with "natural" environments and resources can be envisaged as an integrated coastal management system. The resources of these areas can be used to produce multiple products and services, such as food, energy, recreation, habitat, and waste disposal.

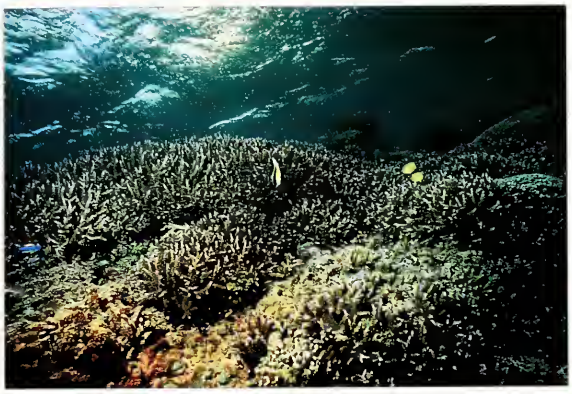
We have to fundamentally change our management from a fragmented to an integrated approach.

As human activities increase in these areas, conflicts between uses escalate. In addition, the demand for certain services may exceed the area's ability to provide them. Waste disposal often becomes a problem as assimilation of higher levels of waste begins to threaten the natural environment. Nutrient overenrichment of coastal waters is a well-known result of this problem. Coastal resources are typically "common property" resources freely accessible to users. This open access often leads to the resource's excessive use and resulting degradation or exhaustion. These "facts of life" increasingly require integrated coastal management.

The Changing Nature of Marine Sanctuary and Coastal Area Management

The Marine Protection, Research, and Sanctuaries Act of 1972 authorized the Secretary of Commerce to designate special areas as national marine sanctuaries to preserve or restore their ecological, historical, recreational, or aesthetic resources. In 1984, Congress made it clear that one of the purposes of the act was to provide authority for comprehensive, coordinated management and conservation of marine areas that would complement existing regulatory authority.

Over the past 20 years, and especially during the past three years, the size and complexity of NOAA's national marine sanctuaries have grown—from relatively small areas such as Looe Key in the Florida Keys (17.1 square kilometers) and Fagatele Bay in American Samoa (0.68 square kilometers), to relatively large areas such as the new marine sanctuaries in the Florida Keys (8,898 square kilometers, incorporating existing sanctuaries at Key Largo and Looe Key) and Monterey Bay in California (almost 15,744 square kilometers). The proximity of the sanctuaries to coastal lands has also changed—from those relatively distant such as USS *Monitor* 25.7 kilometers off North Carolina, Gray's



Michael White

Nancy Daschbach

At Fagatele Bay National Marine Sanctuary in American Samoa, a healthy reef (left) is compared to a reef damaged by hurricane Val in December 1991 (right). It is estimated that about 20 percent of the upper reef sustained this level of damage, which is between 90 and 100 percent of coral cover loss. These numbers are estimates, as NOAA is still performing a damage assessment.

Reef 27 kilometers off Georgia, and the Flower Gardens Banks 200 kilometers off Galveston, Texas, to those that are immediately adjacent to land, such as the Florida Keys, Monterey Bay, and the Gulf of the Farallones.

Conflicts among uses in these larger, closer-to-shore sanctuaries require the integration of sanctuary management with other coastal management activities. At the same time, the basic nature of coastal management is changing.

For the past 20 years, NOAA has provided about $700 million under the Coastal Zone Management Act to coastal states for coastal management program development and implementation. This amount has been matched by state resources, so that the total public investment is well over $1 billion. This year, NOAA will provide almost $50 million to state coastal management programs. Today, 29 of the 35 eligible states and territories have NOAA-approved coastal management programs. Several states, such as Georgia and Texas, that are not part of the program today are actively developing management programs. Some of the world's most innovative ideas and important lessons about how to manage coastal regions have come from real-world experiments in the states of California, Hawaii, Oregon, North and South Carolina, and Massachusetts.

Despite this level of investment in state coastal management programs (and ten times more spent publicly and privately for coastal water-pollution control), something is clearly wrong. Coastal environmental quality conditions continue to deteriorate. In addition, coastal population growth increases coastal area vulnerability to natural hazards—from storms and hurricanes in the short run to the effects of climate change, including sea-level rise, in the long run.

How Can We Make Integrated Coastal Management Work?

First, we have to fundamentally change our management approach, including the institutional arrangements for dealing with coastal problems, from a fragmented to an integrated approach. As we struggle with issues related to population increase, coastal development, and land use, hard choices will involve trade-offs between coastal resource use and protection. One thing is clear—we will be expected to do more with the

same or fewer resources. All of our collective resources, both financial and intellectual, at every government level, as well as across the public and private sectors, will be needed to get the job done well.

Second, while coastal management strategies must often be implemented at the "point of attack" by regional and local coastal agencies that are short of both personnel and funds, the collection and synthesis of technical data required by these agencies will often need to be supplemented by NOAA and academic institutions. New roles and institutional partnerships must be forged to make this work.

Third, we need a commitment to a continuing management process that can accommodate future changes. Typically we spend too much time producing a coastal or sanctuary plan that may work today, but will be inadequate in the future. As a result, the plan is put on the shelf and day-to-day decisions are carried out on an ad hoc basis with little reference to the plan. Little or no commitment is made to develop an ongoing analytical capability for assessing changing conditions. Regulations are written with few or no resources available for enforcement. But coastal management should be a continuous process. Progress should be constantly monitored so that management strategies can be adjusted to changing conditions. (This description of management is common in management textbooks, but it is rarely applied in the real world of coastal management.)

We need a commitment to a continuing management process that can accommodate future changes.

Fourth, we must recognize that increased participation, not only by the general public, but also by the wider scientific and management communities, is not just desirable—it is absolutely critical for long-term success. Not only do these "stake-holders" possess information that is invaluable to the management process, but by explicitly involving them, many conflicts can be avoided. For example, is it better to resolve differences and misunderstandings about issues, objectives, and management strategies early in the process—or simply leave critical management decisions to the legal system? We have to learn how to include scientists and their knowledge base from the beginning when we are identifying problems, specifying management objectives, and formulating and evaluating alternative management strategies. And in the process we must include managers responsible for economic development, local and regional land use, water quality, and natural resource management as well.

Implementing the Concept: The Florida Keys National Marine Sanctuary Management Plan

Talking about the need for more integrated coastal management is relatively easy. Carrying out integrated management activities in the real world is more difficult. Few examples or case studies exist. One is NOAA's recent experience in developing the management plan (and, more importantly, a continuing management process) for the new Florida Keys National Marine Sanctuary.

In 1990, the US Congress designated the Florida Keys National Marine Sanctuary, requiring NOAA to develop a comprehensive sanctuary management plan by 1993. However, Congress did not provide NOAA with new funds to develop the management plan or to manage the sanctuary over time. The Florida Keys sanctuary extends from just

south of Miami to the Dry Tortugas, encompassing almost 8,898.5 square kilometers of coastal waters. This large region is one of the most heavily used coral reef tracts in the world, attracting over a million divers a year; it has many competing, often conflicting, uses and overlapping agency jurisdictions and interests.

In this diverse and complex ecosystem, available data were incomplete and fragmentary, and planners had a short time frame—just two years—to complete the job.

Given insufficient resources and little time to complete the plan, what was done? First, we recognized that developing an initial plan for the sanctuary was only the beginning of a continuing management process that would evolve over an extended period of time. Second, we realized that to make the most out of what was already known about the area, we needed to form a working partnership with relevant public agencies, private citizens, and public interest groups to maximize the knowledge and resources of local scientists and other experts, managers, and decision makers in developing and implementing the plan. Public agencies that became key working partners included: the State of Florida (for example, the Natural Resources and Environmental Regulation departments); Monroe County (the local government for the Florida Keys); the US Environmental Protection Agency (the federal agency responsible for developing a Florida Keys water-quality management plan); and natural resource managers including the National Park Service, the US Fish and Wildlife Service, and the South Florida Water Management District. A "citizens' advisory council" provided the critical link to local citizens and other interest groups, and became an important and effective partner in the planning process.

Third, we needed a clear, integrated framework and process to develop the management plan. Fourth, we recognized that because of the ecological and economic importance of the Florida Keys, any management strategy would have to incorporate an operational level of detail to be taken seriously and have any hope of implementation. Strategies had to be defined sufficiently to include specifications of what would be done, when it would be implemented, how much it would cost, who would implement it, and what the expected results would be.

Finally, we recognized that we needed a "back-to-front" process, one that began with developing a plan that could then be used for structuring data collection, analysis, and research, instead of the other way around. We explicitly acknowledged that the detailed analysis and research required to evaluate the efficacy of the management actions would have to be part of the continuing management process.

Working closely with a "core group" of federal, state, and local specialists, NOAA personnel have been applying structured techniques to acquire and encode data from scientists, resource managers, and the regional public. The process has maintained a "problem-driven" orientation while still recognizing management as a continuous activity, and has made maximum use of existing knowledge and experience to assess alternative management actions. About 80 participants have served as the core working-knowledge base, although some 350 individuals have been involved to some degree. The process is now nearing completion and an integrated management plan for the sanctuary is scheduled for completion in the fall of 1993.

Increased participation by the general public and the wider scientific and management communities is absolutely critical for long-term success.

The plan will present about 100 management strategies, evaluate their likely consequences and costs, establish priorities, and provide an integrated process (federal, state, and local) for continuous management over time. Although the plan is considered only the beginning, it will provide the raw material to "prime the pump" of a continuing management process.

The Florida Keys National Marine Sanctuary legislation also directed NOAA to consider ocean area zoning as a management strategy. Working again through a highly participatory and open process that was led by the advisory council, we have identified a set of small, well-defined "preservation areas," designed to protect specific reefs and reduce conflicts between consumptive and nonconsumptive uses. In addition, "replenishment reserves," designed to encompass large, contiguous habitats, are proposed to sustain important marine species by providing spawning, nursery, and permanent residence areas for marine life protection. The reserves are intended to protect areas that represent the full range of the sanctuary's resources and habitat diversity.

We believe the emerging plan can be implemented and will provide for a balanced approach to sanctuary use, access, and ecosystem protection. Institutional responsibilities and financial requirements have been well specified. Perhaps most importantly, the requirement for a continuing management process for the sanctuary has been accepted—and will continue to evolve.

The process has made maximum use of existing knowledge and experience to assess alternative management actions.

Next Steps: The Monterey Bay National Marine Sanctuary

While it's too early to declare the Florida Keys sanctuary management process a "success story," other opportunities exist for developing similar continuous, integrated coastal management processes. The new Monterey Bay National Marine Sanctuary is an example. Formally designated in 1992, it is now the largest (and deepest) sanctuary in the nation, covering almost 15,743 square kilometers and extending along 555 kilometers of California shoreline and up to 92.5 kilometers offshore. Monterey Bay contains a spectacular submarine canyon and a highly productive, relatively healthy ecosystem. It is immediately adjacent to the Gulf of the Farallones National Marine Sanctuary (3,244 square kilometers), which in turn is adjacent to the Cordell Bank National Marine Sanctuary (1,359 square kilometers). This sanctuary "complex" and adjacent coastal watersheds of Central California provide another opportunity to demonstrate the benefits of using an integrated approach to coastal and sanctuary management.

The integrated, continuing management process evolving in the Florida Keys is a rare bridging of gaps among management, science, and public participation that points toward new—and better—ways of doing sanctuary business. Although none of the methods used in this process are new, the willingness of the local community to commit to and participate in a structured, iterative, and continuing process is. The success of direct participatory efforts will always be context-specific and people-dependent; however, NOAA is committed to evolving a generic approach to integrated coastal management from these experiences.

US marine sanctuaries come in all shapes and sizes, from the relatively small Looe Key in the Florida Keys to the larger Monterey Bay National Marine Sanctuary, with an area over 15,000 square kilometers.

Charles N. Ehler is the Director of NOAA's Office of Ocean Resources Conservation and Assessment (ORCA) in the National Ocean Service. Daniel J. Basta is the Chief of ORCA's Strategic Environmental Assessments Division. They have worked together for over 20 years to develop and apply a framework, and generate information, for integrated coastal management decisions. Both have been extensively involved in developing a continuing management process for the new Florida Keys National Marine Sanctuary.

The Florida Keys National Marine Sanctuary

The Florida Keys National Marine Sanctuary encompasses North America's most extensive living coral reef. Natural communities include patch and bank reefs, seagrass meadows, soft and hard bottom, and coastal mangroves. This matrix of interdependent and interconnected habitats supports highly diverse marine life. The abundant fish population includes both tropical and temperate species. Three sea turtle species (green, hawksbill, and loggerhead) are found throughout the keys, and use various habitats for nesting, feeding, and resting. A variety of coastal and marine birds use the Florida Keys, including several species that are found nowhere else in the country. The endangered West Indian manatee cruises throughout the keys.

There is intense human use of the Florida Keys. In 1990 the total population was estimated to be 134,667 people; 78,000 were permanent residents, and the remainder were seasonal residents or tourists/visitors. Almost 1,400 live-aboard vessels account for 2,500 residents. Tourism, recreational uses ranging from fishing to diving to boating, commercial fishing and shellfishing, military activities, research, and treasure salvaging compete for natural resources that are reduced in both quantity and quality as the population increases. Tourism, recreation, and commercial fishing support large portions of the regional economy. The keys have an unusually large concentration of shipwrecks that represent 500 years of European presence in the Americas.

Joseph Feingold/Key Largo National Marine Sanctuary

The brilliant jewel-red tones on the body of this "candy stripe" (or "barber pole") shrimp resting on a brain coral illustrate just one of many highly diverse species of marine life found in the Florida Keys.

Designation of the sanctuary was inspired by a series of ship groundings in 1989 coupled with the growing threats of coral diseases and increased water-quality problems. When the larger sanctuary's management plan is incorporated later this year, it will include two existing sanctuaries, the Key Largo and the Looe Key national marine sanctuaries, designated in 1975 and 1981, respectively. Key Largo alone has over a million visitors per year. It is a popular diving spot with attractions that include HMS *Winchester*, sunk in 1695, and *Benwood*, a World War II freighter sunk in 1942.

The Florida Keys National Marine Sanctuary Management Plan was drawn with unprecedented public participation and will be the first comprehensive marine-resource-use zoning plan in the US. It is the first sanctuary to have a water-quality protection program as part of the management plan and the first to establish an inter/intra-agency working group to assist in the development of a comprehensive management plan. Over the next year, a visitors' center will be established along with permanent office and boat maintenance facilities to handle operations over the entire Florida Keys.

—Adapted by the editors from material provided by the National Oceanic and Atmospheric Administration Sanctuaries and Reserves Division

Integrated Coastal Management

The Florida Keys Example From An Activist Citizen's Point of View

George Barley

The Florida Keys, a series of islands connected to each other and the mainland by bridges and a freshwater line, were developed haphazardly. For example, 30,000 septic tanks and cesspits, along with uncontrolled, untreated storm-water runoff, constitute an unmonitored, potentially serious inshore pollution problem. On the Atlantic side, a magnificent coral reef system exhibits serious symptoms of stress, while on the Gulf of Mexico side the Florida Bay ecosystem is in collapse.

The multitude of authorities with jurisdiction in the keys include two federal fishery management councils, National Marine Sanctuary and Monroe County officials, several state agencies, and federal fish and wildlife and state undersea park management agencies. Fishery pressure from large recreational and commercial groups is increasing. Jet skiers, divers, fishermen, ocean freighter operators, treasure salvors, and boaters all exert pressure on Florida Keys marine resources.

Following Congress's 1990 designation of the Florida Keys National Marine Sanctuary, the National Oceanic and Atmospheric Administration (NOAA) brought representatives of user groups and the public together with federal and state agency officials to assemble an integrated coastal management plan. How has it worked, and what has been learned from the process?

Is integrated coastal management a good approach? Definitely.

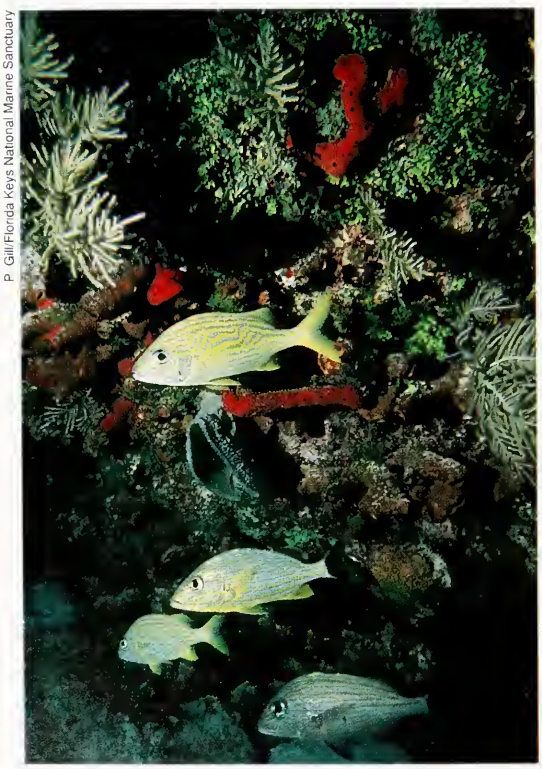
Working Together to Save the Keys

The legislation was skillfully drawn. It vested management authority with the Secretary of Commerce, but created an advisory council to assist, and established a critical Water Quality Protection Plan administered by the US Environmental Protection Agency (EPA) and the Florida Department of Environmental Protection (FDEP). User groups were given comfort language, but their activities were subordinated to the well-being of marine environments and resources.

A "core group" of all involved agencies—local, state, and federal—was formed early to coordinate authority and responsibility, and to brainstorm about problems and solutions with help from the public and the advisory council. NOAA held "focus" meetings with various users including scientists, divers, commercial fishermen, and treasure salvors.

NOAA's Strategic Environmental Assessments (SEA) Division, headed by Dan Basta, responsibly led the core group through numerous "think-tank" sessions. The group listed every conceivable issue and problem/solution scenario, categorized and ranked them, disposed of the unworthy ones, and submitted those remaining to the advisory council. Maps and documents—all the necessary working tools—were assembled concisely, graphically, and responsively in a performance not unlike that expected from a lean, mean, competitive private enterprise.

Led by Ed Lindelof of the Sanctuaries and Reserves Division, NOAA's outreach to other government agencies was skillful and its success was perhaps essential to the sanctuary's survival. Though commercial fishermen and treasure salvors were nervous about them at first, the agency's initial scoping hearings (an effort to inform the public about sanctuary goals) were well-prepared and received an outpouring of support.



P. Gill/Florida Keys National Marine Sanctuary

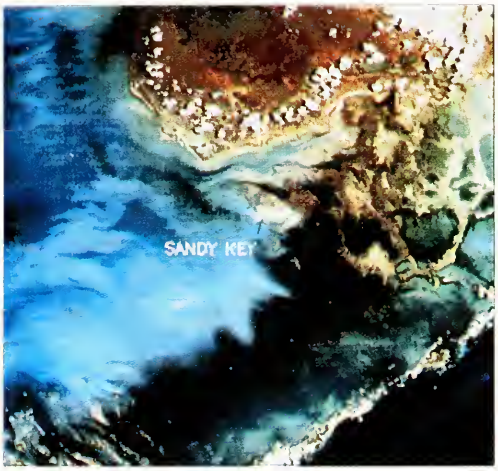
Several species of grunt fish shimmer brilliantly against a background of sponges and algae.

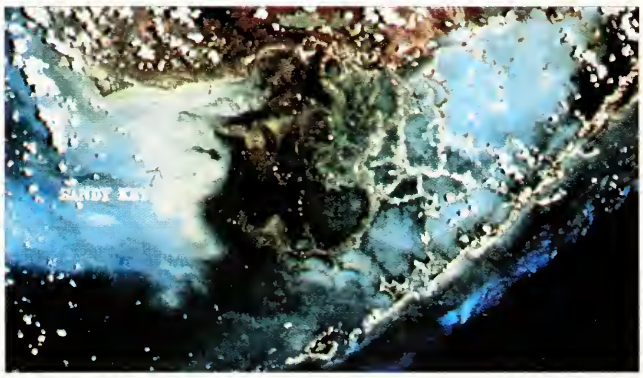
The legislation left fisheries management authority unclear, but this was later admirably sorted out by NOAA. The problem? The State of Florida had jurisdiction in part of the sanctuary, and there was federal jurisdiction in most of the rest, but the two overlapped in some areas. NOAA negotiated a protocol that established the most conservative existing rules as a baseline and designated the Florida Marine Fisheries Commission as the lead agency for developing sanctuary fishery rules in consultation with the federal fishery management councils.

The Florida Keys Advisory Council: Accomplishment in Action

The advisory council surprised nearly everyone except council members themselves. Half of its 22 members represented user groups, with the balance representing environmental groups, science, education, Monroe County, the governor, and citizens at large. The surprise was how strong the council was, how well it meshed, the level of consensus it reached on almost every issue, and the public support it received. Sometimes local people got mad at NOAA, or "the Sanctuary," but not at the advisory council.

The Florida Keys National Marine Sanctuary Water Quality Protection Plan Steering Committee was initially an impressive model of interagency action. In its second year it is considerably less effective, following the appearance of unforeseen Florida Bay pollution problems and the departure of its top leadership. This committee, chaired jointly by EPA and the Florida Department of Environmental Regulation,





In 1987, massive sea grass die offs began in the central part of Florida Bay. By May 1989 (left) approximately 30,000 acres of seagrass had died, and the die-off appeared to be receding. It reoccurred in 1991, however, and by May 1992 (below), was racing through the bay, as shown by the discolored area around Sandy Key.

sagged when Carol Browner left the environmental regulation department for Washington, DC, to become administrator of EPA, and EPA's regional administrator, Greer Tidwell, resigned after the Clinton Administration took office. He has not been replaced, and Browner's successor, Virginia Wetherell, recently appointed, has been occupied with a complex department merger.

NOAA has had public relations difficulties. Agency staff were surprised by a few strong user-sector reactions to sanctuary rules that put them in reactive (rather than proactive) positions. In one case, NOAA was ill-prepared for the industry's counterattack following a decision to declare a moratorium on the entire treasure-salvor industry as a result of extensive habitat destruction by a prominent local salvor. In another, the well-financed Conch Coalition launched a massive campaign to dissolve the sanctuary.

The advisory council adopted a "user-friendly" approach. On the most contentious issue, zoning, council member Mike Collins of the Keys Fishing Guides Association accomplished what seemed impossible when he negotiated a zoning plan with the jet-ski industry. Setting aside reservation or preserve zones was the most difficult, but the subcommittee hearings that included commercial fishermen, divers, charter boat captains, and other interested groups helped tremendously. These groups went on the water together as well, and at the end the commercial fishermen, a hard group to please, said it was the best process they had been through—they weren't totally happy with the result, but they liked the process.

Salinity and the Everglades Ecosystem

The biggest surprise was the advisory council's ability to direct attention to water quality, and to focus on the keys as part of the Everglades ecosystem. The group turned both government and public attention to events far upstream. Everglades National Park encompasses all of southwest Florida. Vast freshwater supplies that historically maintained the Everglades swamps have been diverted over the past 40 years, and

especially the last 10, to supply the growing population of Miami and the rest of Dade County, and also for tomato and sugar farms north of the Everglades. This has changed the Everglades ecosystem, and, in turn, made adjacent Florida Bay more saline. Resulting massive seagrass die-offs (100,000 acres, according to scientists at the Florida Marine Reserach Institute, the Everglades National Park, and the University of Virginia) that began in 1986/1987 and continue today, along with other Florida Bay ecosystem changes including huge algal blooms, affect the water of the Florida Keys National Marine Sanctuary. Huge losses have been suffered by the shrimp industry, and virtually all sponges, which are prime juvenile lobster habitat, died under the algal blooms.

There are some encouraging signs that the Water Management District is finally responding to this crisis. Attention from other agencies, such as the Army Corps of Engineers, which managed some of the water-diversion projects north of the Everglades, is also needed.

So, is integrated coastal management a good approach? Definitely. The Florida Keys would be a lot more vulnerable to the ominous forces threatening it now if it were not for sanctuary designation, and the skillful way NOAA has integrated various government interests and managed the plan development process. It's a good model to approach other coastal problems, and state and local governments could do similar projects on their own initiative.

George Barley, a Florida native, sells and develops real estate in Orlando, but for the last 10 years he has spent most of his time working on environmental issues. Chair of the Florida Keys Citizens Advisory Council, he is on the Board of the Center for Marine Conservation, was Chairman of the Florida Marine Fisheries Commission, and served on Florida's Environmental Regulation Commission. He has been a leader in developing a "people's movement" to restore Florida Bay. The Florida Conservation Association gave him its first "Golden Conservation" award and the Nature Conservancy honored him with its "Florida Chapter Chairman's Award" for his work on Florida Bay.

Conserving Biological Diversity Through Marine Protected Areas

A Global Challenge

Jack Sobel

A comprehensive strategy to protect global biodiversity must focus considerable attention on marine areas.

Scientists believe that off the coasts of the United States, from the frigid ice-scoured waters of the Arctic Ocean to the tropical reefs of the Florida Keys, the West Indies, and the Pacific Islands, there are more kinds of marine plants and animals in more kinds of marine habitats than are found off any other country in the world.

—*A Nation of Oceans*, descriptive document on the US National Marine Sanctuary Program, 1986

Custody of the world's most biologically diverse marine waters bears with it a special responsibility to protect them. The National Marine Sanctuary Program (NMSP), the only federal program specifically designed to provide comprehensive protection of the nation's extraordinary US marine ecosystems, has excellent potential for conserving their tremendous biological diversity. Since its creation in 1972, the sanctuary program has achieved considerable success, despite extremely limited resources and variable levels of administration support.

The recent addition of several new and larger sanctuaries brings important challenges and opportunities. In particular, large, new sanctuaries surrounding the Florida Keys and off the Central California coast provide the opportunity to develop truly state-of-the-art protected areas using an integrated coastal management approach. Some progress has already been made, but more is needed. If the Clinton administration recognizes and seizes this opportunity, the US can establish itself as the international marine protected area leader that our outstanding resources merit.

For too long, marine protected areas and marine conservation in general have been neglected relative to their terrestrial counterparts. This is surprising to marine scientists and others who know and love the oceans. After all, oceans cover 71 percent of Earth's surface. Moreover, considering that organisms occupy three dimensions rather than two, the oceans provide over 99 percent of Earth's living space.

Fortunately, there is a growing international appreciation of the oceans' importance. A comprehensive strategy to protect global biodiversity must focus considerable attention on marine areas or, more precisely, marine volumes. The world community is slowly waking up to the importance of conserving marine biological diversity and the key contribution marine protected areas can make to this effort. This sea change in attitude is reflected in outcomes from the decadal World Parks Congress and the United Nations Conference on Environment and Development held last year in Caracas and Rio de Janeiro, respectively. It is also apparent in the development of the international Global Marine Biological Diversity Strategy by several organizations interested in conservation.

Marine Biodiversity is Threatened

The diversity of life in the seas is spectacular, invaluable to mankind, and likely essential to the maintenance of life on Earth.

Simply defined, biological diversity is the diversity of life, but there are more complex definitions that recognize different levels of diversity. For instance, one definition encompasses species diversity (variety among species), genetic diversity (variety among genes within species), and ecosystem diversity (variety among specific environments and the biological communities they contain). But even this is not the whole story.

Additional definitions of biological diversity are useful for certain purposes. One of these, the diversity of higher taxonomic groups, which recognizes that all species are not created equal, is useful for comparing terrestrial and marine biodiversity. Taxonomy, the science that classifies organisms into groups (taxa) based on their interrelationships, uses a hierarchical classification system. The basic unit of taxonomy is the species. Terrestrial species diversity may be greater than marine species diversity (though there is still much to learn about marine species), but marine diversity is greater at higher taxonomic levels.

The diversity of life in the seas is spectacular, invaluable to mankind, and likely essential to the maintenance of life on Earth. Contributing to the seas' biodiversity are brilliantly hued coral reefs, dense mangrove communities, luxuriant sea-grass beds, lush kelp forests, thriving estuaries, rich upwelling areas, productive high-latitude waters, and the myriad of life they all support.

Living marine resources provide a broad array of goods and services to mankind including foods, medicines, raw materials, atmosphere and climate maintenance, and recreation, as well as less tangible resources of aesthetic, therapeutic, and spiritual value. Perhaps this is why most of the world's population lives within 80 kilometers of the coast and over 70 percent reside within the coastal zone. Even those farther away depend on the atmospheric and climatic influences of marine organisms. We all depend on life in the sea and have an ethical responsibility to conserve it.

The attraction of the oceans and their biota may be their undoing. The world's population continues to grow and relocate ever closer to the coasts. Burgeoning coastal populations and increased exploitation rates adversely

affect the oceans and their inhabitants. Threats to marine biological diversity fall into two general classes, those that involve overexploitation of living resources and those that destroy or degrade marine habitats. Over-exploitation includes both directed or intentional harvest and incidental taking of marine life. Threats to habitat include various sources of pollution, coastal development, and other activities leading to physical alteration. Many of these threats are interrelated and have cumulative impacts. Unless mechanisms are developed for a comprehensive response to these threats, marine biodiversity is likely to be irretrievably lost.

Marine Protected Areas Themselves are Diverse

Marine protected areas offer tremendous potential in the battle to save, study, and sustainably utilize the world's marine biological diversity. Despite this potential, the development of marine protected areas and their conceptual framework has trailed their terrestrial counterparts by nearly a century. Only within the last 20 years has the concept of protecting

In the Florida Keys, mangrove fringes such as these are declining in number. Mangrove communities are vitally important custodians of marine biodiversity, as they support many kinds of organisms at varying life stages.

certain marine areas become widely accepted. Since then, however, this idea has taken hold, and over 1,000 such areas have been established in more than 100 countries around the globe. As their number has proliferated, so too has their diversity and complexity.

Marine protected areas can clearly play a powerful role in preserving special marine areas, increasing public awareness and support for marine conservation, and providing sites for research and monitoring. Through changing public attitudes, improving scientific understanding, and developing effective models that can be applied elsewhere, protected areas can extend their benefits well beyond their geographically limited boundaries.

There are no definitive answers to questions regarding ideal size, approach, degree of protection, and design of marine protected areas. Existing marine protected areas vary dramatically in their reach and effectiveness. Defined broadly, marine protected areas run the gamut

Management Objectives for IUCN-Classified Protected Areas

I. Scientific Reserve/Strict Nature Reserve
To protect nature and maintain natural processes in an undisturbed state in order to keep available representative examples of the natural environment in a dynamic and evolutionary condition.

II. National Park
To protect natural and scenic areas of national or international significance for scientific, educational, and recreational use and to provide ecosystem stability and diversity.

III. Natural Monument/Natural Landmark
To protect and preserve nationally significant natural features and to provide opportunities for interpretation, education, research, and public appreciation.

IV. Nature Conservation Reserve/Managed Nature Reserve/Wildlife Sanctuary
To assure the natural conditions necessary to protect nationally significant communities, or physical features of the environment where these require specific human manipulation for their perpetuation.

V. Protected Landscape or Seascape
To maintain nationally significant natural landscapes and seascapes which are characteristic of the harmonious interaction of man and land while providing opportunities for tourism and recreation.

VI. Resource Reserve (Interim Conservation Unit)
To restrict the use of these areas until adequate studies have been completed on how best to use the remaining resources.

VII. Natural Biotic Area/Anthropological Reserve
To allow the way of life of societies living in harmony with their environment to continue undisturbed by modern technology.

VIII. Multiple Use Management Area/ Managed Resource Area
To provide for the sustained production of water, timber, wildlife (including fish), pasture, or marine products, and outdoor recreation.

IX. Biosphere Reserves
To provide a network of reserves representative of the world's ecosystems and develop effective models for conservation, research and monitoring, training and education, and sustainable development.

X. World Heritage Sites (natural)
To foster international cooperation in safeguarding areas of "outstanding universal value" with respect to conservation, natural beauty, or science.

from small, highly protected reserves to large, multiple-use areas and biosphere reserves. The International Union for the Conservation of Nature has a classification system for protected areas that recognizes 10 categories based on their degree of protection, and most or all of these include marine representatives (see Box).

No single approach has yet emerged (or is likely to emerge) as best for every situation. Diverse approaches can play key roles in maintaining biological diversity, depending on the nature of specific ecosystems, the threats to their biology, and the socioeconomics of the area. As different countries experiment with marine protected areas, scientists and resource managers around the world are identifying how to optimize their ability to conserve biological diversity.

Small Highly Protected and Large Multiple-Use Reserves

Multiple-use management regimes covering relatively large spatial scales are one of the tools that can be highly effective in the international struggle to prevent the loss of marine biological diversity. Although such regimes cover large areas, they are managed to allow most uses of the marine environment to continue within all or parts of the protected area. Only those activities inherently incompatible with the area's sustainability are banned throughout. Other activities may be limited to portions of the protected area or otherwise restricted to ensure compatibility.

The major advantage to working on a larger geographic scale is that it enables managers to effectively protect mobile organisms and address threats such as

pollution and other indirect habitat impacts that are often associated with coastal development and that don't respect arbitrary lines drawn in the aqueous environment. The effectiveness of such protected areas is greatly enhanced when boundaries are based on natural ecological units and when an integrated management approach permits managers to address all activities affecting the area, including adjacent land-based ones.

An alternative and complementary approach that can also play a key role in stemming the loss of marine biodiversity involves setting aside smaller but significant areas as true, highly protected marine reserves. Such reserves are designed and managed to maintain areas in the most natural state possible and therefore require strong regulations, including prohibitions on harvesting marine life. Until recently, few such reserves existed worldwide. Among the earlier and better-documented reserves are New Zealand's Leigh Marine Reserve (from Cape Rodney to Okakari Point), established in 1977; France's Scandola Nature Reserve established in 1975; and the Phillipines's Sumilon Reserve, established in 1974. The documented success of these sites has lead to the development of similar reserves in other countries, including the Turks and Caicos, the Bahamas, Bermuda, and (with hope), soon the US.

The major advantage to the establishment of such "no-take" or "non-consumptive" marine reserves is that they directly address issues related to harvest or exploitation of marine resources and related impacts. Among the benefits of this approach is the maintenance of natural areas replete with unexploited population and community structure, natural equilibrium, and ecosystem balance, and with a nearly full range of intact biodiversity. Specific benefits, rationale, and details for this approach are found elsewhere in this issue (see Marine Reserves, page 63).

Protecting global marine biodiversity requires both smaller, highly protected reserves and larger, multiple-use regimes.

Protecting the full range of global marine biodiversity will require the establishment of both smaller, highly protected marine reserves and larger, multiple-use management regimes. The two approaches are not mutually exclusive, but rather complementary. Ideally, smaller, highly protected reserves should be located within and part of larger, multiple-use management regimes. Australia's Great Barrier Reef Marine Park is a good example of combining these approaches. Where limited resources or other factors prevent joint implementation, each approach is still worth pursuing on its own—the ideal should not preclude the worthwhile.

The United Nation's Man and the Biosphere Program seeks to combine the two approaches via the establishment of "International Biosphere Reserves." The biosphere reserve concept shares three goals with many other protected area programs: conservation, research, and sustainable development. Biosphere reserves include three levels of protected zones: core (most highly protected), buffer (less protected), and transition (least protected). Although a number of marine biosphere reserves have been established, successful application of the concept has thus far been limited to a few sites such as the Great Barrier Reef.

Hope for the Future: Recent International Developments and Emerging Trends

The international community increasingly recognizes the importance of an integrated approach to the conservation of marine biological diversity and the key role marine protected areas can play in achieving this goal.

In 1987, the 4th World Wilderness Congress recommended as a primary goal the creation of a global, representative system of marine protected areas to preserve the world's marine heritage, including ecosystem, species, and genetic biodiversity, forever. In 1988, the International Union for the Conservation of Nature (IUCN) adopted a nearly identical resolution. Last year, IUCN's World Congress on National Parks and Protected Areas placed major emphasis on the marine sector for the first time. Its new Global Marine Program is intended to implement the resolutions mentioned above concerning the establishment of a global system of marine protected areas for the purpose of conserving marine biodiversity. This effort will emphasize the biosphere reserve approach, utilizing strictly protected core areas, buffered by well-managed zones of regulated use and transition zones.

The United Nations Conference on Environment and Development (UNCED) held last year in Brazil also focused unprecedented attention on the importance of marine conservation. UNCED's Agenda 21 devoted a chapter exclusively to the oceans and recommended that coastal states undertake measures to maintain marine biological diversity, including the establishment and management of protected areas. A Global Marine Biological Diversity Strategy was developed for the UNCED Conference by the Center for Marine Conservation, IUCN, the World Wildlife Fund, the United Nations Environment Programme, and the World Bank. This book, published this year by Island Press, states "Marine Protected Areas are a crucial tool in almost any overall strategy for saving, studying, and sustainably using marine biological diversity."

The international community increasingly recognizes the importance of conserving marine biological diversity and the key role of protected areas.

Although international conferences, resolutions, and agreements serve a purpose and can impact future policy decisions, they generally achieve few immediate tangible results. A better view of the current international status and future outlook for marine protected areas may be provided by looking at on-the-ground (or in-the-water) progress in the development of a few marine protected areas.

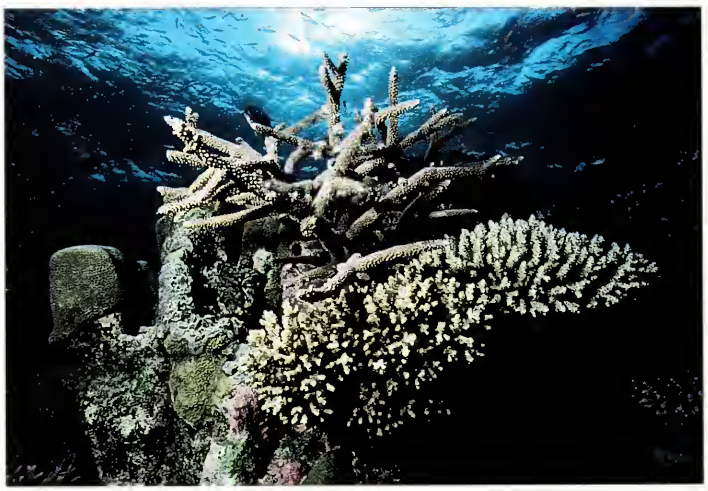
Australia: The Australian Great Barrier Reef Marine Park, Biosphere Reserve, and World Heritage Site (GBRMP) is one of the world's premier marine protected areas. The Great Barrier Reef Marine Park Authority (GBRMPA), which manages the area, has recently completed an ambitious strategic plan for the area as a World Heritage Site, has obtained enhanced protection for the area from vessel traffic through the International Maritime Organization, and is engaged in the continual process of revising its management plans.

Although the highly successful GBRMP continues to enjoy outstanding resources, strong public support, and strong funding relative to other marine protected areas, it is not utopia. In revising and implementing its management plans, GBRMPA continues to struggle with the ticklish problems of overfishing, tourism, and land-based impacts on its biodiversity. This indicates that although marine protected areas can be of great value, they do not provide easy answers and should not be considered a panacea. Nonetheless, the GBRMP provides a good protected-area model.

New Zealand: New Zealand's experience with marine protected areas presents an interesting contrast to the GBRMP model. In contrast to the vast GBRMP, New Zealand's first marine protected area, the Leigh Marine Reserve, only covers 3.88 square kilometers. The Leigh Reserve was

one of the first strict "no-take" reserves established in the world, and it remains one of the best studied. Although small, the complete prohibition on fishing activities has provided interesting information about fishing's adverse effects on biodiversity. While increases in size and abundance of certain targeted species were expected, scientists were surprised at other observed changes, such as rapid increases in lobster populations and secondary impacts on nontargeted species and community structure.

In a lightly developed country such as New Zealand, overfishing is likely the primary threat to biological diversity. Furthermore, the results at Leigh and elsewhere indicate that it is likely an important threat in other areas as well. The success of the Leigh Reserve has led to the development of additional New Zealand marine reserves and a plan to set aside 10 percent of the nation's coast as "no-take" reserves. If implemented, there is reason to be optimistic about New Zealand's marine future.



Rick Sammon

The Australian Great Barrier Reef Marine Park provides a good protected-area model for the integrated management approach. This area is home to an estimated 1,500 species of fish and over 400 species of coral, including branching staghorn corals.

Belize: The small Central American nation of Belize provides another example of how success with small protected areas can spawn more ambitious projects and optimism for the future. In Belize, home of the world's second largest barrier reef (Australia's Great Barrier Reef is the largest), the small but highly successful Hol Chan Reserve established in 1987 paved the way for the development of a much more ambitious integrated coastal zone management plan for the nation as a whole. This venture could result in a nationwide marine protected area analogous to the GBRMP. Again, if implemented, this bodes well for the enormous marine treasures of this small country.

Dominican Republic: Similarly, in the Dominican Republic, the creation of a small humpback whale sanctuary at Silver Bank, the North Atlantic humpback's primary breeding and nursery area, spawned interest in the protection of another Dominican area frequented by the whales, Samana Bay. This has resulted in the creation of a highly effective Dominican organization, CEBSE, dedicated to the protection of the bay, one of the Caribbean's largest and most diverse, and a proposal to designate the area as a biosphere reserve. Although a lot of work remains to be done here, there is much reason to be hopeful here as well.

Phillipines: The case of the Sumilon Reserve in the Phillipines is particularly interesting. When the reserve was originally established in 1974 with a strict "no-take" area, research documented the resurgence of a healthy fish fauna within it relative to control sites. Unfortunately, the protective management regime within the reserve broke down in 1984 and research has since documented subsequent adverse impacts on the fish community. Research here and at the Apo Reserve, also in the Phillipines, has been important in documenting the positive effects of "no-take" reserves on fish populations within reserves, and increased

More than 100 Caribbean protected areas depicted here represent the recent worldwide interest in conserving marine resources.

fish catches in regions surrounding them. This research provides a strong argument in favor of such areas.

France: The positive impacts of "no-take" areas have also been documented at the Scandola Nature Reserve in France. Again, research here has shown increases in fish populations within the closed area and suggested positive impact on adjacent areas as well.

The continued development, documentation, and expansion of both smaller highly protected and larger multiple-use reserves bode well for the future. The examples cited, the growing international interest in combining and applying these approaches, and the implementation of a robust US National Marine Sanctuary Program offer hope for the protection of Earth's diversity of living marine treasures.

As Habitat Program Director for the Center for Marine Conservation, Jack Sobel leads the Center's efforts to develop and strengthen marine protected areas, especially US national marine sanctuaries. He holds a B.A. in Biological Sciences from Cornell University and an M.S. in Marine Environmental Sciences from the Marine Sciences Research Center at the State University of New York at Stony Brook. His thesis research concerned population genetics of queen conchs in Belize. From 1985 to 1987, he directed a USAID Belize Conch Aquaculture and Genetic Project and was involved in the establishment of the Hol Chan Marine Reserve in Belize. He has focused on marine policy since serving as a Sea Grant Fellow with the Senate Commerce Committee in 1988.

Coral Reef Management in Thailand

A Step Toward Integrated Coastal Management

Lynne Zeitlin Hale and Stephen Bloye Olsen

The Kingdom of Thailand has experienced extraordinary economic growth over the past 10 years, leading Asia watchers to call it the next "economic tiger" in the region. Much of that economic growth has come from rapid, unmanaged, and unsustainable exploitation of the kingdom's rich natural-resource base. The consequent pace and extent of environmental degradation has been enormous. When the joint US Agency for International Development (USAID)–University of Rhode Island Coastal Resources Management Project (CRMP) began work in Thailand in 1986, there was little awareness of the need for integrated resource management and little experience in implementing such programs. Today both the Thai people and their government are beginning to recognize the seriousness of the environmental situation and the threat it poses to both continued economic growth and the Thai quality of life.

In coastal areas, there was an especially great need for effective, integrated resource management in the mid 1980s when our project began. Tourism was booming. Pristine coastal areas were rapidly being developed as resorts with little regard for impacts upon environmental qualities—often the same qualities that drew tourists in the first place. Older tourism developments such as Pattaya, a resort near Bangkok, were sliding into environmental and economic decline, but even then the lessons were not being learned. Coastal fisheries were shrinking, mangrove forests were being lost to shrimp ponds and other forms of coastal development, and water quality was declining. Government efforts to stem these trends were usually ineffective.

Thailand ranks third in total reef area among the countries of southeast Asia, following the Philippines and Indonesia.

What Are Coral Reefs?

Coral reefs are massive deposits of calcium carbonate built over centuries by living organisms—primarily coral—but with major contributions from algae and other organisms. Conditions essential to reef growth are water temperatures above 18°C, water depths shallower than 50 meters, constant salinity, and the circulation of clear, pollution-free water.

Coral Reefs Benefit to Thailand

- Providing recreational opportunities
- Providing habitat for commercially important fish
- Protecting shorelines from severe erosion during storms and monsoons
- Nourishing beaches with coral-derived sand
- Producing products for medicinal and phamaceutical purposes
- Providing habitat for rare and threatened species

What Are the Major Causes of Reef Deterioration?

Fisheries

- Dynamite fishing
- Trawling over reefs
- Overharvesting
- Other illegal fishing techniques such as using chemicals

Tourism

- Anchor damage
- Groundings
- Trampling
- Souvenir collection and trade
- Littering and solid waste disposal

Pollution and Sedimentation

- Sedimentation and stormwater runoff from coastal land
- Wastewater discharges from coastal developments
- Offshore sources of sedimentation (dredging, tin mining)

In assessing why resource management programs had so little impact, CRMP concluded that while existing laws, regulations, plans, and resources could all be improved, they were not the major impediments to effective management. Two factors did pose major barriers, here as in many countries: There was a lack of political will, largely because there was no broad, strong constituency for effective coastal management at either national or local levels, and there were no local models for effective resource management.

Within this context, we at the University of Rhode Island Coastal Resources Center (CRC) and our counterparts in the Thailand Office of the National Environment Board (ONEB) were asked by the US Agency for Internatinal Development and the government of Thailandto initiate a coastal management program. Clearly, all coastal management problems could not be addressed at once. We looked for a few strategic opportunities to build support for improved coastal resource management and gain credibility through tangible, short-term successes. Improving the management of coral reefs presented such an opportunity.

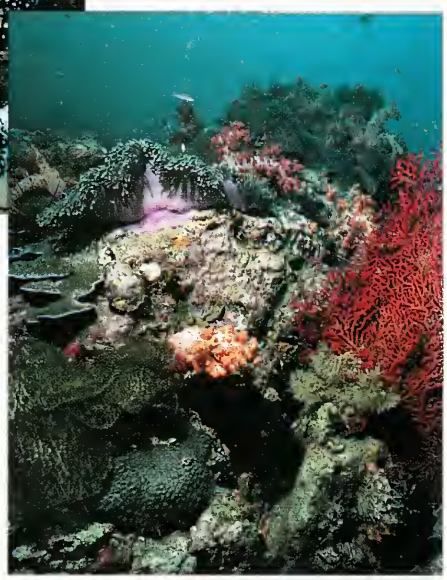
Thailand's Coral Reefs

Lying between 6°N and 13°N, Thailand's coastal waters offer good conditions for coral reef growth. There are over 300 major reef groups in Thailand, covering an estimated area of 12,000 square kilometers. Thailand ranks third in total reef area among the countries of southeast Asia, following the Philippines and Indonesia.

Coral reefs are among the most productive marine habitats in tropical regions. They support an abundance and diversity of fish and invertebrates. Recent surveys conducted in the Andaman Sea recorded 210 species of coral and over 100 species of reef fish from 30 genera and 15 families. The coral reefs of Thailand support a variety of activities that can be grouped into 1) tourism and recreation, 2) fisheries-related uses, and 3) research and education. The nature, intensity, and impact of utilization varies considerably from reef to reef and region to region (See Box on next page). In the last decade, significant changes in reef use patterns have occurred as small-scale or traditional fisheries are gradually being replaced by activities associated with tourism.

Coral reef conditions in Thailand range from very good to very poor. Over 60 percent of all major

Tourism Authority of Thailand



William J. Harrigan

reef groups are either in poor or fair condition; less than 36 percent are in good or very good condition (See Box on page 33). The widespread deterioration of Thai coral reefs is a relatively recent phenomenon associated with the introduction of bottom trawlers and blast fishing in the early 1960s, offshore tin mining in the 1970s, and the expansion of beach resorts, industrial facilities, and other coastal developments beginning in the late 1970s.

The dominant causes of reef deterioration are shifting. Reef blasting is declining in several provinces, but trawling damage is increasing. Sedimentation and wastewater pollution associated with rapid coastal development is increasing in all regions, including offshore islands.

Tourism is steadily growing in Thailand, simultaneously providing economic benefits and causing coastal environmental decline. Patterns of coral-reef use are likewise changing, as fisheries are gradually being replaced by tourism-based activities. Improving the management of Thailand's coral reefs, such as Shark Point (above), is a critical step to forging an overall coastal resource management strategy.

The Phuket Demonstration Project

To gain experience in the impediments to effective resource management, CRC and ONEB began a pilot project in 1987 on Phuket (pronounced pooket) Island to mobilize both private and public support to implement meaningful coastal management initiatives. During this same period, a cooperative Australia-Thailand project was initiated to collect baseline information on the condition and use of Thailand's coral reefs.

Located in the eastern Andaman Sea, Phuket is Thailand's largest island, with an area of 555 square kilometers. Phuket's west coast is a string of beautiful pocket beaches separated by dramatic headlands. The clear waters off the west coast provide excellent coral reef conditions. Fringing reefs are present within 1.5 kilometers of the western and southern shores of Phuket Island and on several nearshore islands. In general, reef conditions within the island's west coast bays are poor to fair, while reef conditions farther offshore are fair to good.

Tourism is Thailand's largest single source of foreign exchange, and Phuket is Thailand's premier coastal destination. Beginning in 1985, tourism began growing, and with the construction of a "ring road" along the west coast in 1988, shorefront development exploded. Both the value of reefs to this rapidly emerging industry and the industry's impact on reefs quickly increased. The traditional users of Phuket's corals—fishermen and shell and aquarium-fish collectors—were rapidly outnumbered by

divers and tour-boat and hotel operators. Tourism and coastal development became the principal causes of reef degradation.

When the project began, awareness of the existence, beauty, or significance of Thailand's coral reefs was limited to communities of fishermen, shell and coral collectors, divers, and a small group of scientists, few of whom were Thai. There was no mention of reefs or their declining condition in the media. Neither the private sector that was reaping sizable benefits from reefs nor the government agencies making decisions that affected their condition considered the impacts of their activities on the coral reefs.

The traditional users of Phuket's corals were rapidly outnumbered by divers and tour-boat and hotel operators.

Project Goals: There were two distinct goals for the Phuket Coral Protection Strategy. The first was to protect and provide for sustainable reef use. The second goal was to use the relatively simple and noncontroversial issues associated with coral reef protection to build local and, later, national support for addressing other coastal management issues in Phuket, and coral reef management nationally. In other words, we hoped that the constituency built around coral protection would later be motivated to address the more complicated and contentious coastal management issues Phuket faced—water-quality degradation, and unregulated and inappropriate land and water use. We also hoped this constituency would support national coral-protection action.

The Process: The Phuket coral protection project attempted to complete the planning and policy implementation cycle in three years. The people involved in the project were keenly aware of the need to build consensus and public support, and much attention was paid not only to *what* was done, but to *how* it was done.

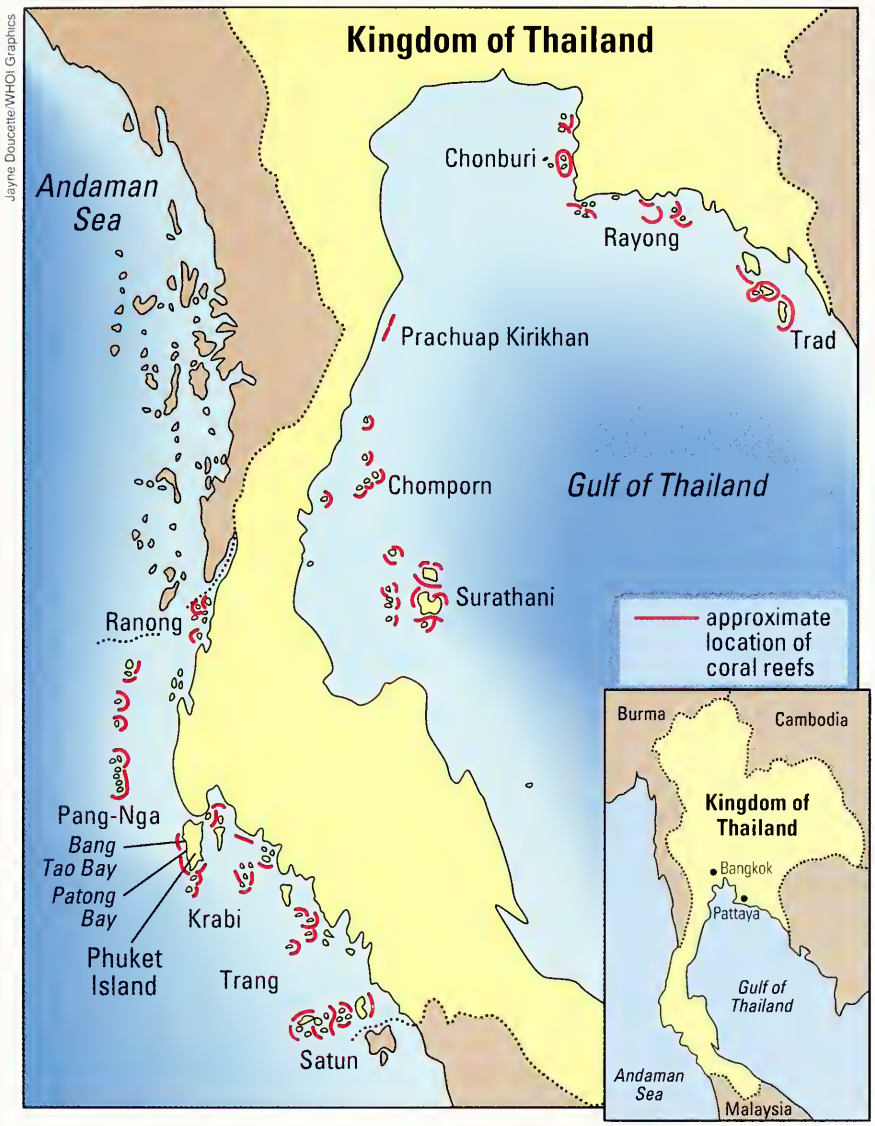
Using information gathered over the preceding 15 years by the Phuket Marine Biological Laboratory on reef distribution and condition, and with the participation of divers and fishermen, trends in the condition of Phuket's reefs and important management issues were identified in 1986 and 1987. The major causes of reef quality loss were:

- siltation from offshore tin mining operations in Bang Tao Bay,
- siltation from runoff and coastal watershed erosion due to construction of tourism facilities along the west coast of the island, and
- increasing nutrient discharges from sewage and runoff in Patong Bay.

Building Support for Management Initiatives: Throughout the year and a half of the issue-identification and analysis stage, we worked to heighten public awareness of coral reefs and build support for subsequent management initiatives. Early activities, which included media campaigns, community events, and distribution of brochures, were designed to enhance appreciation for Phuket's reefs and explain why a protection strategy was necessary. As we defined the management issues, support for coral protection was also built through extensive discussions with reef-dependent businesses and reef users.

Management Objectives and Strategies: In March 1988, a project-sponsored workshop brought together local and national government officials and representatives of key interest groups. They reviewed and verified the outcomes of the issue-definition process and endorsed the following objectives for coral-reef management in Phuket:

- Maintain and promote multiple and sustainable use of Phuket's reefs.
- Promote the recovery and enhancement of coral reef habitat.
- Enhance local commitment to, and participation in, coral reef management.



Jayne Doucette/WHOI Graphics

Abundant coral reefs and beautiful beaches along the Thai coast are major tourist attractions. Tourism is Thailand's largest single source of foreign exchange.

Management strategies to maintain water quality, sustain fisheries, and reduce tourism-related damage were set forth in an attractive, widely circulated document entitled entitled *Phuket Coral Protection Strategy*. The potential for effective implementation, community involvement, and interagency coordination were CRMP's three principle considerations in selecting initial action priorities. We first addressed issues associated with recreation and reef tourism use that could be affected by nonregulatory management techniques. These included educational activities and a mooring buoy installation project.

Educational activities were designed to enhance awareness of coral reefs and their economic significance, and to motivate voluntary changes in attitudes and behaviors. They included installing interpretive signs, hosting community events such as Crown-of-Thorn Removal Days (the crown-of-thorn starfish consumes living coral), new exhibits in the Phuket Aquarium, media campaigns, training programs for tour operators, and school programs.

Mooring buoy installation was selected as a highly visible, tangible action that would build linkages among government agencies and between the public and private sectors. Following a training workshop for local divers who had volunteered to assist the government agencies with buoy installation, 20 permanent mooring buoys were placed at Patong and nearby Hae Island (both popular diving and snorkeling sites) for use by divers and tour boat operators. This activity not only solved a "problem" but also built interagency and public/private sector relationships. By 1989, responsibility for maintenance of the buoys had been assumed by local groups. A model cooperative agreement between the Patong Sanitary District (the local governmental unit), the local private sector, and the central government agencies provides for patrolling and maintaining mooring buoys installed around Phuket.

Private sector monetary contributions to these efforts around Phuket were significant, totaling over 700,000 baht, approximately $24,000 US in two years. Coral reef issues and project results were well covered in both local and national media. By 1988, awareness and appreciation of the significance and value of coral reefs was widespread not only in Phuket, but in government, non-governmental organizations, and tourism circles in Bangkok. Thus significant progress was indeed made toward developing a constituency for coral reef management. In this new context, the CRMP then attempted to make improvements in the formal laws, policies, and procedures that govern coral reefs in Thailand.

Ten years of sustained activism could make Thailand a global leader in coral reef management.

A National Coral Reef Management Strategy

News of the Phuket coral project spread quickly. By the summer of 1989, the Tourism Authority of Thailand, local dive clubs, and nongovernment organizations in Surathani and Chomporn provinces were requesting ONEB assistance for installing mooring buoys and other forms of coral reef protection.

CRMP began working toward a comprehensive national management strategy. Our chief concern was to ensure that such a strategy would be supported and effectively implemented by all Thai government agencies responsible for coral management and by national coral experts, provincial officials, and representatives of key user groups. The national strategy would build on experience in implementing reef management programs in a few specific locations, including our own test case in Phuket; evaluation of existing laws and regulations; and, perhaps most importantly, on a major public education program.

In October 1989, a Coral Reef Management Workshop in Bangkok was held to share and disseminate lessons learned from local initiatives in Phuket, Surathani, and Chomporn provinces. Over 70 people from the central government, provincial agencies, and the private sector attended. After reviewing the outcomes of the local demonstration projects, there was widespread support for initiating work on a national strategy for coral protection that would not only encourage and support similar local coral reef management efforts, but would also address essential issues that required cooperative local and central-government action.

The National Coral Reef Management Strategy was subsequently drafted by CRMP with the several agencies responsible for its implementation. Its goal is the optimal multiple use of one of Thailand's coral reefs for

	Reef Condition			Dominant Causes of Reef Damage		
	Good/ Very Good	Fair	Poor/ Very Poor	Fisheries	Pollution	Tourism
West Gulf	58%	29%	13%	46%	30%	24%
East Gulf	24	37	39	87	12	1
Andaman Sea	34	32	32	67	27	6
All Thailand	36	33	30	71	14	14

After National Coral Reef Strategy for Thailand

Since 1986, the University of Rhode Island Coastal Resources Management Project has compiled data like the table above, detailing the issues faced by Thai environmentalists in their search for strategies.

fisheries, tourism, conservation, education, research, and other activities.

To achieve this purpose, the national strategy adopted six policies (see Box on page 34) as the basis for the site-specific action plan.

The National Coral Reef Management Strategy recognizes that coral reefs, like other habitats, must be managed according to a site's specific conditions—ecological status, uses, and development potential. The policies and measures of the strategy are therefore organized around a coral reef classification system whereby all major reef groups in Thailand are assigned to one of three management categories:

- reefs managed for local needs and benefits,
- reefs managed for national tourism and recreation, and
- reefs managed for national ecological and scientific benefits.

There are marked differences in the management objectives for each category and major differences in the activities that are prohibited, restricted, or allowed. There is also a distinct planning process for each management category, tailored to the different public and private sector interests affected.

In July 1991, at the final national workshop of the URI Thailand Coastal Management Project at Jom Tien in Chonburi Province, Thai agencies and the Coastal Provincial Governors endorsed the National Coral Reef Management Strategy. In April 1992, the Thai cabinet formally adopted the strategy and allocated 51 million baht (about $2 million US) for its initial implementation.

What will full implementation of the strategy's six policies and eighteen measures achieve? Ten years of sustained activism could make Thailand a global leader in coral reef management and should produce concrete and much-needed results.

- A small but strategic network of marine scientific reserves will be created. They will ensure effective protection of both unique and ecologically representative coral reefs that will serve as control sites for a monitoring program and for research.
- Coastal communities will be actively involved in maintaining and protecting coral reefs. Community groups, small tourism businesses, and fishing associations would have access to technical assistance and reliable information on how to manage reefs and encourage sustainable fisheries and recreational use.
- A significant proportion of Thailand's coral reefs will be managed

Thailand Coral Reef Management Strategy Policies

Policy 1: Manage coral reefs according to their different ecological and economic values and maintain a balance of uses.

Policy 2: Reduce degradation of coral reefs by increasing the effectiveness of existing laws and measures.

Policy 3: Build and maintain public support for the management of Thailand's coral reefs.

Policy 4: Make revisions to existing laws, administrative directives, and institutions required to make effective management practically feasible.

Policy 5: Monitor and evaluate progress in accomplishing the objectives of the National Coral Reef Strategy.

Policy 6: Support management through scientific research and innovation.

within a system of marine national parks. Educational and safety programs would ensure that recreational divers, snorkelers, boaters, and sightseers enjoy high-quality reef experiences. Sustainable use of these parks will generate income and employment for nearby coastal communities and the nation.

• Provincial governments, working in partnership with the national government, will have undertaken a significant first step in assuming responsibility for coastal habitat management. A corps of skilled, experienced government staff will provide technical assistance, develop and apply new techiques in reef management, and monitor progress. The practical experience gained in coral reef management should subsequently be extended to other coastal habitats.

It will take years of commitment to implementation of the national coral reef strategy, as well as sustainable coastal development practices to reverse trends in coral-reef degradation in Thailand. With adoption of the national strategy, the Kingdom of Thailand has made an important first step.

Lynne Zeitlin Hale first became interested in the science and management of coastal regions while spending the summer on a small island in northern Maine in 1970. That interest led her to study biological oceanography at the University of Rhode Island (URI) Graduate School of Oceanography. She has since spent her professional life working from Rhode Island to the Bering Sea coast of Alaska to the tropical coasts of Asia, always attempting to find a way to engage the peoples of these places to better manage their living environments. Lynne, who has been with the University of Rhode Island's Coastal Resources Center since 1985, and is currently its Associate Director, attempts to have a "second life" as full-time mother of two boys and part-time chicken and sheep farmer.

Stephen Bloye Olsen grew up in Italy and interspersed academic life at Oberlin College and URI Graduate School of Oceangraphy with stints on North Sea fishing boats and small farms in a number of countries. He has been Director of the Coastal Resources Center since 1975, and has worked to help define a new balance between humans and nature through coastal management plans and programs in New England, and, for the last decade, in low-income tropical nations. He lives on a small farm and has a penchant for building stone walls.

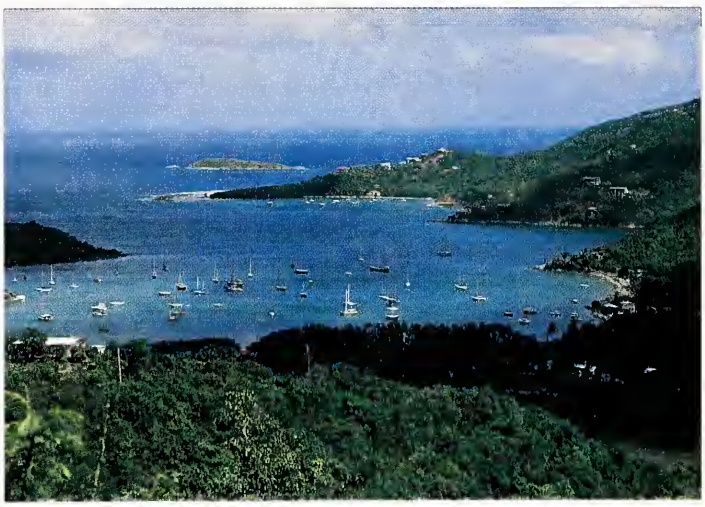
Editor's Note: The Coastal Resources Management Project described in this article recently received the "Blue Planet Award" sponsored by the Fundación Natura of Ecuador, a national environmental organization, and the country's national press as part of an effort to promote and reward environmental leadership. The award cited the program's outstanding work in environmental protection and conservation. The $5,000 prize will be used to support coastal management projects in Ecuador.

Economic Benefits of Marine Protected Areas

John A. Dixon

Marine protected areas contain valuable economic resources important to local and national economies. Careful management can allow both protection of biodiversity and economic development. Indeed, it is obvious that, rather than selecting the extremes of strict preservation or unmanaged development, balanced use of these resources for both economic and ecological functions is central to their sustainable management.

Economic benefits of marine protected areas (MPAs) include job creation through harvest of renewable and nonrenewable resources such as fish and shells, and through use of MPAs for nonconsumptive activities such as tourism and recreation. Some MPA benefits are difficult to express in monetary terms; examples include the economic value of biological resources and "environmental services" such as wave-buffering by healthy reefs. Other benefits are easier to calculate in dollar terms: a prime example is the direct financial benefit to local economies from recreational and other activities centered on MPAs.



James O. Sneddon

Is tourism compatible with the protection of marine parks? This question begs addressing at marine protected areas world over, including the Virgin Islands National Park.

The trade-offs between protection of rich ecological resources and use of the same resources for economic gain is clearly seen in the Caribbean, where "sun and sea" tourism is an economic mainstay for a number of small countries. Tourist arrivals number in the millions and generate billions of dollars worth of expenditures for transportation, food, lodging, services, and local purchases. In many Caribbean states, tourism accounts for 15 to 30 percent of the gross domestic product (GDP), the total value of all goods and services produced in the country.

Tom van't Hof

At right, Judy Halas drills a hole in the Saba Marine Park living reef to insert a stainless steel pin (foreground) for a permanent mooring. Dive boats can be tied to lines floated from these moorings, which are important in preventing anchor damage, one of the most common threats to heavily visited tropical reefs. Similar moorings have been installed in the Bonaire Marine Park, the Florida Keys, and other marine parks. The brain coral below was cut in half by an anchor in Saba Marine Park. Such damage can happen in a moment, but the reef can take decades to regrow and repair.

Tom van't Hof

In 1990 Caribbean tourism earned $8.9 billion (all figures are in US dollars) and employed over 350,000 people. Divers and other special-interest tourists may account for one-fifth or more of this total, and MPAs are increasingly important recreational sites.

Are protection of marine parks and tourism compatible? What are the trade-offs between prevention of biodiversity loss and the use of protected areas to generate income, usually from tourism or sport diving? Is ecotourism or nature tourism a viable option? This discussion reviews studies of several MPAs to examine these issues. Although the focus is on the Caribbean, other areas where MPAs are important economic resources include both Ecuador's Galapagos Islands and Australia's Great Barrier Reef. The Red Sea is also presently developing into an important MPA-based recreational diving destination.

Over the past decade, a number of studies have considered the economic benefits, both actual and potential, of Caribbean MPAs. They have tended to focus on direct-use benefits, largely from recreation, and assume that proper park management would prevent significant marine ecosystem damage.

Virgin Islands National Park

The Virgin Islands National Park (VINP), created in 1956 and later expanded through land purchases and donations, is located on the island of St. John, the smallest of the three major islands comprising the US Virgin Islands. The island economy is based on resorts and tourism; the principal attractions are the beautiful scenery and the marine park.

A 1981 Island Resources Foundation study examined the direct economic costs and benefits associated with tourism and recreational use

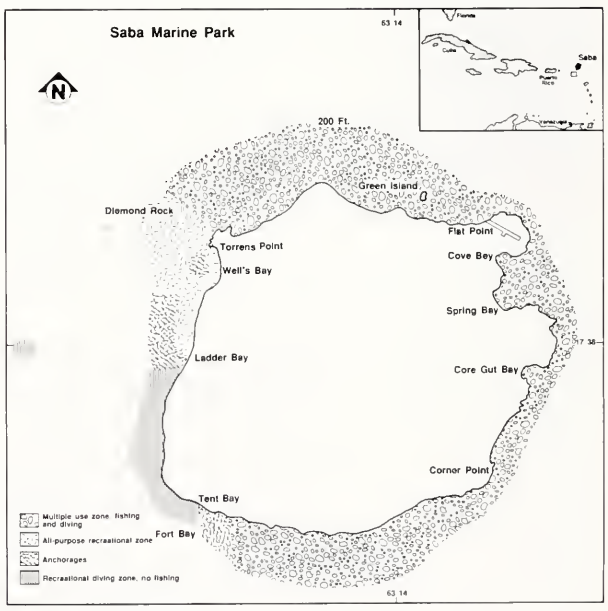
of VINP. Against total annual costs of about $2.1 million in the early 1980s, the study identified benefits more than ten times larger, totaling $23.3 million ($3.3 million in direct benefits and $20.0 million in indirect benefits). Most of the direct benefits were VINP concessionaire expenditures in the local economy—largely the payroll, taxes, and local purchases of St. John resorts. The largest benefits attributed to the park, however, were labeled as indirect and included visitor expenditures ($12 million per year), demand for boat charters and the boat industry ($3 million per year), plus increased land values attributed to VINP's existence ($5 million per year). These numbers are based on surveys of St. John visitors and island businessmen.

Although the VINP study focused on a subset of park-related benefits, the results clearly demonstrated VINP's importance to the local economy. This importance will grow since the trends in boating and individual recreational use are all strongly upward (visitor days increased from about 450,000 in 1980 to 750,000 in 1986), indicating growing demand for recreational use of these protected resources.

Saba Marine Park, Netherlands Antilles

Established in 1987, the Saba Marine Park (SMP) includes all of Saba's offshore waters. To help cover management costs, the park implemented a three-pronged fund-raising effort based on user fees, souvenir sales, and donations. The $1 per-dive fee collected by dive operators yielded some $10,000 in 1988 from 2,100 divers. A conservative estimate of total local-economy expenditures by divers in 1988 ranges from $1 to $1.5 million ($500 to $700 per person). Souvenir and guidebook sales generate revenue, and a Friends of Saba Marine Park organization solicits private donations.

In the first six months of 1992 a total of 2,300 divers made 9,200 dives; raising the dive fee to $2 per dive yielded direct-use revenues of some $17,500. Combined with another $2,500 from a recently introduced yachting fee, SMP became entirely self-supporting for the first time. By 1994, 5,000 visitors are expected to make a total of 30,000 dives, a level of diving activity that should not be ecologically harmful with proper management. Local economic benefits increase proportionately with the number of divers. Although operating costs are low because of the modest visitation rate and lack of management problems, Saba Marine Park illustrates what can be done to generate user revenues to help support MPAs. The projected growth in diver tourism provides a strong economic incentive to protect the marine resource.



The Saba Marine Park, established in 1987, completely surrounds the small island of Saba, from the high-water mark down to a depth of 61 meters, and divides its water into several different use zones. The largest area is a multiple-use zone for fishing and diving. A section of the more sheltered leeward side of the island is reserved for recreational diving only, with no fishing allowed.

The Virgin Islands National Park, Saba Marine Park, and other protected areas help ensure long-term conservation of these fragile ecosystems. In turn, this protection allows continuing use of resources by both local residents and foreign visitors, thereby ensuring a flow of revenue and economic benefits for both groups. Many MPA uses (such

as diving, snorkeling, and sailing) can be "sold" over and over again. Nevertheless, there may well be a physical limit to the use of protected areas beyond which resource degradation, and biodiversity loss, sets in. This in turn affects the MPA's attractiveness and their ability to produce economic benefits.

Bonaire Marine Park

In contrast to previous studies, the Bonaire Marine Park study (conducted by the author, marine biologist Tom van't Hof, and resource economist Louise Fallon Scura and published in the May 1993 *AMBIO*) explicitly combines an analysis of ecological with economic factors. It attempts to answer the questions posed earlier: Are protection and tourism compatible? What are the trade-offs between protection of biodiversity and use of protected areas to generate income? Are there physical limits on multiple uses of protected marine ecosystems?

Bonaire is a 288-square-kilometer, crescent-shaped island in the Caribbean Sea approximately 100 kilometers north of the Venezuelan coast. The resident population was estimated at 10,800 in 1990, up from 8,750 in 1981. The island is generally flat, and the Caribbean waters surrounding Bonaire from the shoreline to a depth of 60 meters are officially protected as the Bonaire Marine Park (BMP).

There may well be a physical limit to the use of protected areas beyond which resource degradation, and biodiversity loss, sets in.

Bonaire's economic mainstay is tourism, particularly tourism related to scuba diving; almost 17,000 scuba divers visited Bonaire in 1991, making an average of 10 dives each, for some 170,000 dives in all. Supporting activities include hotels, a modest number of restaurants and shops, and a few casinos, nightclubs, ground-tour operators, rental-car agencies, and transport services. Based on tourism statistics, the annual increase in Bonaire diver visitation is approximately 9 to 10 percent.

The Bonaire Marine Park was established in the early 1980s with aid from the Dutch government, and 38 permanent moorings were placed in the park to provide dive-site access while eliminating anchor damage to reefs. A snorkel trail was also created. However, failure to introduce a visitor-fee system for BMP brought financial difficulties, and the park became a "paper park" in the mid 1980s—management and access control were left to the dive operators. This continued until the early 1990s when new resources and management allowed BMP to begin operations again.

Relation Between Diver Density and Impact on the Bonaire Marine Ecosystem

Perhaps the most difficult question to address is: "What diver-induced damage is acceptable and what isn't?" Diver interviews and coral-cover and species-diversity data from a systematic, comparative photoanalysis of sites with varying intensities of dive use indicate that visitation at certain sites has already exceeded the reef's natural carrying capacity.

Diver impact appears to become significant above a certain critical visitation level. There seems to be a threshold level between 4,000 and 6,000 dives per year per site. If the "critical level" theory has merit, diver impact should become apparent at an increasing number of sites over the next few years.

Because of uncertainty over the exact relationship between diver intensity and reef degradation, it appears prudent to set the BMP carrying capacity at half the maximum theoretical capacity (based on the total number of designated dive sites) of some 400,000 dives per year. Annual use was already more than 180,000 dives in 1991 and, with an annual 10 percent increase in visiting divers, the carrying capacity of the Bonaire Marine Park will soon be reached.

Economic Benefits of Protection of BMP

Economic activities (hotels, restaurants, dive operations, and other service industries) associated with direct use of BMP waters produce yearly gross revenues of over $23 million dollars, or almost half of Bonaire's entire income (see Table). Note that these are not net figures; they represent the total amount of sales of goods and services associated with park-related tourism (the costs of purchased inputs and labor are not subtracted.) Nevertheless, the amount is large and indicates BMP's uniquely important role in the Bonaire economy. In contrast, annual BMP operating costs are about $150,000, which are just covered by the newly introduced user fee of $10 per person per year (sold as a plastic "admission ticket" that all divers must affix to their tanks).

Revenues and Expenses Associated with the Bonaire Marine Park
(1991 summary, in US dollars)

Revenues	
Diver fees (estimated for 1992)	$0.19 million
Hotels (rooms and meals)	10.4 million
Dive operation (including retail sales)	4.8 million
Restaurants, souvenirs, car rentals, miscellaneous services	4.7 million
Local air transport	3.3 million
Total revenues	**$23.2 million**
Expenses: The Costs of Protection	
Establishment, initial operation, rehabilitation	$0.52 million
Annual recurring costs	0.15 million
Opportunity cost expenses	?
Total expenses	**more than $.67 million**

Various sorts of revenues are generated by the diver-based Bonaire tourism industry. The major items include hotels, dive operations, and other visitor services. Direct park revenues are from sales of "admission tickets." Major expenses are the initial establishment and the rehabilitation costs, plus annual operating expenses of about $150,000.

This economic analysis illustrates the dependence of Bonaire on dive tourism. Are continued expansion of dive tourism and ecosystem protection compatible? The Bonaire data indicate that it may rapidly be approaching a point whereby increased dive tourism results in measurable marine-environment degradation. This may be partly avoidable, however; it may be possible to increase the number of divers (and economic benefits) by improved management and diver education—rotating dive sites, spacing out divers, regulation of underwater photography (ban tripods, for example, and promote better buoyancy control), controlling land-based pollution, and monitoring and supervision of park users. (These management measures do not increase the marine ecosystem's tolerance to stress, but rather they help to distribute the burden more evenly across the ecosystem. Enforcing such measures requires both money and legal authority.)

Improved park management and diver education increase the effective "carrying capacity" of any given dive site, and the park as a whole. Increased spending associated with doubling the number of dives (and divers) from the estimated present level of 200,000 dives per year to as many as 300,000 to 400,000 dives could mean increasing gross revenues

by $20 million or more per year. Nevertheless, Bonaire is approaching the limit of compatibility for resource protection and dive tourism. It may be possible to expand these limits; whether this in fact happens is directly dependent on both better management and improved diver education.

Though annual park-related revenues are large, and management costs are small, it has proved difficult in the past to find the small amounts of money needed for park management. This is a common story, not only in the Caribbean but in all parts of the world where marine parks are important "generators" of income. The problem is even more severe when MPAs do not produce direct financial returns.

The maximum sustainable-use level must be respected for marine protected areas to continue to meet both ecological and economic goals.

Protecting the Economic Benefits of MPAs: Management Lessons

Bonaire and its marine park are representative of the issues facing many MPAs in the Caribbean, including those in the Virgin Islands and Saba mentioned earlier. Bonaire illustrates the difficult trade-offs of combining economic and ecological goals. Its marine ecology is rich and protected, but threatened. Even relatively benign forms of use such as diving and yachting in a well-managed protected area have had adverse impacts on the marine ecosystem. The management challenge is to minimize these conflicts. Several lessons can be drawn from the BMP case for other marine parks in the Caribbean:

- MPAs can be effective means of protecting marine biodiversity while still generating important economic benefits from recreational and tourism uses.
- Localized overuse within an MPA is commonly observed before large-scale degradation begins, and can serve as a useful "early warning."
- Park-management costs are small compared to gross economic benefits associated with and directly dependent on the park.
- Park-user fees, levied either directly on users or on firms that organize use, can be implemented to cover costs but they are often resisted.
- It is important to plan coastal and marine development so that the local economy retains a larger share of the economic benefits. This allows increasing economic benefits, and the share that remains in the local economy, without always increasing the number of visitors.
- And finally, even with good management and enlightened divers and other users, there is a maximum level of both ecological and economic sustainable MPA use. This maximum sustainable-use level may be lower than that desired by local governments or business interests, but it must be respected for marine protected areas to continue to meet both ecological and economic goals.

John A. Dixon is a Senior Environmental Economist in the Environment Department of the World Bank—but at heart he is an island boy, having spent most of his life on tropical islands including Puerto Rico, Taiwan, Java, Penang, and, for the last 10 years before joining the World Bank in 1990, Hawaii. Eclectic by nature, his undergraduate degrees are in Chinese and economics from Berkeley, with a Ph.D. in economics from Harvard. His professional interests center on applying economic theory to environmental and resource management problems, preferably in tropical settings. More economist than environmentalist, he owns a chain saw but rides his bicycle 37 kilometers round-trip to work each day.

Los Marineros
An Investment in the Future of Our Oceans—and Our Children

Sheila Cushman

It gives the children more knowledge about the ocean, helps them become aware of the damage being done to our earth and our oceans, and, what really counts to kids, it's fun!

—Jennifer, a Los Marineros student

To the strains of "Pomp and Circumstance" playing softly in the background, students march solemnly in a line across the lawn and take their places amid rows of folding chairs. Dignitaries seated on either side of the flag-bedecked podium watch the proceedings, nodding occasionally in approval. After inspirational speeches by students and officials, one by one the graduates file by the podium to receive a a diploma, a handshake, and a warm wish of congratulations....

But, wait a minute! There's something different about these graduates. They're very young—11 and 12 years old—and the traditional mortarboards have been replaced by caps fashioned from bright red construction paper. Each "board" is topped by a whimsical, dancing crab with prominent claws and bulging eyes. The tassel is a brown paper kelp stipe that bobs gaily with each measured step. After the ceremony, the crab hats are tossed joyfully in the air.

Glenn Allen

Students march in to take their seats at the Los Marineros graduation ceremony.

This unusual graduation ceremony marks the end of the school year for 550 fifth graders currently participating in the Los Marineros marine education program, which is cosponsored by the Channel Islands National Marine Sanctuary and the Santa Barbara Museum of Natural History. After a full year of study about the ocean and its inhabitants and an exciting itinerary of field excursions to local marine-related sites, Los Marineros students are rewarded for their hard work with accolades, a book about the local channel waters, and an official-looking diploma adorned with dancing crabs—the program's logo—empowering them to "preserve and protect the oceans of the world and the strange and wonderful plants and animals that live there."

Los Marineros Field Excursions

- Adopt-a-Beach Day: beach cleanup
- Santa Barbara waterfront: walking tour and visit with Harbormaster and Waterfront Director
- Sea Center: docent-led tour and "Oceanographer for a Day" program
- Santa Barbara Museum of Natural History: guided research activity and behind-the-scenes tour
- University of California Santa Barbara Marine Science Institute: hands-on lessons in lab with biologists, campus tour
- Carpinteria State Beach: docent-led exploration of tide pools and beach
- Santa Barbara Channel: half-day whale watching trip
- Santa Barbara City College: diving demonstration and tour of the Marine Technology Lab
- McGrath State Beach: "The Treasures of the Estuary" program
- American Petroleum Industry Energy Information Day: demonstrations and interactive exhibits about the petroleum industry
- Santa Cruz Island: visit to sanctuary waters and island with tour of Painted Cave

Protection of these precious resources was one of the expressed goals of the National Oceanic and Atmospheric Administration's (NOAA) Marine Sanctuary Program when it was established in 1972 as part of the Marine Protection, Research, and Sanctuaries Act. The provisions of this legislation authorize the Department of Commerce, through its agency, NOAA, to designate discrete areas as national marine sanctuaries to promote the comprehensive management of their special ecological, historical, recreational, and aesthetic resources. Sanctuaries may be designated in coastal and ocean waters and in the Great Lakes and their connecting waters. To date, 13 marine areas have been designated around the country, and several additional sites are under consideration for future designation.

The move to have Santa Barbara's coastal waters designated as a sanctuary came after a disastrous 1969 oil spill fouled the waters of the Santa Barbara Channel. Politicians and representatives from various levels of federal, state, county, and city governments worked with concerned citizens for 11 years to achieve the designation. Eventually, in 1980, it was granted. The Channel Islands National Marine Sanctuary encompasses 4,284 square kilometers of water surrounding San Miguel, Santa Rosa, Santa Cruz, Anacapa, and Santa Barbara islands, extending from mean high tide to 11 kilometers offshore around each of the five islands.

In 1987, Lieutenant Commander Francesca M. Cava of the NOAA Corps came to Santa Barbara as the newly appointed manager of the nation's third marine sanctuary. (The NOAA Corps is the seventh US uniformed force, composed of 400 people who operate ships, planes, and helicopters, and provide many technical assistance functions.) Cava believed strongly that education was crucial to achieving the sanctuary's goal of resource protection, and that the most effective way to create an informed public was to start early. She recruited a dedicated group of

educators and community leaders to establish a program that brought marine science and environmental issues into the elementary school as part of the regular curriculum. Kathy Dubock was the teacher selected to pilot the Los Marineros program in her combined fifth and sixth grade class at McKinley School in the fall of 1987. The number of participating classes has since grown to 20 during the program's six-year history.

Partnerships Make It Happen

From the start, collaboration has been key to the success of Los Marineros and to sanctuary operations as well. Over the years, the sanctuary has established partnerships with other agencies and institutions as an efficient way to implement some of its programs. For example, the Sea Center on Stearns Wharf in Santa Barbara is an aquarium and marine education center cosponsored by the sanctuary and the Santa Barbara Museum of Natural History. This arrangement with the museum also funds the publication of *Alolkoy*, a quarterly education journal, as well as the salaries of four staff members, including two who administer the Los Marineros program.

The cost for one child to participate in Los Marineros for the entire school year is about $55, which includes a T-shirt, log book, and passport, as well as all curriculum materials and supplies, trip fees, and related expenses. These costs are met by partners in the business community and other levels of government. Current sponsors include Chevron, Exxon, Texaco, Cellular One, Sunrise Rotary Club, Alliance for Environmental Education, American Petroleum Industry, and the County of Santa Barbara. Others such as Fred Benko, owner of a large whale-watching boat, Eastman Kodak, and the *Santa Barbara News-Press* (owned by the *New York Times*) provide services or supplies at no cost or at a substantially reduced rate. Like Cava, these sponsors are motivated to invest in the future. In awarding one of three $10,000 grants to Los Marineros, Mike Marcy, public affairs manager for Chevron in Santa Barbara County, wrote: "We at Chevron are keenly aware that our operations touch nature at many points, providing numerous opportunities for impact on mammals, birds and marine life. So, too, are we aware of the numerous benefits afforded Santa Barbara's children-at-risk by programs like Los Marineros. Through our support for the good works of Los Marineros, the people of Chevron hope to assist in the preparation of creative and critical thinkers, to nourish their curiosity, and lay the ground work of skills and knowledge that keep us all aware of the vital links between humanity and the environment."

Sanctuary Library

Santa Barbara Harbor Patrol Officers demonstrate firefighting equipment aboard their vessel during a harbor tour.

Community input comes from the Los Marineros Advisory Board, comprised of community leaders, scientists, and educators, including

representatives from the sanctuary and museum, the school district, the University of California at Santa Barbara, Santa Barbara City College, Western States Petroleum Association (a consortium of oil companies operating in the area), and others with an interest in the marine environment and/or education. Meeting quarterly, the 19-member board assists by networking in the community, recommending potential funding sources, and searching out new field-trip and classroom opportunities for the expanding program.

Through collaborations with the Environmental Studies and Geography departments at the University of California at Santa Barbara, student interns, usually juniors or seniors, assist Los Marineros staff and classroom teachers. Their projects have included handling enrollment and evaluation for teacher in-service workshops, developing slide talks and science kits for the Los Marineros Teacher Resource Library, and working in the classroom with students on the inaugural issue of *Under the Sea*, a science journal for children.

Glenn Dubock

Looking toward Santa Cruz Island's Painted Cave, from Condor's *deck. Located near the western end of the island's north side, Painted Cave is reportedly the world's largest sea cave, reaching heights of 49 meters above the water level. Its name is derived from naturally occurring colors created by various rock types, lichens, and algae.*

Another partnership with the Santa Barbara School District helped incorporate the Los Marineros program into the regular fifth-grade science curriculum. Although naturalists and other marine specialists are the primary instructors on Los Marineros field excursions, district teachers implement the Los Marineros curriculum in their classrooms. In 1987, the Santa Barbara Board of Education authorized teacher and student participation in the cooperative venture. Blas Garza, the district's Assistant Superintendent of Elementary Instruction, has termed Los Marineros "one of the best and most exciting programs in marine ecology for elementary school age children."

Hands-On Experiences Make Science Concepts Unforgettable

Just what makes the Los Marineros program so exciting? Vanessa Mack, a Los Marineros graduate from Washington Elementary School, expresses the viewpoint of many student participants: "It was neat to get a hands-on experience, rather than out of a book or off the TV!"

Los Marineros takes students out of the classroom, away from their books, right into the marine environment. After classroom lessons and experiments on tides and beaches, students spend the morning with a naturalist exploring the tide pools at a local beach. Scampering over rocks, they get to observe and even touch the brilliant sea stars and urchins they have studied in class. Classroom lessons on estuaries precede a visit to McGrath State Beach in Ventura to hunt for "Treasures of the Estuary." During this morning-long education program offered by California Department of Parks and Recreation, small teams of students roam the wetland, gathering clues at a variety of learning stations in an attempt to find the "treasure." The learning stations include a mock "travel agency" that tracks the migrating patterns of birds that regularly visit the estuary, the estuary "kitchen" where student-chefs mix up a pungent batch

of estuary soup, and the uplands, where, at the touch of the Magic Crayfish Claw, students are transformed into raccoons foraging at night for food. (The treasure of the estuary, students learn, is the estuary itself.) Vivid experiences like these enhance learning and provide excellent reinforcement of lessons presented previously in class. Concept retention is high because students learn by direct participation.

Glenn Allen

Students examine an urchin while on a tidepooling trip.

The Los Marineros curriculum addresses the major science themes explained in the 1990 California Public Schools Science Framework, as well as the fifth-grade science topics prescribed by the local school district. The 1991 edition of the *Los Marineros Curriculum Guide* is a comprehensive introduction to the local marine environment, with content ranging from general marine science topics, such as currents and beaches, to those specifically related to the Santa Barbara Channel, including history of the Chumash Indians and early Santa Barbara settlers, as well as local marine-policy issues. The curriculum guide is given to teachers selected to participate in Los Marineros, and is available at a nominal charge to the public. To date, more than 500 copies have been distributed across the US and worldwide.

Motivating At-Risk Children

The *Los Marineros Curriculum Guide* and the program itself are specifically aimed at the student population in the Santa Barbara School District. Of this population, 64 percent are Hispanic, many from low-income families without the financial resources to provide enrichment experiences for their children. Lacking positive role models to encourage them to achieve academically, many of these students are considered "at risk" of dropping out of school. The exciting Los Marineros lessons and field trips show them that science and school can be fun. They have the opportunity to meet and interact with people who work in a wide variety of marine-related professions such as naturalists, divers, marine biologists, and oceanographers. We hope that exposure to such a diversity of rewarding careers will motivate these high-risk youngsters to stay in school, and go on to college. To better serve the needs of Hispanic students, the guide offers suggestions for teaching the lessons using the Sheltered English teaching method, which involves student-centered, content-driven instruction in English using simplified, contolled vocabulary, gestures, and visual aids. Just recently, a Spanish translation was completed and is ready for distribution.

A Select Group of Teachers

The number of new classes added to the Los Marineros roster in any given year is dependent on available funding, which comes in the form of grants from foundations and businesses. Each spring the program coordinator waits on pins and needles to see the fruits of fall's grant-writing

A Los Marineros Teacher

Ask Kathy Dubock, the teacher chosen to pilot the Los Marineros program, why she likes the program and you'll get a rapid reply: "It's such a turn-on to kids. I love teaching it because it's the highlight of their year." Kathy was selected in 1987 to be the first Los Marineros teacher, not for her marine science background (she has none), but for her reputation as a highly organized and dedicated teacher. At the time, she had taught in Irvine and Santa Barbara schools for eight years and was ready for a new challenge.

She admits that, during the first year, organization was not a high priority and that much of what was accomplished was done through networking in the community. Francesca Cava had recruited a Steering Committee that devoted countless hours to arranging worthwhile classroom speakers and field trips for Dubock's class. Because the program was so small and so new, members of the community were eager to lend a hand (or a boat) to help ensure its success.

Dominic Barth

Kathy Dubock shows eager teachers how to stage an end-of-the-year Sea Fair, at the 1991 Los Marineros Marine Education Workshop.

Kathy co-authored, with fellow Steering Committee members Cava, Eduardo Hernandez, Linda Cabral, and Alicia Sell, the first draft of the *Los Marineros Curriculum Guide* in 1988. She saw the pilot program grow to four classes in 1988 and eight classes in 1989. After the Sanctuary hired a part-time coordinator the program grew even more rapidly—to 10 classes in 1990, 16 classes in 1991, and 20 classes in 1992. She was the first teacher representative elected to serve on the Los Marineros Advisory Board, a reconfiguration of the old Steering Committee.

How has all of this growth changed Los Marineros? Dubock misses the close relationships that developed between teachers and Steering Committee members when the program was in its infancy and she's a bit concerned about the lack of dedication on the part of some of the new teachers recruited to participate. However, she feels that the growth and success of the program have attracted local and national recognition (see article), which, in turn, has facilitated fund-raising efforts. She's delighted that the program reaches so many children because she has seen firsthand the positive effect it has on children. Not only do students learn about ocean processes and the plants and animals living the sea, but they become quite knowledgeable about marine issues as well.

Over the years, some of Kathy's classes have decided to wage public campaigns against the growing problem of marine debris, writing letters to the local newspaper, the governor, and even the President. In 1991, because of their strong commitment to the environment, Dubock's class was selected by California State Senator Gary K. Hart to evaluate projects submitted by classes from around the state that address the need to preserve endangered species.

Yet another challenge lies ahead for Dubock. This fall, along with four other Los Marineros veteran teachers, she will pilot a new middle school program for the Santa Barbara School District. —*SC*

labors. Once the results are in, plans for expansion and trip scheduling for the coming school year are put into play. A multiyear grant from a large foundation would provide a guaranteed source of support and ease the minds of program staff.

New Los Marineros teachers are chosen from a large field of applicants recommended by school principals. The applications, including student evaluations, are reviewed by the program coordinator and a small committee to assess classroom experience, enthusiasm, commitment to teaching hands-on science, and willingness to devote time beyond the regular school day to the program. This commitment of time is what keeps some qualified techers from submitting applications. In response to teacher comments, the program staff have attempted to make the materials and procedures as streamlined and user-friendly as possible to minimize this requirement.

Once selected, teachers remain in the program until they move to a different grade level or school. They are required to attend monthly in-service meetings that feature demonstrations and background information about upcoming teaching units and trips as well as opportunities to share experiences and techniques. Every other year, the Los Marineros program expands its reach by offering a marine education workshop that attracts a sellout crowd of nearly 100 educators from around California. "Making Waves '93" treated participants to two days of fun-filled activities designed to make the ocean "come alive" in the classroom.

For example, on the first day, storyteller David Novak shared his wild and witty tales of the sea and then, using his easy-to-learn storytelling techniques, teachers created their own stories with colorful adjectives and exaggerated gestures. Science wizards Jean Rogers-O'Reilly and Eunice Paloutzian set out an interesting array of simple experiments dealing with ocean density and salinity that gave teachers a chance for some hands-on practice. Later in the day, at the Sea Center on historic Stearns Wharf, teachers watched in amazement as urchin spawning was induced by the injection of potassium chloride. The next day included a cruise to the waters of the sanctuary and a visit to Santa Cruz Island's Painted Cave, the world's largest sea cave. During the voyage, divers brought specimens up from the ocean floor and placed them in a portable touch tank, where naturalists discussed characteristics of the various creatures and encouraged the sometimes-reticent teachers to observe and touch them. On the way back to Santa Barbara, magnificent humpback-whale sightings rounded out the weekend.

Editor's Note:
To order a copy of the *Los Marineros Curriculum Guide* mentioned in the Box at left, write to: Los Marineros Coordinator, Channel Islands National Marine Sanctuary, 113 Harbor Way, Santa Barbara, CA 93109, or call (805) 966-7107.

An Award Winner

During its short, six-year history, Los Marineros has successfully marshaled the forces of federal and local governments, educational institutions, and the business community to provide high-quality science and environmental education for children in Santa Barbara's public schools. The program helps students develop skills and knowledge that we hope will help them become productive citizens, capable of making important decisions about environmental issues—particularly those pertaining to the ocean. For these efforts, Los Marineros has captured the attention of both state and national organizations. In June 1992, Renew America, a national nonprofit organization committed to restoring our nation's

communities through environmental action, awarded Los Marineros a Certificate of Environmental Achievement for its success in protecting the environment, while serving as a model that can be replicated around the country. Later that year, Los Marineros was selected as one of five youth winners in the 1992 Take Pride in California Awards Program. Linked to a national awards competition, Take Pride in California recognizes individuals and public and private groups for outstanding stewardship projects or awareness efforts involving federal, state, and local land, water, historic, or cultural resources.

Not content to rest on these laurels, plans call for the program to be offered to every fifth-grade class in Santa Barbara schools by fall 1994. Beyond that, a variety of expansion plans are under consideration, such as including adjacent or outlying districts and creating a related program for students in sixth, seventh, and eighth grades. A number of districts on California's central coast have used the curriculum guide as a model for their fifth-grade science programs. Neighboring school districts have repeatedly begged for the opportunity to offer the program to their students. Francesca Cava, currently head of NOAA's Sanctuaries and Reserves Division, would like to see programs similar to Los Marineros replicated at all 13 sanctuaries.

Organizing a program like Los Marineros isn't easy. Locating a sponsoring agency or organization—perhaps a museum, school district, government department—is an important first step. Establishing partnerships in the marine, education, and business communities can provide field trip opportunities, naturalists and classroom speakers, and of course, funding. If more communities followed the lead of the Channel Islands National Marine Sanctuary and the Santa Barbara Museum of Natural History, we would see hundreds of more well-informed graduates march forth each year to protect and preserve our oceans.

Sheila Cushman barely survived 15 years of teaching in elementary classrooms in San Diego before escaping to Los Angeles and the world of educational publishing. A couple of years later, in Santa Barbara, she signed on as a curriculum writer for Los Marineros and, shortly thereafter, despite no formal background in science, seized control of the entire program. Over the years, her sea legs have helped her weather many rough channel voyages with scores of berserk children and their slightly dazed teachers.

Steve Sterling

Bon voyage....Students commandeer Condor's *uppermost deck for a voyage to Santa Cruz Island.*

Alternative Support For Protected Areas in an Age of Deficits

Brian O'Neill

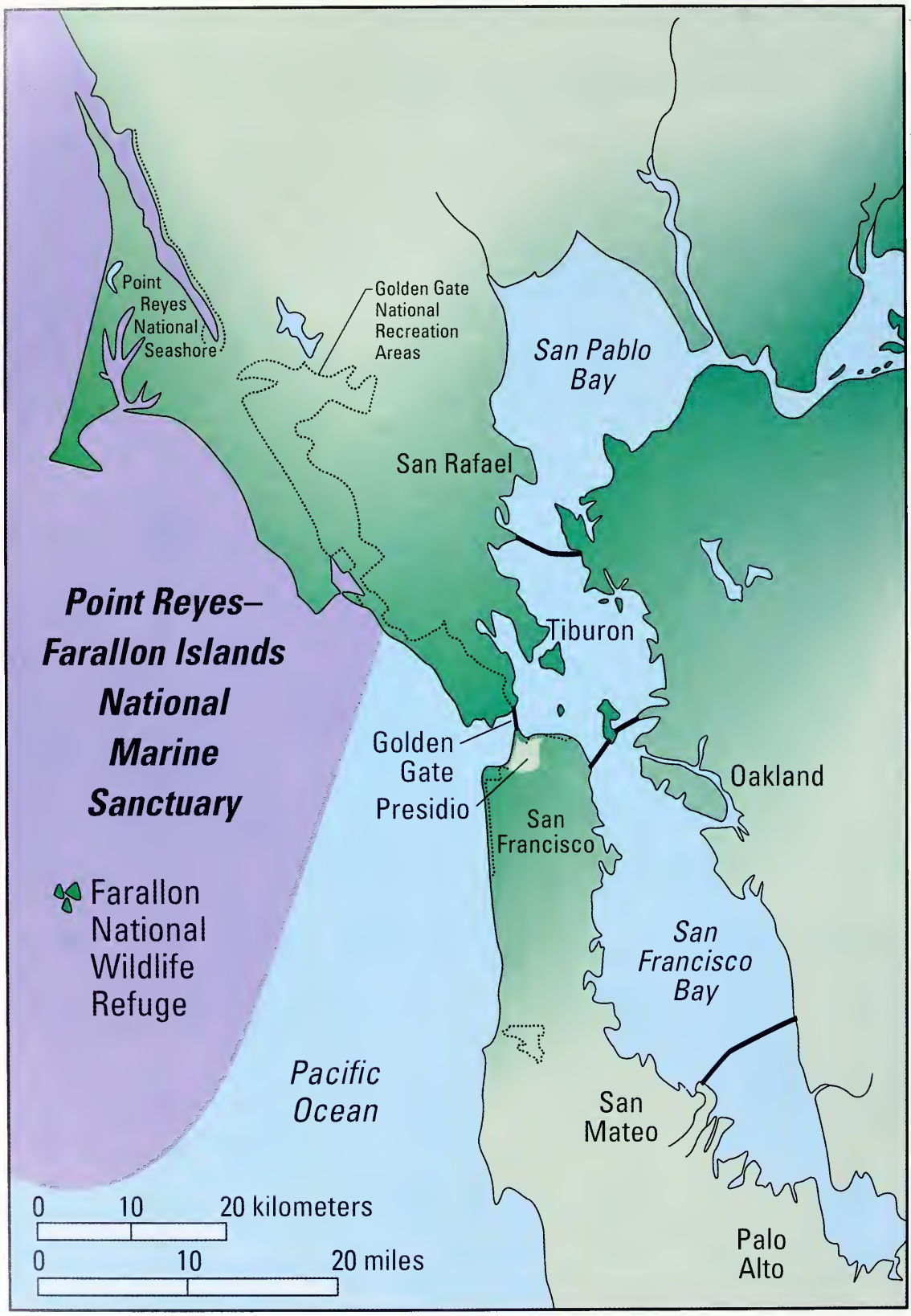
In this Age of Deficits, where governmental budgets continue to tighten, the National Park Service is no different from any other agency in streamlining its organization and focusing on cost-saving measures. Although appropriations have historically covered most of the needs of governmental agencies, every year it gets more and more difficult to balance the budgets. And because funding is limited and there just isn't enough money to cover all the needs, most (if not all) agencies are in some way feeling constrained. Certainly, adding to this problem of limited funding is the backlog of projects and needs that continues to grow and increase in severity. A tremendous portion of that backlog is this country's deteriorating infrastructure—some of the same problems many resource-managing agencies, including the National Park Service, are already facing and attempting to deal with. Certainly, times are tough, but they are not bleak; there are things that can and should be done to appropriately supplement appropriations.

National Park Service

The Golden Gate National Recreation Area relies extensively on philanthropy and fund raising to continue protecting the park's resources and to better serve the public.

Appropriated funds from Congress, state legislatures, counties, and cities do continue to maintain core operating costs of resource-managing public agencies. But alternative means of support such as donations, volunteerism, and revenue retention (admission or user fees partially retained to be used at the site where they are collected), help bridge the gap between appropriated funds and what is needed to ensure top-quality resource protection and visitor services.

The National Park Service is fortunate in that philanthropy, also known as alternative support, has a long history in the National Park System. Over the years, countless numbers of people have wanted to help preserve and protect the national parks—they have donated their



Jayne Doucette/WHOI Graphics

Encompassing some 74,000 acres of land and water, it is easy to see why the Golden Gate National Recreation area is heavily dependent on volunteers for funding and services.

time and money, historic artifacts, art, land, and buildings. For most, their assistance is an expression of their genuine commitment and love for these very special areas that make up the National Park System.

At Golden Gate National Recreation Area (NRA), for example, philanthropic support in the form of donated funds, services, and materials has afforded the park a significant "margin of excellence." Golden Gate NRA includes 74,000 acres of land and water; approximately 45 kilometers of Pacific Ocean, Tomales Bay, and San Francisco Bay coastline lie within the park's boundary. The magnificent Gulf of the Farallones National Marine Sanctuary is immediately offshore of the park. In 1989, Golden Gate NRA was included within the Central California Coastal Biosphere Reserve by the United Nations Educational, Scientific, and Cultural Organization. The park's natural resources include beaches, headlands, grasslands, forests, lakes, streams, estuaries, and marshes. Its cultural resources—lighthouses, military forts, and gun batteries—richly represent hundreds of years of history of one of the world's most spectacular natural harbors.

Allen Fish

Volunteers scan the skies above Golden Gate for hawks. In a six-month period, more than 15,000 raptors will pass overhead. Hawk migration is continually monitored by volunteers.

As with most national parks, there never seems to be enough funding and personnel to manage this resource in the way that park staff feel this special place deserves. Since the 1980s, the National Park Service has moved from serving largely as a passive recipient of private philanthropy to actually facilitating private donations. Taking on a more active role is both an appropriate and necessary response to constrained National Park Service budgets that must focus limited resources on core mission responsibilities. Philanthropy enables us to better accomplish our mission by doing much more than the basics. Without a doubt, it allows us to better serve the public and, most importantly, preserve and protect our resources.

The park has a potent fund-raising ally in the Golden Gate National Park Association, a nonprofit organization created in 1981 to support the park's education and conservation programs. Association members help the public understand park resources and give park users a sense of personal responsibility for the park and its well-being. Association membership now numbers 8,000 strong supporters who provide personal time, services, materials, and dollars. Three of the association's many efforts are:

- *The Golden Gate Raptor Observatory.* On a Marin Headlands hilltop, over 250 volunteers educate visitors and conduct research on birds of prey. More than 15,000 raptors pass overhead during a six-month migration season. Volunteers maintain a count of the birds, band them to track their migration patterns, and explain raptor migration to visitors.
- *The Volunteer-in-Parks Program.* The association is an active partner in this program, helping to recruit and acknowledge volunteers. More

than 4,000 volunteers contribute over 100,000 hours annually, providing critical assistance to all the park's operations. Just some of the ways that they help include planting native plants throughout the park; giving environmental education programs to inner-city children; reconstructing trails in the back country; leading history and nature walks for the general public; working at information desks in visitor centers; assisting in beach cleanups; and aiding in back country horse patrols.

- *The Presidio Conversion.* Golden Gate NRA is currently transforming the Presidio of San Francisco from an army post to a national park. This magnificent historic post is situated at the Golden Gate (the strait between San Francisco Bay and the Pacific Ocean) itself. It comprises 1,480 acres of open space and more than 800 buildings. To assist the park in this unprecedented conversion, the association has raised close to $1 million to supplement federal funds and almost $1 million in donated services from San Francisco Bay Area firms and corporations. These funds and services support technical studies and advice outside the National Park Service's normal range of expertise.

Philanthropic support is only one important form of assistance. Consideration is now being given across the country to instituting fees or in other ways asking the "user" of a protected area to help defray costs. As legislatively mandated, recreation use fees, such as entrance and user fees, are deposited in a special US Treasury account. The funds collected are available for appropriation back to the National Park Service for distribution throughout the park system the following year. It appears likely, however, that beginning in 1994 the National Park Service will retain a portion of the recreation use fees at the individual parks to at least cover the administrative costs of collecting the fees. The National Park Service is also considering ways to generate revenues without putting undue financial burdens on visitors; commercial filming location fees are one example. Experience at state and local park systems indicates that when visitors and other users know their money will be used to help the protected areas, they do not object to paying reasonable fees.

Philanthropy enables us to better accomplish our mission by doing much more than the basics.

How important is revenue retention? The Presidio conversion project shows just how critical it can be. Transforming the Presidio into a national park area is a complicated, expensive, and difficult undertaking that will require innovative management approaches to minimize the amount of taxpayer dollars needed. Revenue retention will be essential in making it a cost-effective site. Rents from tenants and concessions applied back into the management and operations of the Presidio can significantly decrease administrative costs and demands on federal appropriations.

Philanthropic support and revenue retention provide much more than just additional revenue to a protected area; they allow people to invest directly in protecting areas they care about.

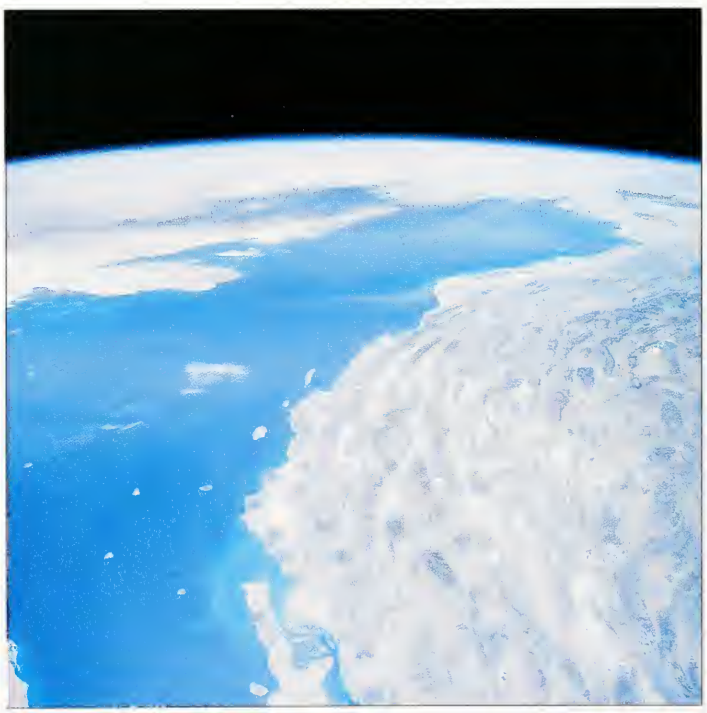
Brian O'Neill is General Superintendent of Golden Gate National Recreation Area in San Francisco. He is widely known within the National Park Service as an expert on developing alternative support opportunities. As Superintendent, he is responsible for managing and protecting the park "for" as well as "from" its 20 million annual visitors—park staff note that his hair has become progressively grayer during his 8 years as Superintendent.

Should the Arabian (Persian) Gulf Become a Marine Sanctuary?

Francesca M. Cava, John H. Robinson, and Sylvia A. Earle

Against the background of a growing awareness of the relationships among human health, a sound economy, and a healthy environment, attention worldwide has been drawn to the devastating assault on the Arabian (Persian) Gulf regional environment—its air, land, water, and biota—by the war waged against Kuwait by Iraq in 1990 and 1991. Among the horrors of the war was the injury caused to the region's natural resources from the torching of Kuwait's oil fields, the fallout of thousands of tons of oil and soot, and the deliberate dumping of an estimated 11 to 12 million barrels of oil into the Gulf from several tankers and loading facilities off the coast of Kuwait. These massive oil spills destroyed whole ecosystems that had developed and prospered over many millennia along the Saudi Arabian coast.

In recent decades, other actions adverse to the environment have taken their toll. Overfishing is thought to have reduced localized populations of shrimp and many commercial fish species. Wetlands have been destroyed by coastal development, and siltation from seafloor disturbances has smothered important coral-reef and seagrass communities.



NASA

Much of the Gulf study area is visible from this Space Shuttle photo, taken over the Strait of Hormuz. At the top are Kuwait and Iraq; at right are the mountains of Iran. The dark smudge at center, below the horizon, is the plume from the 1991 Kuwait oil fires.

Since the final days of the Gulf War, the authors have been extensively involved in several international studies of war-related environmental damage, helping regional governments to cope with the war's consequences. This work included planning and executing a major oceanographic expedition in the Gulf aboard the US National Oceanic and Atmospheric Administration (NOAA) research vessel *Mt. Mitchell*. Based on these experiences and discussions with environmental officials and marine scientists from virtually every nation in the Gulf, we believe that continued assaults on the Gulf's ecosystem can only be stopped by very bold action by the surrounding nations. One such action would be the designation of the Gulf, in its entirety, as a marine sanctuary.

How could this body of water, ravaged by the Gulf War and commonly thought to be among the most polluted in the world, benefit from the protection afforded by marine sanctuary status? Given their dependence on the Gulf for offshore oil development and transportation, how would regional governments greet an environmental initiative of this significance? How could the bordering nations, historically at war or at tenuous peace, reach agreement on the treaties necessary to establish such a joint designation? Despite these difficult questions, marine-sanctuary status for the Gulf may be both warranted and achievable.

Mark Eakin

Light penetrates the Gulf water column from top to bottom, making it one of the most productive bodies of water in the world. A rich variety of organisms thrive in this environment. This butterfly fish is at a coral reef offshore of Karan Island, Saudi Arabia.

The Gulf Ecosystem

Civilizations have prospered in the Gulf region for thousands of years. During the last ice age, approximately 15,000 years ago, the area now occupied by salt water, seagrass meadows, and coral reefs was a fertile river basin. As glaciers melted worldwide, sea level rose, and water entered the area gradually from the Indian Ocean, through what is now the Strait of Hormuz. These waters formed the shallow, highly productive sea that has, over the ages, been a significant factor in shaping the direction of the region's human development.

For at least 5,000 years, Gulf region terrestrial vegetation has been sparse, but the sea, characterized by extensive seagrass meadows, planktonic and benthic algae, and intricate shoreline marshes, has been a highly productive source of food, oxygen, and other benefits of the sort typically derived from productive terrestrial ecosystems, such as rain forests. Diverse assemblages of invertebrates, fish, birds, and other organisms inhabit the Gulf, including some that occur nowhere else in the world.

With an average depth of 35 meters and generally clear waters, light penetrates the Gulf water column from top to bottom, providing the basic setting for one of the world's most productive bodies of water. Photosynthesis here is not limited to plankton; there is also production in abundant seagrass meadows and stands of benthic macroalgae, as well

NOAA

The Mt. Mitchell *expedition combined the efforts of hundreds of individuals (including 142 scientists from 15 nations) in the Middle East, Europe, and the US to investigate the environmental aftermath of the Gulf War. The 100-day expedition ended in July 1992. The 70-meter long* Mt. Mitchell *was built from 1966 to 1968, and carries 54 crew and 22 scientists.*

as numerous microscopic photosynthetic organisms living in the mud and sand of intertidal flats, in and on submerged porous limestone rock, and within the tissues of living coral and certain other invertebrates.

Marshes border the western shore, along with small but important patches of mangroves that are low in species diversity but high in productivity. Throughout the ecosystem, the sun's energy is translated into plant tissue and food for historically abundant populations of resident fish, sea mammals, turtles, sea snakes, birds, and invertebrates. The rich communities of marine organisms also attract millions of birds that stop over to feed in shallow embayments, intertidal flats, and marshes during spring and fall migrations, thus linking the Gulf to distant ecosystems in Europe, Asia, and Africa.

Wide-ranging temperature and salinity limit the diversity of life, as do storms and high spring tides. Species that have prospered in the area since the end of the last ice age are those capable of adapting to the rigors of temperatures that may span 20°C in a season and salinity that is significantly higher than the world average.

Species diversity is not the only measure of ecological value, however. Samples taken of superficially barren mudflats along the Saudi Arabian coast prior to the 1991 oil spill proved to have several hundred thousand small invertebrates in six or more phyla per square meter sampled. Such abundance is reflected in productive commercial invertebrate fisheries, including pearl oysters, crabs, squids, 10 shrimp species, and at least two kinds of lobsters.

Coral reefs occur where appropriate depth, substrate, and other required conditions allow, along the shoreline, as well as fringing offshore islands in scattered locations where submerged rocks or other hard surfaces provide footholds for recruitment. Thus far, 57 coral reef species have been reported.

The chemistry, physical environment, and geologic history of the area have shaped a unique and resilient ecosystem that deserves special attention. Designation of the Gulf as a marine sanctuary may stimulate heightened appreciation of that system's natural assets and help stem the human assault on this most important body of water.

Defining a Marine Sanctuary

Many nations have established marine sanctuaries, marine protected areas, marine ecological reserves, etc., to recognize and enhance the environmental and economic value of their coastal waters. Some nations have defined the terms in a very restrictive sense, setting aside areas in which all exploitive uses (fishing, oil and gas development, even visitation in some instances) are prohibited. In other nations, there are few restrictions on activities determined to be compatible with both the national economy and a healthy ecosystem. There are also instances where graduated restrictions apply within a sanctuary, consistent with the vulnerability and uniqueness of a particular area.

William J. Kenworthy

Scientists are deployed in one of several small boats that were used extensively for nearshore studies during the Mt. Mitchell *expedition. During Leg II of the cruise,* Mt. Mitchell *remained at anchor offshore, serving as a remote logistics base and field laboratory.*

While US marine sanctuaries focus on resource protection, flexible approaches are employed from region to region in protection and management. With passage of the Marine Sanctuaries Act in 1972, Congress defined US marine sanctuaries as "areas of special national significance due to their resources or human use values with reference to conservation, recreation, ecological, historical, educational or aesthetic qualities." This definition seems relatively straightforward, but as the US program has developed over the last 20 years, each marine sanctuary has been more sharply, and individually, defined by the nature of its resources, the specific uses of the area, the impact of these uses, and the concerns of local residents.

The Flower Gardens National Marine Sanctuary, for example, is a relatively small area around two unique coral-reef pinnacles in the Gulf of Mexico. The site, about 200 kilometers off the Texas coast, is not heavily visited—its closest human neighbors are located on several nearby oil and gas platforms. At this sanctuary the US recognizes that marine life can coexist with responsible oil and gas development. The central management focus has been to monitor the effects of oil and gas development and marine transportation on nearby coral reef health, with special concern for possible effects on coral spawning. The US government has worked closely with industry, user groups, and regulatory agencies most concerned with preserving these reefs to solicit active partnerships in resource management and protection.

The Florida Keys National Marine Sanctuary, designated in 1990, is quite different in terms of both the magnitude and complexity of resource protection issues. It is much larger, over 7,700 square kilometers, and one of the most heavily used and visited coastal areas of the world. And the number of visitors is increasing.

In Florida, the sanctuary program has had to develop an innovative planning and management strategy to cope with multi-resource, multi-

use issues—more than two and a half years after designation, the process is still not complete and it is evident that resource protection within the sanctuary's boundaries may not be enough. Water quality of nearby areas is a growing concern, since pollution obviously does not recognize the sanctuary boundary. The US is now beginning to determine how to address threats to the sanctuary from areas outside its boundaries. Similarly, in Australia, efforts to protect the Great Barrier Reef ecosystem have led to consideration—and in some cases management—of adjacent land and water.

Marine sanctuary experience in the US, Australia, and elsewhere has heightened awareness of the need for an integrated ecosystem management approach if the process is to be successful (see the articles beginning on pages 6 and 27). This approach clearly depends on the best possible understanding of threats to the marine environment, the status of the health of the resources, and identification of specific actions that can be taken. It provides the link between land-based actions and the marine environment and puts the health of marine resources on par with other priorities in planning and development discussions. It has been a key method for including the public in the decision-making process and providing educational working sessions on how development actions or management decisions affect the economic and environmental well-being of the community. Lastly, and perhaps most importantly, a marine sanctuary provides the forum for a public/private sector alliance. No one organization has the expertise or authority to implement the full range of management actions required for resource management and protection.

Marshes of Dawhat al Musallimiyah, just north of Abu Ali Island, Saudi Arabia, were heavily oiled as a result of the Gulf War oil spill. Abu Ali provided extensive natural containment of the spill (see page 61).

A Gulf Marine Sanctuary

Sylvia Earle

The degradation and corresponding economic and aesthetic losses in the Gulf have not been unnoticed or unappreciated by those living on its shores. Rather, several measures have been taken over the years to address the region's declining marine environment. All nations bordering the Gulf are members of the Regional Organization for the Protection of the Marine Environment (ROPME). This organization has been instrumental in many regional environmental activities and was the primary regional sponsor of the *Mt. Mitchell* expedition.

In addition to cooperative measures, there have been national initiatives to understand and develop ways to protect the marine environment. For example, in Saudi Arabia, an assessment of the marine ecosystem began in the 1970s, and during the 1980s the Meteorology and Environmental Protection Administration (MEPA) reviewed Saudi Arabia's coastal areas as part of a national management plan aimed at balancing development with conservation. In a 1987 report (MEPA

Report No. 7), 11 environmentally sensitive areas were listed for consideration as part of a coastal and marine protectorate system.

In 1990, the National Commission on Wildlife Conservation and Development of the Kingdom of Saudi Arabia proposed a system of protected areas including the waters surrounding several offshore coral islands within Tarut Bay. The proposal was based on management strategies to assure sustainable use of the area's living resources, to increase understanding of the diversity of the marine environment generally, and to address problems of overfishing, debris, and oil and sewage pollution.

However, in view of the massive Gulf War damage and evidence of continuing decline in some indicators of Gulf ecosystem health, these strategies may no longer be enough. In extreme cases of widespread ecosystem injury, there are limitations to the philosophy of protecting ecological niches. Experiences of the US and other nations indicate that the boundaries of protected areas are often too limited to provide an effective barrier to threats from the outside. Such is certainly the case in the Gulf, an almost totally enclosed ecosystem subject to massive internal threat.

Declaration of the Gulf, in its entirety, as a marine sanctuary would provide impetus for Gulf-wide recognition of threats to this most important body of water. The first step should be a formal agreement by all bordering nations that conditions in the Gulf, at the minimum, *will not be allowed to worsen further* while the full implications of sanctuary status are explored. As part of a general declaration to this effect, an organization should be empowered to identify and suggest solutions to the region's most pressing environmental problems. The agreement, and the explicit designation of the Gulf as a marine sanctuary, will signal to the world the region's commitment to action, and engender support from the world's marine-science community to help regional experts find solutions to the Gulf's environmental problems—solutions consistent with, and supportive of, the recognized economic uses of the Gulf's seabed and waters.

The Gulf is a microcosm where global issues can be seen with special clarity.

Such action would profoundly benefit the Gulf countries, and might stimulate similar cooperative efforts elsewhere. Environmental concerns evident in the Gulf echo problems found worldwide, and many nations with diverse interests and views must find common ground for effective protection of environmental assets shared by all.

The Gulf is, in fact, a microcosm where global issues can be seen with special clarity. The terrifying swiftness of the 1991 damage focused world attention on the vulnerability of natural systems to human misbehavior. The before-and-after consequences of the war are immediately obvious, and the memory of the benefits of pre-war natural assets are still fresh in the minds of those now making decisions concerning the future of the region. People of several nations, diverse cultures and varying interests in Gulf use must cooperate and grasp the principle underlying the marine sanctuary concept—that everyone will win if all take care, and all will lose if even one misbehaves. On a grand scale, this is a key—perhaps the key—to achieving global environmental health.

Francesca M. Cava was named Chief of the Sanctuaries and Reserves Division for the Office of Ocean and Coastal Resource Management at the National Oceanic and Atmospheric Administration (NOAA) in October 1992. A captain in the NOAA Corps, the seventh US uniformed force, she has served aboard several NOAA ships, as acting director of NOAA's Program, Policy, and Evaluation Office within the Office of Marine Pollution Assessment, as manager of the Channel Islands National Marine Sanctuary, and as Special Assistant for the Under Secretary for Oceans and Atmosphere, Department of Commerce. Cava was NOAA's agency lead for response to the Gulf War. She holds a BS from the University of Alaska and an MPA from Harvard University.

Courtesy of Sylvia Earle

During Leg V of the Mt. Mitchell *expedition, Francesca Cava (foreground) and Sylvia Earle press plants as part of a biota survey of the Gulf region.*

John H. Robinson oversees NOAA scientific support to the Gulf states in dealing with the atmospheric and marine consequences of the oil fires and spills that occurred during the Gulf War. He has managed NOAA's spill-response and hazardous waste site programs, and was responsible for providing scientific support to the US Coast Guard during oil and chemical spills affecting US coastal waters. For the last 14 years, he has served as scientific coordinator for many major spills, including Exxon Valdez, Ixtoc I, *and* Argo Merchant. *Robinson originated the Computer-Aided Management of Emergency Operations (CAMEO) program, an automated information system used in responding to hazardous materials spills. He holds a degree in Industrial Engineering from Texas Tech University.*

Sylvia A. Earle is founder and Director of Deep Ocean Engineering, Inc. Her present focus is on marine sanctuaries and exploration of the aftermath of the Gulf War. She served as Chief Scientist and then as advisor to the National Oceanic and Atmospheric Administration, from 1990 to 1993. Well known for her underwater research and exploration, she has spent 6,000 hours happily submerged. She is a marine scientist, with a BS from Florida State University and MS and PhD degrees from Duke University. As a worldwide ocean explorer, she has written over 80 publications.

The Environmental Response to the Gulf War

The oil fires and oil spills resulting from the Gulf War are the worst-ever acts of eco-terrorism. Of the two, the implication of the oil fires were more far reaching and difficult to quantify, as over 700 oil wells were damaged or set afire. At the peak of the fires it was estimated that approximately 4 t o 5 million barrels of crude oil per day (1 barrel = 42 US gallons), plus an unknown quantity of natural gas, were being burned.

In addition to the pollution from the oil fires, between January 19 and 28, 1991, an estimated 11 to 12 million barrels of oil were released into the Gulf from several tankers and damaged loading facilities off the coast of Kuwait.

In retrospect, the international response to these unprecedented events was both bold and dramatic, effectively supplementing regional efforts to minimize adverse effects on public health and environment. With the exception of nuclear accidents, there is no formal, recognized mechanism for responding to potentially catastrophic environmental events; to have two such events during a war made it even more difficult to organize and implement any kind of response action. The most pressing problem initially was to assure the safety of the local citizenry. Successful understanding and response to the human and environmental health issues can be largely attributed to the organizational ability and infrastructure provided by United Nations agencies and the cooperative spirit of member nations who actually carried out the response.

The World Health Organization, the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission, the International Maritime Organization (IMO), and the United Nations Environment Programme were prominent in providing the international framework for discussion, planning, and implementation of the needed actions, allowing inclusion of the best expertise worldwide. The programs could not have been implemented, however, without the initiative and commitment of such regional organizations as the Regional Organization for the Protection of the Marine Environment (ROPME), headquartered in Kuwait, and the intellectual drive and technological expertise of the academic community, the private sector, and several key governmental agencies.

Once activated in response to the Kuwait oil fires, the United Nations system facilitated rapid and urgently needed international communication. It assisted in early data-collection efforts for a quick, first-level evaluation of the problem's scope. It also produced the most extensive set of atmospheric data ever taken in the region, and possibly the most comprehensive data set on plume dynamics, chemistry, and optical properties ever compiled. The most important conclusions of the May 1992 WMO expert meeting on the oil fires and their impact are these:

- Kuwait oil-fire smoke significantly affected air quality and Gulf region weather. However, scientific studies indicated that the fires were unlikely to have affected the global weather or climate.
- Approximately 9,000 tons of sulfur dioxide were emitted per day, equivalent to about 57 percent of daily US electric utility emission. Carbon dioxide emissions were about 2 percent of the annual global amount.
- The effects of meteorological and geographic conditions in the area were to confine most of the pollution to an elevated plume, with little mixing down to ground level.

Unfortunately, some shortcomings in the United Nation's response to the oil fires became obvious in follow-up evaluation meetings. To begin with, the international response was ad hoc. It lacked the critical management and financial support necessary to define and fully implement a focused response strategy and to assure that the status and findings of the research efforts were communicated to the press, the public, and other concerned scientists around the world who could have provided off-site assistance. However, this effort must certainly be judged successful overall. The scientific community and the countries involved learned a great deal about available international capabilities, and were able to apply advanced technology to gather data not only for this event but also to further scientific knowledge on similar atmospheric problems for the future.

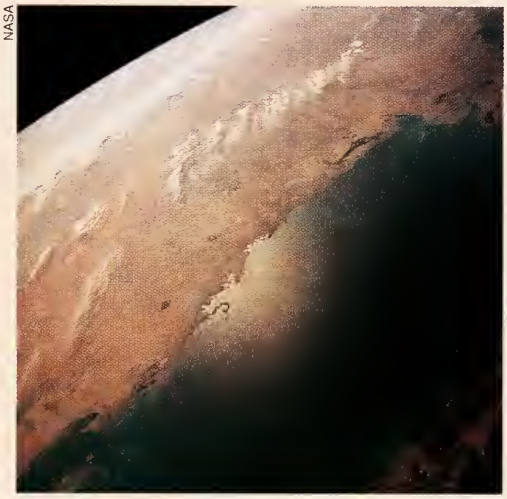
A Synopsis

The international response to the oil spill was also substantial and proved to be equally successful. The deliberate release of oil into the Gulf resulted in the world's biggest oil spill. Weather and currents played a prominent role in lessening the spill's impact, keeping the slick predominantly off the Kuwait shore. Evaporation also played a key role in impact containment. Approximately 5.5 million barrels of the spilled oil were estimated to have evaporated during the first five days of the spill.

Saudi Arabian efforts recovered another 1.5 million barrels of floating oil, surpassing any other oil-recovery effort to date. Some 4 to 5 million barrels are believed to have dispersed in shallow water or been entrained in intertidal sediments.

Immediate needs following the oil spill were for spill-trajectory forecasts, oil containment and removal, and cleanup, and marine-bird and mammal rehabilitation. Because the region's water supply depends on desalination, there was considerable concern about where the oil would come ashore. Water intakes along the northeastern Saudi coast provide not only drinking water, but serve industrial purposes as well, and their protection is important to the nation's economy. Without these industrial plants, human health and life in the region were at considerable risk. Luckily, earlier bilateral efforts between the US and regional scientists and agencies had resulted in significant training and technology transfer, especially in oil-trajectory modeling.

NASA



Space Shuttle Atlantis *obtained many views of the* Mt. Mitchell *study area, including this aerial image of Iraq and Kuwait (top right), Saudi Arabia (top center), and Iran (lower right). The small hook-shaped island near the center of the photo is Abu Ali.*

Oil-spill response was spearheaded by the Saudi Meteorology and Environmental Protection Agency (MEPA) and Saudi ARAMCO, with technical assistance from representatives seconded to MEPA from the IMO, the International Council for Bird Preservation, IUCN, and a US Interagency Oil-Spill Response Team, composed of the US Coast Guard, the National Oceanic and Atmospheric Administration (NOAA), the Environmental Protection Agency, and the Fish and Wildlife Service.

However, nature provided the most important spill containment. Abu Ali, a small island connected by a causeway to the mainland, acted as a natural boom, blocking southward spill progression. As a result, the spill backed up into the farthest recesses of embayments north of Abu Ali, heavily affecting the local lagoons and bays. Abu Island effectively concentrated the spill along a 483-kilometer section of the Saudi coastline, and most of the rest of the Gulf was unaffected. However, the intertidal zone of northern Saudi Arabia was devastated; virtually all life in the sheltered areas of the affected coast was destroyed, and there is little evidence of recovery two years later.

It is important to note that only a small fraction of the oil reached the more productive regions of the Gulf to the south of Jubayl. Fortunately, there has also been little evidence of offshore effects on fisheries, coral reefs, seagrasses, or benthic productivity in the region closest to the devastated shoreline.

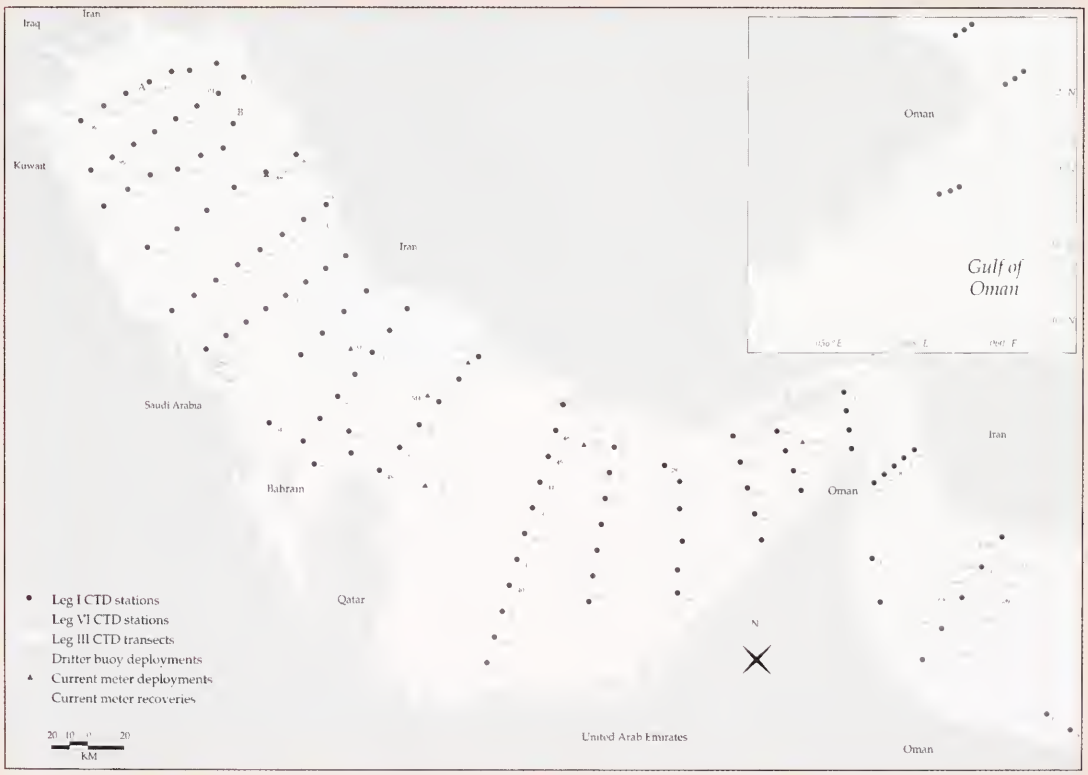
A Synopsis, continued

The urgency of evaluating the environmental impact of these oil spills prompted one of the most ambitious oceanographic research projects ever launched in the Gulf—the 100-day *Mt. Mitchell* expedition, involving over 140 scientists from 15 countries. Questions raised during the expedition concerned nature's ability to deal with the effects of such a big spill, the relative environmental benefit of human intervention, and the best approaches to improving state-of-the-art cleanup technology. Research investigations included shoreline and near-shore studies along the most heavily impacted Saudi coastline, regional circulation and sedimentary measures, studies of the region's coral reefs, and seafood quality investigations.

Mt. Mitchell sampling was more extensive than that of any previous expedition in the region. *Mt. Mitchell* results were reported at a symposium held in Kuwait earlier this year and are in the process of being published. For further information, contact NOAA's Office of the Chief Scientist, 14th and Constitution Avenue NW, Room 1617M6, Washington, DC 20230.

—Francesca Cava

NOAA



The Mt. Mitchell *expedition was a huge undertaking, resulting in vast amounts of new scientific data on currents, salinity, depth, temperature, and seawater-light transmittance. The expedition was organized around six sequential legs, each of which had a major scientific focus. Legs I, III, and VI centered on physical oceanography, with the intent of obtaining enough information to model future oil spills in the area. Leg II was the longest leg, and focused on a multidisciplinary study of the biological, chemical, and physical impacts of the 1991 spill along the shoreline. Legs IV and V investigated the effects of oil on fisheries resources, their supporting ecosystem, and coral reefs. This map shows the extensive sampling performed during the entire expedition.*

Marine Reserves

They Enhance Fisheries, Reduce Conflicts, and Protect Resources

James A. Bohnsack

In wildness is the preservation of the world.

—Henry David Thoreau, 1862

It has taken almost a century for Thoreau's words to be applied to the oceans. In that time, the world population has quadrupled, and more people are migrating to the coast with the hope of utilizing the marine environment as a source of food and employment, and also for recreation, tourism, education, and research. Unfortunately, increased use brings user conflicts, and many fisheries have been depleted or have collapsed. To most people the ocean seems boundless, its resources inexhaustible, and its ability to tolerate human activities unlimited. We now know that these perceptions are false: Ocean resources are finite, and human activities can be devastating.

For the first time in human history, we have the ability to catch fish faster than they are produced. Our catch ability must be tempered with new ways of preventing overfishing and resource depletion. Marine fishery reserves, areas protected from all fishing and other harvesting activities, provide one approach. Since the first modern reserves were established in the mid-1970s, they have been increasingly used for fisheries management and resource protection.

For the first time in human history, we have the ability to catch fish faster than they are produced.

Species Protection is a Fundamental Goal

The primary purpose of marine reserves is to ensure that fisheries continue by protecting a portion of the spawning stock from exploitation. In a refuge, abundance, average size, and total egg production can be increased over what it would be if the area were fished. Eggs and larvae produced in reserves are then spread by oceanic currents to both exploited and protected areas.

The concept of marine reserves is simple: If protected from human interference, nature will take care of itself. A large body of scientific literature attests that harvested stocks will recover if fishing stops. The

reserve concept is not really new. Until recently, most reef fisheries were probably partly maintained by natural refuges: areas too deep, too remote, or too difficult to locate easily. With improved fishing methods and more people fishing, the effectiveness of natural refuges diminishes. Marine reserves are best suited to protecting species with the restricted geographical movements typical of most reef organisms. Reefs are common in coastal areas, and include some of the world's most taxonomically diverse, biologically complex, and productive ecosystems. "Reefs" include not only coral reefs, but also rock outcrops, artificial reefs, and other hard-bottom areas. Reef habitats are geographically well defined, long-lasting, and restricted to relatively small areas of ocean bottom. Their importance, however, far exceeds the percentage of bottom covered because of their high biological productivity. Tropical reefs support economically important species such as snapper, grouper, spiny lobster, coral, and conch; those found at temperate reefs include rockfish, kelp, lobster, and abalone.

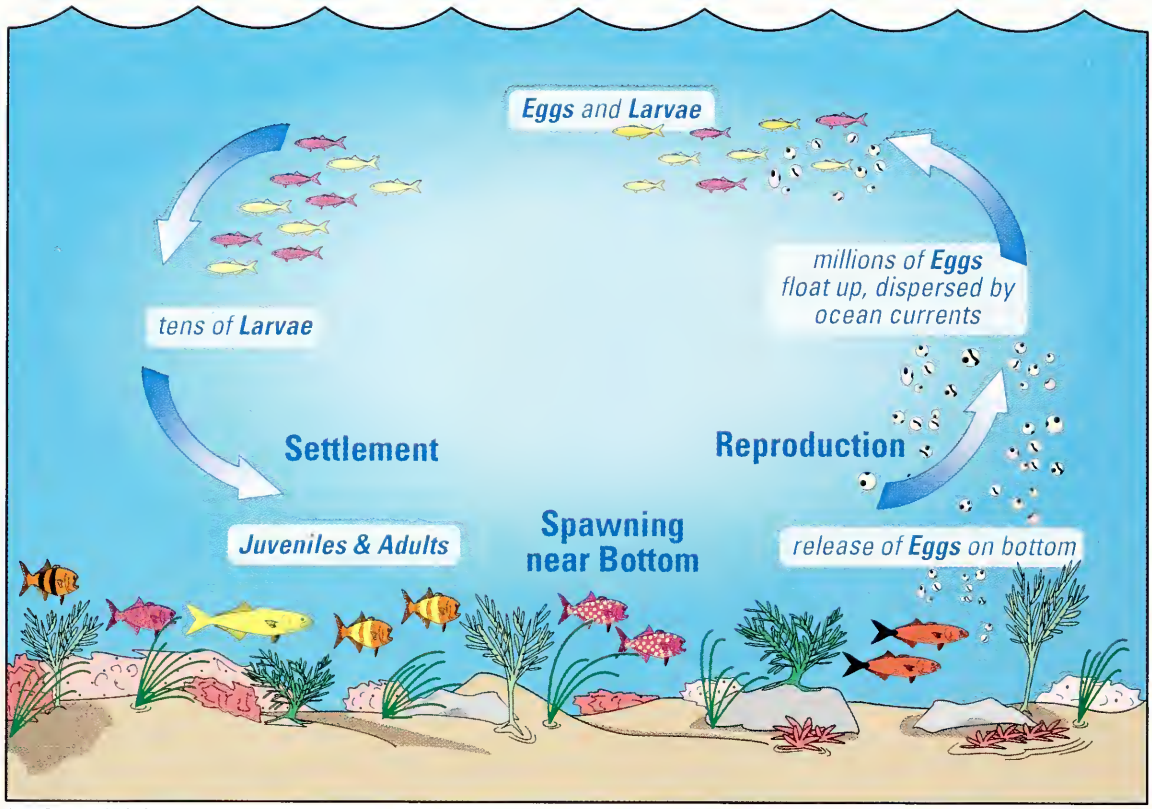
Life History on a Reef

The ecology and life history of reef organisms make them vulnerable to fishing. Most species have a two-stage life cycle: a pelagic (open water) egg or larval stage, and a demersal (bottom) juvenile and adult stage. Eggs and larvae are passively transported and dispersed as plankton by ocean currents. Depending on the species and location, eggs and larvae can drift from about a week to several months before larvae settle (recruit) to bottom habitats. Once settled, juveniles and adults live a comparatively sedentary demersal existence. Most settled individuals are considered "sedentary" because they tend to associate with a particular reef or a specific area for most of their adult lives.

Planktonic survival is generally very poor. Abundance at settlement can vary by orders of magnitude from year to year due to uncertainties in currents, weather, food availability, and predation. This annual variability results in good or poor recruitment years, reflected by the abundances of various year classes for individual species. In a good recruitment year, large numbers of young fishes survive and are added to the population. In a poor recruitment year, few young are added to the population. Once settled, reef organisms have greatly increased chances of survival, and typically live for many years, often decades. Some corals live for centuries.

The jewfish, Epinephelus itajara, *is representative of reef organisms attractive to fishermen because of their large size and ease of capture. Its life history makes it vulnerable to overfishing.*

Juveniles allocate most of their surplus food energy to growth; reproduction is often delayed for several years. Adults tend to grow slowly because their energy is largely allocated to reproduction. Fecundity (total egg production) usually increases exponentially with body size. For example, one 61-centimeter red snapper can produce as many eggs as 212



Jayne Doucette/WHOI Graphics

The typical life cycle of reef organisms includes a pelagic dispersal phase as eggs and larvae, and a sedentary demersal phase as juveniles and adults.

smaller 42-centimeter females. The result of this size relationship is that a few older individuals may be extremely important to total egg production and population replenishment.

From an ecological perspective, reef-fish life-history characteristics are adaptations for extreme recruitment variability. Presumably, reef fishes live long lives and breed over many years to insure that some offspring will survive to replace them in the next generation. Adults of exploited reef species are typically characterized by slow growth, low adult natural mortality, long life, and large body size. In the natural environment, large body size is often an advantage because it helps in capturing prey and escaping predation. It also allows for greater mobility and provides a competitive advantage in protecting territory and securing mates. Unfortunately, fisheries tend to selectively target and remove larger individuals because they provide more excitement, food, and revenue than smaller fish.

Vulnerability to Fishing

In the broad perspective, fishing includes not only capturing fish but also harvesting other organisms, including corals, crustaceans, sponges, and sea turtles. Although fishing is an important and widely practiced activity, excessive fishing can deplete the populations (stocks) of certain species, disrupt the marine ecosystem, and damage a coastal area's overall economy. Many fisheries around the world have been depleted or have collapsed entirely, such as the reef fisheries in Bermuda and

Puerto Rico. Initial symptoms of overexploitation usually include a decline in average fish size and the disappearance of larger species.

Recruitment overfishing occurs when fishing disrupts the replenishment process. Recruitment failure occurs because too few eggs are produced to replace the adult population. For species such as grouper (family Serranidae), which change their sex by switching from female to male with age, size-selective fishing can create a shortage of males to fertilize eggs. Even if fishing levels are acceptable for average conditions, a population could collapse after several years of unusually poor recruitment due to natural environmental events. This would happen because not enough adults survive during poor recruitment years to adequately resupply the population when favorable recruitment conditions reoccur.

Reef fishes are also vulnerable to overfishing because they can be predictably located in time and space. Some species form large spawning aggregations at specific places and times, making them easily exploited. Aggressive behavior, curiosity, and inexperience with humans also make many species vulnerable to fishing.

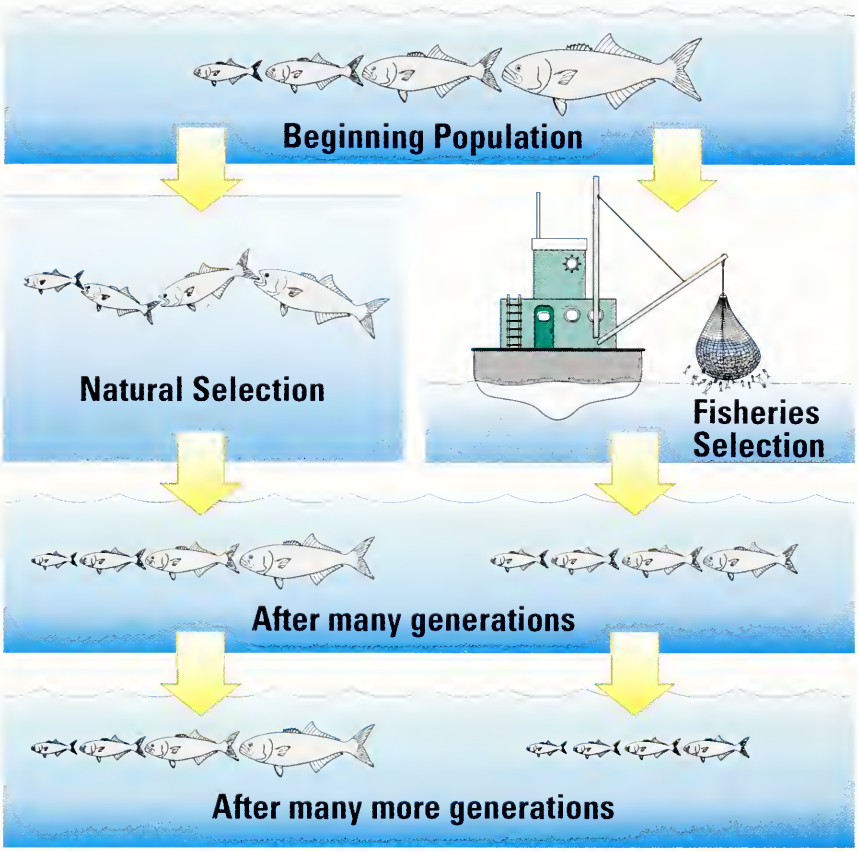
Fishing can also reduce genetic diversity within a species, especially when a stock size is greatly reduced from natural levels. Fishing depends on harvesting a wild stock. Unlike animal husbandry, which protects animals with desirable characteristics from slaughter in order to breed those characteristics into future generations, fishing operates by removing the most desirable individuals (from a fisherman's perspective) from the breeding population. Excessive mortality can alter genetics by selecting for individuals that mature early and have a shorter life span, smaller adult size, and wary behavior. Although the species continues to exist, it may be less desirable from a human perspective and differ greatly from its original condition. This effect has been demonstrated for chinook salmon (*Conchorhynchus gorbuscha*), whose average size has declined by more than 50 percent and whose average age of maturity has declined by 2 years, all within a 60-year period.

The average size of chinook salmon has declined more than 50 percent in 60 years.

Sustained fishing can also lead to the loss of diversity between species by selectively removing vulnerable species. Loss of certain species could cause unforeseen disruptions or permanent alterations to the ecosystem. Many species targeted by fishing, for example, are top predators that can be critically important in regulating certain marine ecosystems. The most well-known example is how sea-otter (*Enhydra lutris*) hunting on the US Pacific coast resulted in loss of kelp beds. Sea otters controlled sea urchin populations. When otters were removed, sea urchin populations increased, and their grazing prevented new kelp from recruiting to rocky reefs.

Resource Conflicts

Fishing is often a source of conflict between competing fishing interests. Commercial and recreational fishermen are often in conflict, partly because of different values and objectives: Commercial fishermen usually want to maximize revenue for their effort, while recreational fishermen are more interested in having fun, catching their dinner, hooking a large fish, or just catching anything. Conflicts also occur because of interactions between different fisheries. Spearfishing and hook-and-line fishing are usually considered incompatible because



Jayne Doucette WHOI Graphics

Fishing can have deleterious effects on fish populations, as it operates by removing the most desirable individuals from the breeding population. High levels of fishing can alter the population's genetics, by selecting for individuals that mature earlier and have a shorter life span and smaller adult size.

spearfishing causes fish in the area to "quit biting." Shrimp trawls can destroy stone crab and lobster traps, and may impact other fisheries by incidentally killing juvenile fishes, which are discarded as bycatch. Finally, some fishing methods, such as bottom trawling, can damage or destroy habitats that are important for some species.

A fully exploited fishery can be incompatible with other goals such as protecting biodiversity or maintaining undisturbed natural marine areas for other purposes. For example, activities that involve education, diving, photography, tourism, and scientific research often depend on areas with abundant, large, and approachable organisms. Scientists, for example, frequently need undisturbed areas to do experiments. In the past this was not much of a problem, because remote areas relatively free from fishing activity were available. However, as fisheries have expanded, undisturbed areas have become scarce, creating problems for some kinds of research. In fact, many scientists now consciously avoid studies that involve exploited species. Even though fishery scientists study fisheries, questions concerning basic biology, behavior, and ecology of economically important species may not be studied. As one of my colleagues noted, "What graduate student or scientist wants to spend years working on a problem just to have someone eat the experiment?"

One traditional way of dealing with conflicts is through "multiple resource use" (See *Oceanus*, Spring 1988). Multiple use has often been interpreted to mean allowing many, if not all, different activities in an area. Often this approach has proved unsatisfactory, especially with

increased resource use, because some uses are directly incompatible. For example, trolling in an area used for snorkeling can cause injuries. Also, some activities have inherent advantages over others. Over time, activities that can survive on low-quality resources tend to dominate. For example, a tourist industry based on divers being able to see large and abundant fish is unlikely to persist in a fished area. The concept of multiple use increasingly incorporates zoning as a way to separate conflicting activities.

Traditional Management Actions and Benefits of Marine Reserves

Many of the traditional actions used in fishery management are ineffective or impractical to use with reef fisheries, especially when fishing levels are high. For example, *closed seasons* and *temporarily closed areas* may not be effective, because fish can be caught in other areas and at other times. *Quotas* and *bag limits* can be expensive to monitor and difficult to enforce; they also require timely, accurate data and precise knowledge about the various species in the fishery. The number of reef species involved and the number of different users, gear types, and access ports make collecting adequate data for compiling statistics about individual species either difficult or impractical. Bag limits and *size limits* can be ineffective due to unintentional release mortality: Fish often die when caught in deep water because of injuries associated with depth changes, and, even when handled carefully, a certain percentage die because of the way they are hooked. When fishing levels are high, incidental mortality may be sufficient to dissipate any benefits of having a size limit. Rare or protected species continue to be caught incidentally and exposed to sources of bycatch mortality. *Limited entry* and requirements for *selective fishing gear*, such as artificial baits and large net-mesh and hook sizes, may reduce fishing mortality but still tend to select against larger individuals and certain species. *Hatchery programs* and *artificial reefs*, although popular, have not proved to be effective for increasing marine species' abundance. Closing and reopening areas (*pulse fishing*) is usually not practical because areas must be closed for many years to be effective, and the benefits of closure can be quickly lost when fishing resumes.

Marine fishery reserves offer several advantages over traditional approaches to fishery management.

Marine fishery reserves offer several advantages over traditional approaches to fishery management. They are attractive from a management perspective because they can simultaneously treat conflicting objectives. For example, fisheries can continue outside the reserves while nonfishing activities can be allowed within the reserves. Protecting biodiversity and providing areas with a natural balance of organisms would otherwise be impossible with active fisheries. Marine reserves have both fishery and nonfishery benefits.

Fishery Benefits

An important fishery management objective is to protect some fishes from harvest to ensure an adequate quantity and genetic quality of offspring. Marine reserves are designed to achieve this objective based on the ecology of typical reef organisms. The dispersal of eggs and larvae

from reserves to surrounding areas can maintain, and perhaps improve, fisheries yield, especially if total egg production is higher than it would be if all areas were fished. With fishery reserves, data collection needs are reduced and management can operate without complete information and understanding about different species and their interactions.

There are additional direct benefits to fisheries. Because fishes are never caught or handled, incidental bycatch mortality is eliminated. Also, important species that have become rare or that are particularly vulnerable to fishing will have an opportunity to rebuild their populations in the reserves. Fisheries could also benefit from fishes that occasionally wander out of the reserves into surrounding areas. This process would especially benefit those seeking large trophy fish, which are most likely to survive in protected areas.

One of the most important functions of reserves is to provide insurance against stock collapse. All fishery management has some degree of uncertainty and risk; it can fail because of inadequate scientific models, errors in the data, inadequate compliance, or ineffective management actions. Chance events, such as environmental uncertainties in recruitment, could also lead to stock collapse even if fishery management were adequate for average conditions. If a stock collapses for whatever reason, fishery reserves can act as a reservoir for rebuilding a stock at a faster rate than would otherwise be possible.

Reserves can also provide indirect benefits to fisheries. They facilitate scientific studies of behavior, social organization, and dynamics of harvested species that are useful in fishery management models. Natural mortality, a critical parameter for most fishery management models, is virtually impossible to measure in an active fishery, but can be measured in reserves.

One benefit to fishermen is that regulations, such as quotas and size and bag limits, can be less restrictive. Reserves are also equitable in that they apply to all fishery participants. Enforcement is often simplified, because it is easier to determine if someone is fishing or not, than to determine if they are using legal methods or have a legal catch.

One important function of fishery reserves is to insure against stock collapse.

Nonfishery Benefits

Marine reserves offer many benefits not related to fishing. They can protect biodiversity and provide areas in a natural balance free from direct human disturbance. They may protect against ecosystem disruption due to excessive fish removal and can reduce user conflicts by separating incompatible activities, including those involving fishing. Reserves can be used to improve public awareness and understanding of natural systems and human impacts on those systems.

Reserves may be especially important for monitoring long-term environmental changes. The only effective way to have an understanding of the impacts of human activities on natural systems is to have reference areas with minimum human impact. Reference areas not only help resource managers to detect changes, but they also help distinguish which changes are natural and which are caused by human actions.

Marine reserves can enhance some activities and allow new uses not possible in harvested areas. Underwater photographers, naturalists, ecotourists, and scientists can benefit from reserves. By having natural,

undisturbed areas, divers and photographers are more likely to encounter abundant, tame, and large fish. Naturalists will be better able to observe natural behavior instead of having fish flee in the presence of a diver. Certain kinds of scientific experiments, ecotourism, and education are only possible in natural areas protected from fishing.

Problems with Marine Reserves

Marine fishery reserves alone will not solve all fishery problems. They are not likely to provide much benefit to highly migratory species, which can be caught outside reserves. For species that can be protected, few scientific data exist to precisely determine the ideal number, location, size, and total area that should be included in reserves. While too little area will not provide much protection, too much area could unnecessarily limit fisheries production. Current information, although limited, suggests that 10 to 20 percent of the continental shelf should be protected for optimum benefit. Reserves must be large enough to have some biological integrity and include the normal movements of protected species.

With intelligent use of fishery reserves, we can protect reef ecosystems and allow sustainable harvests for present and future generations.

Despite scientific support, the use of reserves is not without controversy and opposition. Fishing interests are usually apprehensive and skeptical about marine reserves because of a lack of direct long-term experience with them. Opposition is likely from special interests near proposed reserves. Even when accepted as a good idea, most fishermen do not want reserves to include their favorite fishing spot—the NIMBY ("not in my back yard") problem. However, experience suggests that attitudes change over time: Terrestrial wildlife reserves, for example, are now common and widely accepted. In New Zealand, marine reserves initially faced great public opposition when introduced in 1977; however, resistance quickly diminished and marine reserves gained strong support. Various commercial, recreational, and fishing interests routinely nominate areas for reserve protection. In Australia, fishing near reserves has grown and is referred to as "fishing the line." Fishermen discovered that good fishing and the largest fish are likely to be caught near reserves.

For reserves to be successful, public education and awareness about the function and importance of reserves is needed. Also, as resources within reserves increase, adequate surveillance and enforcement will be necessary to discourage poaching. Despite these problems, creating a reserve is a more attractive alternative than dealing with a collapsed fishery, or closing a fishery in order to rebuild depleted stocks.

Henry David Thoreau probably never appreciated how prophetic his words would be or their eventual application to the oceans. Growing scientific evidence indicates that marine reserves are successful and benefit both fishery and nonfishery activities.

Despite their increasing popularity around the world, no significant marine reserves exist in US waters although several very small protected areas exist in Hawaii. This pattern will likely change. Several reserves are currently being planned as an essential part of the Florida Keys National Marine Sanctuary. The draft plan includes three large "replenishment reserves" and many small "sanctuary protected areas." The draft management plan is scheduled for public comment in the fall of 1993 and should become effective in 1994. The use of reserves is also being discussed in several other areas around the country.

In conclusion, fishery reserves are based on the fundamental ecology of marine organisms and offer benefits to both fishery and nonfishery interests. Although marine reserves are primarily intended to protect or enhance fisheries by protecting the quantity and quality of reproductive output, they also help protect biodiversity and reduce user conflicts by separating incompatible activities, and they can act as reference areas for study of natural processes with limited human disturbance. Some of these goals are impossible without reserve areas. Finally, reserves provide an insurance policy against fishery collapse. With intelligent use of fishery reserves, we can protect reef ecosystems and allow sustainable harvests for present and future generations.

Jim Bohnsack was born in Michigan and moved at age 14 to Florida, where he discovered warm, clear water and decided that marine biology was an attractive possibility for an occupation. While not the only person to have this realization, he persisted in this endeavor even when common sense suggested otherwise. After attending Tulane University and receiving advanced degrees from the University of Miami, Bohnsack conducted extensive research on artificial reefs and coral-reef ecology. He currently does research on reef fisheries and marine reserves as the Reef Resource Team Leader for the Miami Laboratory of the Southeast Fisheries Science Center, National Marine Fisheries Service.

Author Jim Bohnsack and a large yellowfin grouper, Mycteroperca venenosa.

Stellwagen Bank

New England's First Sanctuary

Maureen Eldredge

Stellwagen Bank is home to leaping whales and teeming fish.

On June 26, 1993, Secretary of Commerce Ron Brown signed a formal declaration making Stellwagen Bank the nation's thirteenth and New England's first National Marine Sanctuary. Home to leaping whales and teeming fish, Stellwagen Bank is an undersea sand and gravel deposit that forms a shallow curve in Massachusetts Bay between Cape Ann and Cape Cod. Left by receding glaciers 16,000 years ago, the bank's unique topography creates tidal-wave packets and upwelling of nutrient-rich water around the bank. The nutrients feed phytoplankton, the tiny photosynthetic base of the food chain, which in turn support a diverse fish, invertebrate, and whale population.

Stellwagen Bank is one of three Atlantic areas critical to migrating whales. Humpback, minke, right, and fin whales are regular Stellwagen Bank visitors. The spectacular sight of whales, as well as the rich fisheries, captured human attention and led to a 12-year effort to gain protection for Stellwagen Bank. The area was nominated for sanctuary status in 1982, and Congress mandated in 1988 that NOAA make Stellwagen an active candidate.

Despite continual pressure from many environmental organizations and the Stellwagen Bank Coalition of environmental and fishing interests, the federal process moved slowly, opposed by the Minerals Management Service (MMS) in the Department of Interior because of interest in sand and gravel mining on the bank, and by US government administrations generally unsympathetic to resource protection and management. Ten years after its nomination, Congress finally designated the area a marine sanctuary in 1992.

NOAA's management plan for the Stellwagen Bank National Marine Sanctuary contains several simple but important regulations that prohibit:

- sand and gravel mining,
- ocean dumping or discharging,
- alteration of or construction on the seabed,
- taking of marine mammals, reptiles, and seabirds,
- placing submerged pipelines or cables, and
- vessel lightering (transfer of fuel at sea).

In addition, NOAA is empowered to take action against any outside source of pollution that enters the sanctuary and injures its resources.

Intense urban pressures from Boston and the surrounding areas make these regulations critical to preserving a small bit of New England marine waters from impacts of our industrial age. Another important benefit of sanctuary designation is increased monies for research and education. This will not only help protect Stellwagen Bank, but will also improve understanding of the entire Massachusetts Bay ecosystem.

John Domont/Center for Marine Conservation

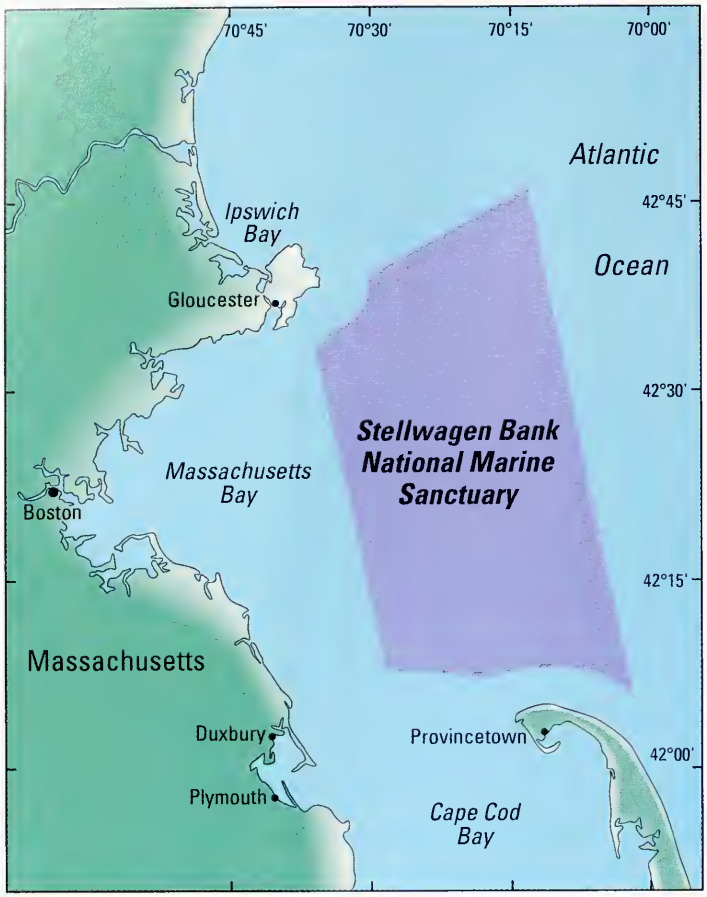
Magnificent humpback whales like this one live peaceably within the protective waters of Stellwagen Bank.

All is not safeguarded by the sanctuary regulations—they alone do not stop ocean pollution, nor can they erect a shield around Stellwagen Bank resources to protect them from harm. For example, under a multiple-use approach to sanctuary management, fishing activities are not regulated by the sanctuary management plan, so accidental entanglement of marine mammals by fishing gear is still possible.

While ocean dumping is prohibited within the sanctuary, the Environmental Protection Agency (EPA) has designated the Massachusetts Bay Disposal Site for dredge materials less than 1 kilometer from the edge of the Stellwagen Bank sanctuary. This site is to be used for "clean" (nontoxic) material only, as defined by the Army Corps of Engineers (ACOE).

However, Boston Harbor and other harbors in the area are reaching a critical need for dredging to maintain adequate depth within the next few years. Sediments in these harbors are highly contaminated with polychlorinated biphenyls, heavy metals, organochlorides, and other industrial wastes. Currently there is no site available for disposal of these sediments. If no suitable site is found, the pressure to use the Massachusetts Bay Disposal Site for these sediments will be enormous. Environmentalists and fishers alike must remain vigilant to protect against this event.

The Army Corps of Engineers has attempted to get clearance to test "capping," a controversial procedure in which contaminated sediments are dumped in the ocean and covered with clean material. EPA has reported that it will give clearance to test capping, provided the Army



The Stellwagen Bank National Marine Sanctuary

Corps of Engineers uses clean material for the test. If ACOE can prove the efficacy of this procedure, it will be very difficult to advocate against capping toxic material at the site. At this point, the technical feasibility is unknown.

Environmental and fishing organizations strongly oppose testing this procedure in Massachusetts Bay, but the fate of Boston's contaminated sediments remains uncertain. This issue illustrates the need for NOAA to address pollution sources outside sanctuary boundaries. Some groups are also concerned about the potential effects on the sanctuary of moving Boston's sewage effluent outfall from Boston Harbor out into Massachusetts Bay (see *Oceanus*, Spring 1993).

Sanctuary designation for Stellwagen Bank highlights the uniqueness of this ecosystem. Home to marine wildlife and important fisheries, the bank also faces intense human pressures from the highly populated eastern seaboard. As New England's first sanctuary, Stellwagen is expected to both help protect the variety of life found here and increase public awareness of problems such as marine pollution.

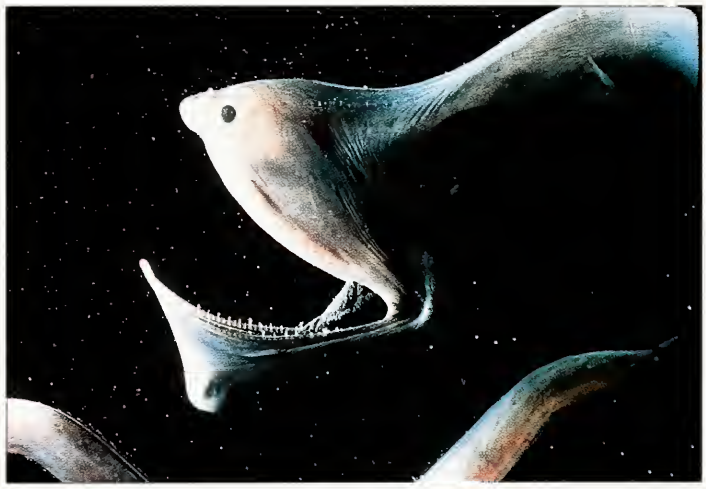
Maureen Eldredge is habitat conservation specialist for the Washington, DC, based Center for Marine Conservation. Although currently trapped inside the DC beltway, she travels frequently to New England and the Florida Keys to work on sanctuary and habitat issues. Her dual background in marine biology (BS in Biology, College of the Holy Cross) and policy (MA in Marine Affairs, University of Rhode Island) enables her to navigate the scientific problems of marine protected areas, as well as the more treacherous political waters of Washington.

New Technologies for Sanctuary Research

Bruce H. Robison

Research is a basic element of good sanctuary management. The kinds of research needed include survey and assessment, characterization, monitoring, experimental work, and modeling. Like many other branches of marine science, sanctuary research is poised on the brink of a technological revolution that will fundamentally change the way this work is done.

The Monterey Bay National Marine Sanctuary is the largest, deepest, and, ecologically speaking, perhaps the most complex in the National Oceanic and Atmospheric Administration (NOAA) Marine Sanctuary Program. Monterey Bay is also home to a unique grouping of institutions, which, taken together, comprise a powerful, growing synergy for the evolution of research technology and methods. The bay's proximity to Silicon Valley and its long tradition of classical marine research are both strong factors in this evolutionary process.



Bruce Robison

Deep-sea gulper eel from the midwaters of the Monterey submarine canyon. Many such sanctuary residents have never before been seen alive or photographed.

The scientific investigations of all the marine science institutions around Monterey Bay enhance the sanctuary research program. What follows are examples of new technologies under development or already at work in Monterey Bay that have significant applicability to sanctuary research, both in Monterey and around the country.

New Surface Vessels Are More Stable

Research ships provide us with basic access to our work sites. While improvements in ship design have enhanced their ability to work in rough seas and heavy weather, conventional monohulls have limited stability. To push the stability factor up a notch or two, the Monterey Bay

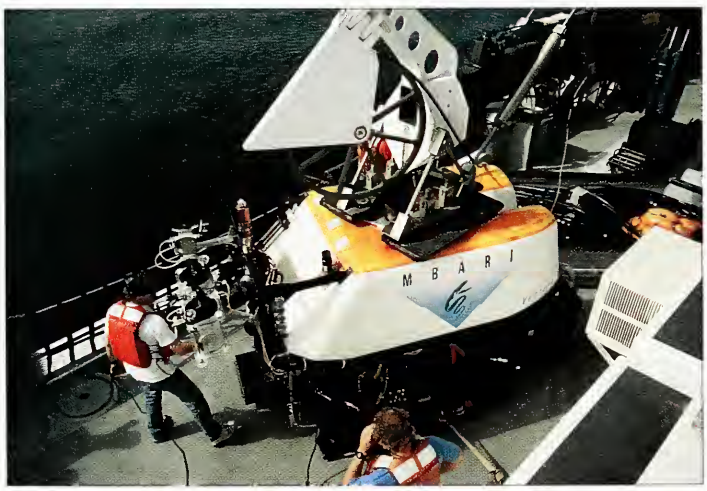
Aquarium Research Institute (MBARI) is developing a SWATH vessel, *Western Flyer* (see *Oceanus*, Summer 1993). SWATH stands for Small Waterplane Area Twin Hull, a design that places the principal hull volume below the sea surface, and supports the main deck and interior areas on thin struts that reach up from submerged twin hulls. This greatly increases the ship's stability by reducing the hull surface area that is affected by the moving sea surface.

In the sanctuary, this innovation means that shipboard operations, from hydrocasts to submersible launches, can be conducted in higher sea states than with a comparably sized monohull. While there are benefits to having scientists working comfortably at their stations in heavy weather (instead of "painting stripes" over the side), other payoffs may not be so obvious. Greater stability also means that we will be able to investigate the ocean under conditions that previously made both ships and scientists inoperable. We can study the effects of storms on habitats and their populations in real time, instead of extrapolating from data gathered before and after storm events. The ability to conduct research on natural processes during extremes of natural conditions will go a long way toward giving us the predictive capability to deal with other sorts of sanctuary perturbations.

Undersea Vehicles Image the Depths

Three undersea-vehicle types are riding the wave of science-driven technological evolution in the Monterey region: remotely operated vehicles (ROVs), autonomous underwater vehicles (AUVs), and manned (or "crewed") submersibles. The present state-of-the-art science vehicle is MBARI's ROV *Ventana*, which conducts daily biological and geological research in the Monterey Submarine Canyon. Starting with the basic framework of an offshore oil field ROV, *Ventana* was built by International Submarine Engineering in Canada to perform a variety of scientific functions.

Bruce Robison



Configured for work in the water column, ROV Ventana *sits on the deck of* Point Lobos, *awaiting its next voyage.*

Ventana carries a broad suite of sensors, tools, and instruments, and has a depth rating of 1,850 meters. Through its tether the ROV receives power and control instructions from the surface. At the core of the tether are optical fibers that carry computer-processed signals from sensors aboard the ROV to computers on the mother ship above. Chief among these signals are broadcast-quality video images that give the topside scientists unprecedented observational capability. Data from standard oceanographic instrumentation including recorders of temperature, salinity, depth, oxygen concentration, and light transmission are coupled to the high-resolution imagery. A scanning sonar, low-light video cameras, still cameras, a hydrophone, and a flowmeter/odometer are also aboard.

Collection gear includes detritus and suction (like an underwater vacuum cleaner) samplers, a manipulator arm, and rock drills.

Integrated data from these systems offer Monterey area scientists a new perspective for studying the bay. *Ventana*'s operational record (625 dives and more than 3,000 hours in the water over the last five years) provides high-resolution data sets. Significant work has been done with *Ventana* in several research areas:

- vertical transport of organic material into the deep sea,
- the geology of cold-seep sites and the biology of their resident communities,
- the fate of storm-generated drifting kelp masses,
- the role of gelatinous animals in water column ecology,
- geological effects of the 1989 Loma Prieta earthquake, and
- the importance of marine snow.

There are recent new findings in each of these areas that would have been difficult or impossible to achieve with conventional technology.

The next scientific ROV generation, presently under construction at MBARI, will have all *Ventana*'s scientific capabilities and an operational depth of 4,000 meters, which encompasses the full vertical range of the Monterey sanctuary. In addition to its core capabilities, this vehicle will also have a variable buoyancy system, quiet electric propulsion, and removable tool sleds configured for specific tasks that can be quickly exchanged at the surface.

AUVs are currently being developed at the Navy Postgraduate School in Monterey and at MBARI. Both systems are designed to function without surface tethers. This approach reduces power requirements and allows operation during bad weather. Eliminating the tether also means that AUVs must be battery powered and that their control systems must be preprogrammed to function without a human in the loop.

AUVs offer the potential for cost-effective measurements of environmental parameters that do not require full commitment of a surface vessel. Carrying standard instrumentation, they can be programmed to "mow the lawn," that is, to run a geographical sampling grid and then return to a designated site. Alternatively, they can be programmed for periodic surface visits, to transmit data and receive new programming by radio or microwave transmission. Data transmission and reprogramming via underwater acoustic signals will add a degree of real-time control in the near future.

Additional jobs for AUVs will involve technology transfer from defense-related developments. Control systems programmed for target recognition and tracking can be used to follow fish schools or to monitor the activities of individual animals. Signal recognition software will allow an AUV to sniff out a subsurface pollutant plume, follow its concentration gradient upstream, and locate its source. Likewise, patrolling AUVs can alert us to diatom blooms linked to the neurotoxin domoic acid (produced by the diatom *Pseudonitzchia australis*), which has had negative effects recently on Monterey Bay bird and pinniped populations.

Technological innovation also holds new promise for crewed submersibles. At Deep Ocean Engineering in San Leandro, not far from Monterey and the contiguous Farallones Sanctuary, the next generation of crewed submersibles is under construction. Unlike most of its predecessors, *Deep Flight* is a small, lightweight, relatively inexpensive, one-person

Technological innovation holds new promise for remotely operated vehicles, autonomous underwater vehicles, and crewed submersibles.

submersible. By incorporating new materials, new electronics, and new software, *Deep Flight* eschews the design philosophy that subsequent generations must be bigger, heavier, and more costly.

This approach complements the evolution of ROV and AUV technologies because for some under-sea applications there is no substitute for having the human eye and mind on site. The issues of "manned vs. unmanned" and ROV vs. AUV are moot—ultimately, we will require all three vehicle types.

Buoys and Moorings Monitor Environmental Changes

The ability to make high-resolution measurements of physical, chemical, and biological variables over time is critical to the development of reliable marine-system models. In Monterey Bay, MBARI has deployed a mooring system called OASIS (Ocean Acquisition System for Interdisciplinary Science) that makes time-series measurements of the parameters essential to understanding the variability of primary productivity.

The OASIS moorings each comprise a suite of instruments: a thermistor chain to measure temperature with depth, a conductivity-temperature-depth sensor, a fluorometer to measure chlorophyll, a transmissometer for light transmission, meteorological instruments, a spectroradiometer, that measures light at different wavelengths, an acoustic Doppler current profiler, a carbon-dioxide sensor, a PAR (photosynthetically active radiation) sensor, and such system diagnostic information as battery-power levels. Data from all of these elements is assimilated by a unique set of control electronics and telemetered in real time via packet radio or ARGOS satellite to scientists ashore.

Gary Thurmond

The OASIS mooring on station in Monterey Bay. Solar panels provide supplemental power, and the spikes keep birds from landing on the frame.

This is an important advance in our ability to monitor environmental variables in the sanctuary or in almost any marine area. Not only does the control system provide real-time data, it also allows remote adjustment of sampling frequencies and data transmission parameters in response to changes at the site. The system is easily reconfigured with the addition or replacement of alternate sensors, and field servicing is reduced to a minimum.

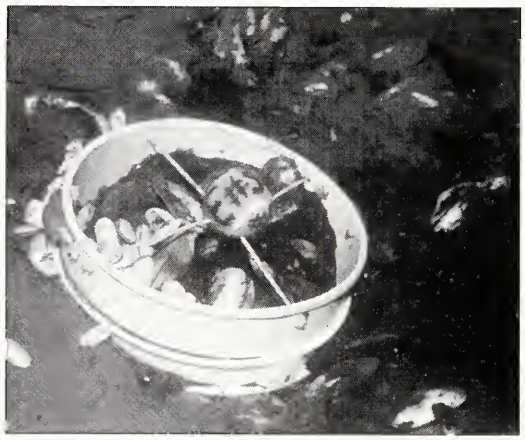
The value of moored instrument arrays goes beyond traditional shipboard measurements by providing time-series data that are fixed spatially but continue temporally. Such data are vital for verifying data from satellite-borne instruments and for calibration of shipboard data sets. Sanctuary networks of instrument systems like OASIS would provide sanctuary researchers and managers with unprecedented levels of information about protected areas.

Bottom Stations Relay Changes on the Seafloor

Just as buoyed moorings can provide time-series data about water-column variability, benthic stations can give us data on the temporal variability of seafloor processes. Several Monterey Bay benthic sites are designated as continuing-research areas. Most are associated with

geological features of the canyon structure that lead to slow expression of hydrogen-sulfide-rich water. These "cold seeps" are of interest to biologists as well as geologists because of the chemosynthetic communities that surround them. Using differential Global Positioning System navigation, it is easy to return regularly to these locations (at depths between 450 and 900 meters). While no permanent bottom stations are yet established, *Ventana* visits the designated sites regularly to collect data and to deploy and recover a variety of gear that includes larval settlement traps, a time-lapse video camera, a current meter, and a dissolved-oxygen sensor.

Long-term deployment of gear at "permanent" bottom sites has been proposed as part of the Ridge Inter-Disciplinary Global Experiments Program to study hydrothermal vent regions in the Juan de Fuca Ridge area off Washington state. Lessons learned from this program will further the development of benthic-station technology, with broad applications for deep sanctuary research programs in Monterey, the Gulf of the Farallones, and elsewhere.



Jim Barry

A "clam corral" isolates specimens from their neighbors for growth studies in a Monterey Bay chemosynthetic cold-seep community.

Communications Permit Rapid Response

Once data has been collected, its means of transmission greatly affects its utility. In the case of the OASIS moorings, two-way communication with the instruments allows real-time response and control. In Monterey Bay, two additional technological developments are advancing the field of data communications, with obvious benefits to sanctuary researchers.

In the "live link" system, live video images from *Ventana* travel up the tether's optical fibers to the surface vessel, *Point Lobos*. Aboard the ship these images are converted to microwave signals that are transmitted ashore to antennas atop Mt. Toro. From Mt. Toro the signal is relayed to MBARI's laboratories in Pacific Grove, and to the Monterey Bay Aquarium in Monterey. These incoming signals are coupled with an audio link, and there is a counterpart outgoing audio/video signal from the shore. This two-way link allows scientists at sea to interact with colleagues ashore, and provides the lab-based researchers real-time access to the canyon environment. On many occasions this system has broadened scientific participation in a dive without sending a large contingent of scientists to sea. It is invoked each time *Ventana* goes to work.

At the Monterey Bay Aquarium, the live link is used for public education. Video images are projected on a screen in the auditorium, usually to a highly receptive crowd. Interpreters explain the live images to the audience, aided by a computerized catalog of information, taped video footage, and occasional comments from the scientists at sea. This allows the public to look over the researchers' shoulders as they conduct their investigations in the canyon. It is a powerful way to reach out to the public, and it could have great potential for promoting public awareness of sanctuary programs and issues.

Another communications technology under development in Monterey Bay (in conjunction with Woods Hole Oceanographic Institution engineers) is an Acoustic Local Area Network (ALAN) for real-time underwater communication. The network utilizes underwater acoustic

modems for data transmission. The modems work like cellular telephones to communicate with distant computers. Pulsed acoustic signals, coded with data, control signals, or other information, travel through the water between modems.

At its present state of development, this technology can communicate at a 9,600-baud underwater data rate. This is fast enough to support electronic mail via the UNIX computer operating system, and can transmit single-frame video or sonar images at 3- to 4-minute intervals. This technology has great potential for enhancing a network of sanctuary research applications. Through ALAN, a variety of instrument packages and sensors—aboard vehicles, on moorings, and deployed at bottom stations—could communicate with one another to coordinate activities among stations and with researchers ashore for real-time control and data retrieval.

While the technology of pulsed acoustic communications is still in the early development stage for network-level use, point-to-point use by the US Navy's AUSS (Advanced Unmanned Search System) autonomous vehicle has been very successful. Developing a network on the scale of Monterey Bay is challenging, but it may prove to be an enabling technology that links all of the other technologies described into a system that transcends their individual value.

These technologies provide new kinds of information that bring new perspectives to old problems.

Other Technologies Are Lowering Costs and Opening New Doors

Technological development by research institutions around Monterey Bay goes well beyond the examples discussed here, including new chemical sensors, undersea navigation systems, satellite links, new tools for undersea vehicles, biotechnology, and new data management systems. Most of these developments are science-driven and are coupled to the evolution of new research methodologies.

The value of these new and emerging technologies for sanctuary research is essentially twofold. First, they offer the means to gather and manage more data, precisely and reliably and at lower cost than conventional technologies allow. Second, and perhaps most important, these technologies provide new *kinds* of information that bring new perspectives to old problems and enable researchers to make the conceptual progress necessary to better understanding of natural systems. These technologies are evolving rapidly. Virtually everything discussed here already is or by 1998 will be operating within the Monterey Bay Marine Sanctuary. What the future holds should be even better. Stay tuned.... ⁂

Bruce H. Robison is Senior Scientist and Science Department Chair at the Monterey Bay Aquarium Research Institute. He began college with the goal of becoming an aeronautical engineer—ten years and five majors later he received a Ph.D. from Stanford University in biological oceanography. He uses both crewed and remotely operated vehicles for his research on the ecology of deep sea animals.

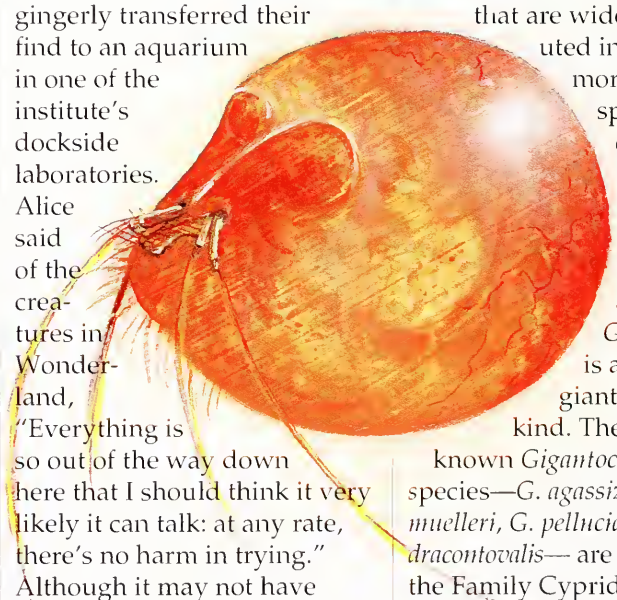
Gigantocypris
Miniature Halloween Pumpkin of the Deep

Cheryl Lyn Dybas

Deeper than the Grand Canyon, a 15,000-square-kilometer section of California coastal waters last year became America's eleventh marine reserve: Monterey Bay National Marine Sanctuary. Less than 1 kilometer from shore, the bay's deep canyon cuts across the narrow Pacific continental shelf and the ocean floor rapidly falls away. Within 10 kilometers, the waters of Monterey Bay are more than 1,000 meters deep.

The new marine sanctuary protects this unique area's wildlife, including sea otters, seabirds, whales—and a creature as improbable as any in Alice's Wonderland: the *Gigantocypris*. Far from looking like a monster, however, the animal resembles a miniature Halloween pumpkin, with its deep orange color and yellow "eyes," its body the shape of a small ping-pong ball.

One afternoon last June, the Monterey Bay Aquarium Research Institute's remotely operated vehicle (ROV) *Ventana* encountered a *Gigantocypris* as they both cruised the depths of Monterey Bay. Startled scientists aboard *Ventana's* mother ship, the research vessel *Point Lobos*, quickly maneuvered the ROV into position. After several attempts, the researchers gently scooped the creature into a collecting bin. When the ship reached home port, they gingerly transferred their find to an aquarium in one of the institute's dockside laboratories. Alice said of the creatures in Wonderland, "Everything is so out of the way down here that I should think it very likely it can talk: at any rate, there's no harm in trying." Although it may not have communicated in words, the *Gigantocypris* provided answers to some of the unknowns about how this species lives in the depths. It survived for several months, and "even had babies," according to Monterey Bay Aquarium Research Institute (MBARI) scientist Bruce Robison.



Unfamiliar to most biologists, *Gigantocypris* is in fact the largest known ostracod. These mussel or seed shrimps are small crustaceans that are widely distributed in the sea; more than 8,000 species of ostracods have been described. Since most ostracods are tiny, *Gigantocypris* is a veritable giant among its kind. The four known *Gigantocypris* species—*G. agassizii*, *G. muelleri*, *G. pellucida*, and *G. dracontovalis*— are members of the Family Cypridinidae in the Order Myodocopa. Cypridinids brood their eggs in the back of their shell cavity; the eggs hatch enclosed in a round carapace just like the adults'.

First described by the German scientist G.W. Mueller in 1895 after he caught one of the creatures in a net-tow from the deck of the vessel *Valdivia*, *Gigantocypris* haunts the mid-water depths (hundreds to thousands of meters down) of the tropical and subtropical Atlantic and Pacific Oceans, and the cold waters surrounding Antarctica. Like many mid-water crustaceans, its orange-red color is an adaptation to depths where no red light penetrates: A red animal doesn't reflect light at these depths and so "disappears" into the blackness, thereby eluding potential predators.

In 1963 and 1964, scientists on two Antarctic research cruises of the vessel *Eltanin* found so many specimens of *Gigantocypris mnelleri* in the waters of the Antarctic Convergence region (where antarctic surface waters and deeper subantarctic waters meet) that they suggested using the creature's presence as an indicator of the area. "*Gigantocypris* may be virtually cosmopolitan in deep, open ocean areas," wrote polar oceanographer John Tibbs (of the University of Southern California in Los Angeles) in a 1965 edition of the journal *Limnology and Oceanography*. "And once seen, the ostracod would not be mistaken for any other pelagic form." Anne Cohen, an ostracod expert at the Los Angeles County Museum of Natural History who participated in other *Eltanin* research cruises during the mid-1960s, agrees. "If I hadn't seen it swimming around in a tank onboard the ship, I'd never have believed that such a distinctive little animal could even exist, let alone in one area in such numbers."

Propelling itself with a pair of fanlike antennae that protrude from its shell, the *Gigantocypris* pulls itself along with balanced strokes. Movement of just one of the antennae steers the animal to the right or left. Like many deep mid-water animals, it's capable of hovering for long periods of time. With a chemical composition similar to that of a jellyfish, its body has an extremely high water content (95.6 percent), according to biologist Jim Childress of the University of California at Santa Barbara. Gelatinous material makes these creatures more buoyant, and conserves energy that would otherwise be used to keep from sinking.

But *Gigantocypris* is also a good swimmer, much to the dismay of the scientists aboard *Point Lobos* last summer. Early researchers believed that *Gigantocypris* was a "sit-and-wait" predator, but more recent work by British biologist John Davenport of the University College of North Wales has shown that this giant ostracod can keep up quite nicely with its prey, fast-moving creatures like small crustaceans called copepods, and young fish.

Its swimming ability isn't all that allows it to find food successfully, however. The *Gigantocypris* has large reflecting eyes that enable it to concentrate the extremely faint light that remains at ocean depths of hundreds to thousands of meters. "The paired eyes have metallic-looking reflectors behind them, making them appear like the headlamps of a car," wrote the British biologist Sir Alister Hardy in his 1965 classic *The Open Sea: Its Natural History*. Hardy was the first to speculate that these "mirrors" serve to focus light. "The reflectors look out through clear glass-like windows in the otherwise orange carapace and no doubt the mirrors behind serve instead of a lens in front." Later research has shown that although the sharpness of these reflecting eyes is low, they produce an image some 17 times brighter than that formed by the lens eyes of fishes. *Gigantocypris* may have a bad case of astigmatism, but it can detect extremely low levels of light, such as those

emitted by the light organs of the luminescent crustaceans and fishes upon which it feeds.

The ostracod is also an important food item for other animals. Ostracods are eaten in large numbers by trumpet fish, horse mackerel, and deeper-living fish called myctophids. One of the more numerous organisms in the ocean's community of animal drifters, or zooplankton, ostracods have made up as much as 12 percent of the total numbers of zooplankton sampled.

Studies like those conducted at MBARI are just beginning to reveal the relationship of ostracods to other organisms. The larger message of the *Gigantocypris* captured by *Ventana* in 1992 may be that marine sanctuaries like Monterey Bay aren't only for the conservation of familiar animals like sea otters and brown pelicans. Marine sanctuaries may also be for the protection of the lesser-known creatures that lie hidden from view in the sea's depths.

Cheryl Lyn Dybas is a science writer who was pleased to make the acquaintance of a Gigantocypris *last summer: She was aboard the research vessel* Point Lobos *when* Ventana *encountered the giant ostracod in Monterey Bay's depths. Her articles on "underappreciated" marine life have also appeared in* National Wildlife, International Wildlife, Wildlife Conservation, *and the National Science Foundation's* Directions *magazines.*

Watercolor illustrations of *Gigantocypris* by E. Paul Oberlander/WHOI Graphics. Reference images provided by Kim Reisenbichler.

Sixty Years of Publications at Woods Hole Oceanographic Institution

Kenneth O. Emery

The 60-year publication history of the Woods Hole Oceanographic Institution (WHOI) reflects the growth of oceanography there and at other world-class ocean science organizations. This article updates a chapter written by the author and Richard L. Haedrich for *The History of Oceanography*, a commemorative volume for WHOI's 50th anniversary (Springer-Verlag, 1980). In *The History of Oceanography*, we wrote, "The first 50 years of the Woods Hole Oceanographic Institution span a sequence of political, scientific, and socioeconomic changes that have influenced its work and its growth. The situation is not unique to Woods Hole, but applies widely. These changes have influenced other oceanographic institutions, oceanology as a whole, and science in general. What has happened at Woods Hole is a microcosm of the growth and behavior of science in a changing world. Because its growth has been so rapid and has occurred mostly within the lifetimes of its present practitioners, and because good and fairly complete records have been kept since the institution's founding, its history provides a useful object lesson." The years since 1980 have exhibited such large advances that this update may be helpful in projecting future growth.

WHOI was founded in January 1930 by a $3,049,000 grant from the Rockefeller Foundation, at the instigation of a National Academy of Sciences committee. The new institution provided geographic balance for the three other large oceanographic organizations—University of Washington, Scripps Institution of Oceanography at the University of California, and Bermuda Biological Station. Subsequently these four have been joined by many others in the US and elsewhere in the world. During its 60 years, the size of the WHOI staff,

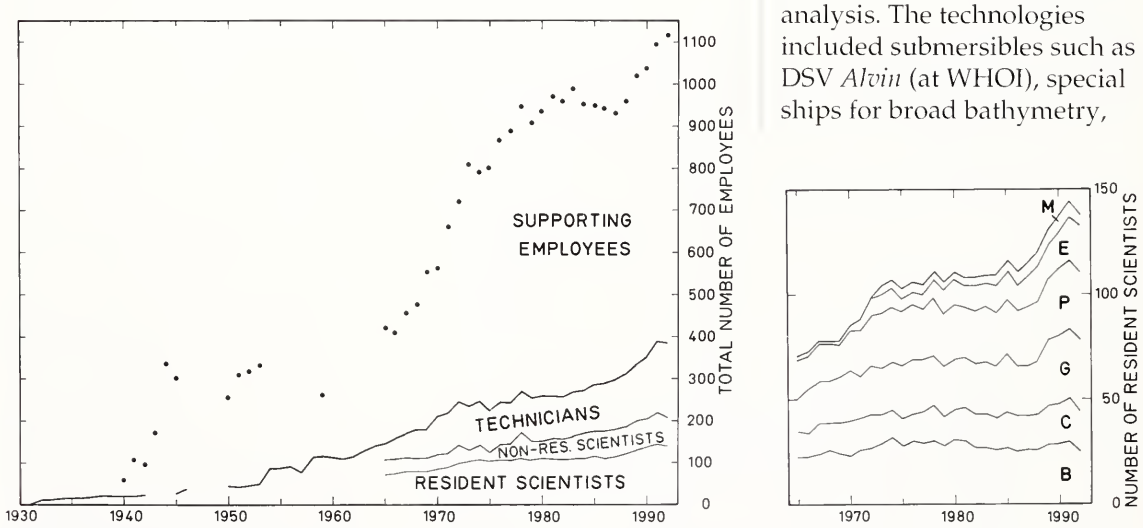
WHOI

From 1931 to 1966, R/V Atlantis *sailed more than half a million miles on 299 research voyages.*

capability of its ships, number of worldwide cruises, extent of sample collection and analysis, competence of studies, publication of journal articles and books, and, of course, its budget have all increased.

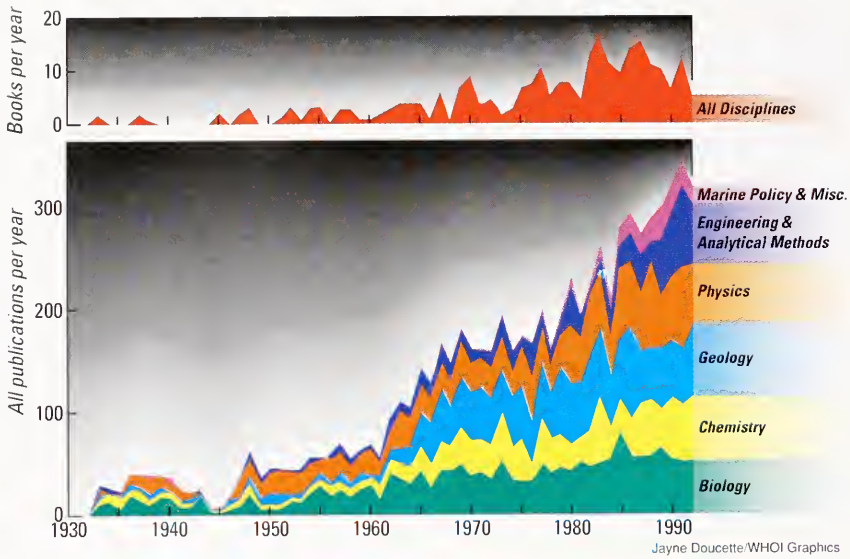
Departmental affiliations of the staff and the nature of their publications is an interesting means for evaluating the evolution of oceanographic investigations. WHOI began as a summer institute modeled after the Marine Biological Laboratory in Woods Hole, which was staffed largely by university professors who did most of their field or laboratory work during summers and wrote their reports at their home universities during winters. Although this method was inexpensive, it tended to produce local studies of single disciplines, mainly biological. At the same time, the availability of the large ketch R/V *Atlantis* allowed cruises to establish regional patterns of more general biological, chemical, geological, and physical oceanography that were mostly descriptive in nature. In the next decade, the onset of World War II shifted emphasis from basic science to military projects, such as evaluating the effects of the physical properties of seawater and continental-shelf sediments on the acoustics employed for both detection of enemy submarines and defense of our own submarines. Other military applications of oceanography included predicting smoke-screen behavior, drifting of life-rafts, and testing of atomic bombs.

After the war, there was an attempt to return to prewar kinds of oceanography, but by that time oceanographers had learned the value of multidisciplinary research and the navy had recognized oceanography's value enough to supply ships and funds for expanded ocean studies. Thus began a period of broadening vistas that led to oceanwide investigations beginning about 1960 and progressing to international, multiship cruises about 1975. These efforts permitted technology transfers among disciplines and fostered inventions of new technologies for sampling, data collection, and analysis. The technologies included submersibles such as DSV *Alvin* (at WHOI), special ships for broad bathymetry,



Since its incorporation in 1930, WHOI's staff has grown (left). The scientific and technical staff consists of resident scientists, nonresident scientists (especially during the 1930s and 1940s), and technicians. The scientists are chiefly responsible for securing grants and contracts to fund research and operations. They are aided by the technical staff and supporting employees such as laboratory and staff assistants, mechanics, shipboard personnel, and administrators. The distribution of resident scientists is shown by department (right): B=Biology, C=Chemistry, G=Geology & Geophysics, P=Physical Oceanography, E=Applied Ocean Physics & Engineering, and M=Marine Policy and other centers. These scientists not only secure most of the grants and contracts, but also write most of the journal articles and books. Note that all but two departments (Applied Ocean Physics & Engineering and Marine Policy) began early at the institution.

Publications per year and books per year are identified by the authors' disciplines (not necessarily their departments). Authors are commonly in departments having names similar to these disciplines, but they also may write about subjects that supplement their own departmental disciplines, a necessity for the discussion of multidisciplinary studies.



speedy and accurate position finding, deep-ocean-floor drilling, digital data processing, and the use of long-term, deep-ocean moorings. Satellites began to be used for mapping ocean-bottom topography and for rapid and precise measuring of currents and chemical and physical components of the water.

Oceanography's transformation via new methods and interrelationships between disciplines during the past decade or two is readily apparent in the literature record. Quite clearly, scientists who fail to keep up with multidisciplinary oceanographic literature soon become sadly limited in their knowledge of techniques and their awareness of relationships between different subfields and changing objectives of ocean research. At the same time, new subjects in literature are appearing—authors are concentrating on new methods of chemical and other analyses, new statistical treatments including fractals and chaos theory, political aspects of the oceans, and uses of mechanical and electronic aids that include new methods of holding position and maneuvering.

Keeping up with oceanographic literature is difficult. Its volume is constantly increasing and in 1981 the annual assembly of *Collected Reprints* (for delivery to about 1,000 libraries worldwide) was discontinued owing to the rising cost of journal reprints. Scanning *Collected Reprints* each year was a source of pleasure and a way to learn about new work and new methods, gain insight into relationships between different disciplines, and obtain ideas for possible future investigations. Merely comparing titles reveals that many in the current literature would not have been identifiable a decade or two ago, an indication of the great advances that have been made in science and technology. This transfer of information by literature is augmented by oral presentations at departmental seminars, national conferences, and international meetings.

Inspecting the figures yields some insights into the nature of WHOI's 60-year growth, and may provide some guidance concerning the opportunities for and limits to future growth.

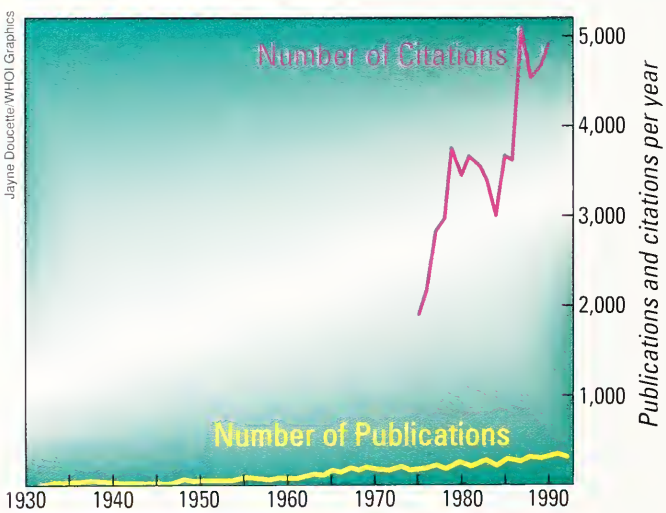
The institution's annual budget has increased about a thousandfold since 1930. Components of the increase include augmented total tonnage and superior seakeeping ability of the surface ships, and inclusion of submersibles and robot probes; a hundredfold increase in total staff (largely for laboratory and staff assistants, ship personnel, and administrators); and inflation of the US dollar. In terms of the 1983 dollar, the institution was little more than level funded between 1960 and 1987. In contrast, the number of resident scientists, who secure funding for research grants and contracts, increased only about tenfold (note that it should not be assumed that

twice as many scientists would be able to secure twice as much research funding).

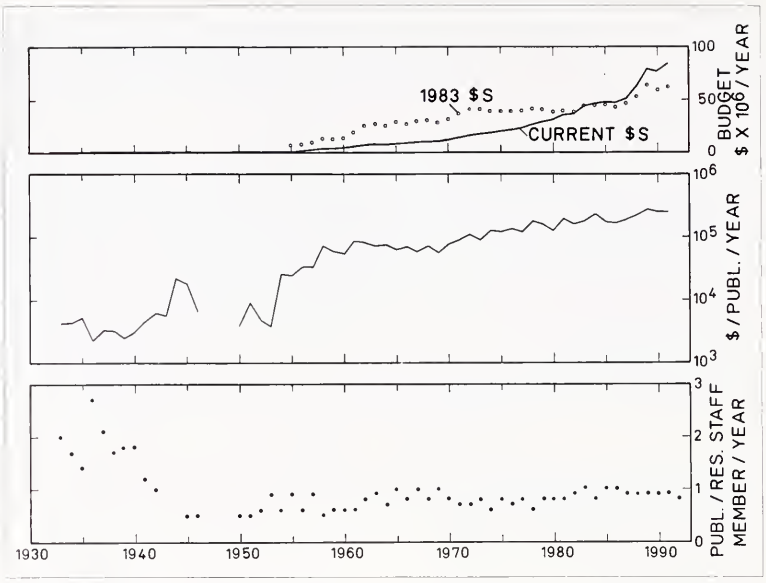
During the same period the cost per WHOI publication has increased about sixtyfold from about $4,000 to about $250,000 in current dollars, but the number of books relative to journal articles has simultaneously increased. Clearly, books are much broader in their treatment of multidisciplinary subjects of oceanography, and require far more time to write than journal articles, thus complicating the cost accountability of publications. During the history of the institution, the average number of publications (journal articles plus books) per member of the total research staff increased from about 0.5 per year in 1950 to about 0.9 per year in 1991. Most are written by resident scientists, some of whom consistently average four or more articles and books each year, perhaps because of greater than usual breadths of interest or supplies of energy. Others are by technical staff members, especially in the relatively new department of Applied Ocean Physics and Engineering, and by students and postdoctoral scholars. A major obstacle to publication, especially for younger staff members, is the urgent need to write as many as four proposals each year to secure funding for salaries, assistants, and ship costs. If the publications were ascribed only to resident scientists, the annual publication would have increased from 1.5 per scientist in 1950 to 2.3 in 1991.

Much past progress in oceanographic knowledge resulted from scientific curiosity about the evolution of the ocean and its biology, chemistry, geology, and physics (the fundamental branches of oceanography). This work was funded largely by universities and organizations such as the National Science Foundation. Military needs have produced funds for specialized work, and this new information has also added to general knowledge about the ocean. Seismic and drill-hole searches for fossil fuels and for information about the origin and distribution of these fuels expanded the knowledge of shallow-water geology, and related investigations produced much information about deep-ocean geology through studies of the nature and rate of crustal- plate movements.

The need to learn more about ocean environmental deterioration is likely to provide additional funds for understanding the effects of oil pollution and radioactive wastes, especially on the ocean's chemistry, biology, and physics, but these funds may be too small and too slow in coming to be very useful. An example of the interdependence of the various oceanographic disciplines is illustrated by chemosynthesis at hot brine vents on the deep ocean floor, discovered about 1975. Still more futuristic are current investigations of early Earth and its oceans, derived from studies of other planets in the solar system and other components of the universe.



Growth of the total number of publications (journal articles and books) with time, compared with the number of entries in the citation index under the names of resident scientists. Virtually all of the resident scientists were cited. There were 4,644 and 4,901 citations in 1989 and 1990 to previous publications by 148 and 144 writers. Fewer than one-third of the technical staff were cited (290 and 314 citations in the same two years to previous publications by 53 and 62 writers). This comparison reveals something of the range reached by publications within an active field of research.



The annual WHOI budget (top) in current dollars (continuous line) and in 1983 dollars (open circles) shows the effects of monetary inflation in the US. The average cost of each publication per year is shown (center), calculated as the total institutional budget in current dollars divided by the number of publications per year. The average number of publications per member of resident staff (both scientific and technical staff) per year is shown at bottom.

Projecting current trends into the future suggests that the different disciplines of oceanography (and especially their subdivisions) are likely to become progressively more detailed, focused, and perhaps esoteric, with the danger of becoming less intelligible to workers in other subdisciplines. However, such specialization may provide unique opportunities for the relatively few generalists who are able to grasp and combine specialists' findings. It is this ability that allowed J. Murray and A.F. Renard in their *Challenger* expedition report (1891) and 50 years later H.U. Sverdrup, M.W. Johnson, and R.H. Fleming in *The Oceans* (1942) to make great syntheses of earlier oceanic knowledge. Perhaps in another decade or two, even greater syntheses may be produced by generalists at one of the leading oceanographic institutions.

Interestingly, a major obstacle to constructing a several-year broad synthesis of modern oceanography is the preference of such government agencies as the National Science Foundation and the Office of Naval Research to fund many small-range, detailed investigations rather than fewer broad syntheses. This means that synthesizers-to-be must demonstrate unique abilities to raise the necessary funds for support or develop an ability to work without special funds. Is it possible that there is a rising opportunity for a major effect on oceanography's future, perhaps to be provided by a large grant to support broad field studies by a few generalists, independent of masses of highly detailed analyses and large numbers of technical aides and assistants? Such a grant could affect the future of oceanography as strongly as has the founding of WHOI or the establishment of the Office of Naval Research and the National Science Foundation after World War II.

K.O. Emery is a Scientist Emeritus in the Geology & Geophysics Department at the Woods Hole Oceanographic Institution (WHOI). He wrote this article to commemorate the 20-year service of Carolyn P. Winn as WHOI Research Librarian and her dedication, along with her competent staff, to improving the library and its usefulness to the oceanographic community.

The Policy Makers' Challenge
Radioactive Dumping in the Arctic Ocean

John Lamb and Peter Gizewski

Recent revelations concerning the possible environmental hazards posed by the sunken Soviet nuclear submarine *Komsomolets* and the disposal of radioactive materials in the Arctic and North Atlantic oceans have generated much controversy and debate. Too often, however, the key scientific and policy issues that the dumping raises are treated as two solitudes. In reality, decisions taken by national governments and international agencies in connection with remediation, regulation, and even research must be based on both science and policy. Indeed, a sound approach to the dumping issue must integrate scientific evidence and policy considerations relating to legal, political, social, and economic matters.

The Policy Makers' Context

Radioactive waste disposal is an exceedingly difficult problem. Information detailing the Soviet Navy's past dumping practices, and increasing awareness of the problems that Russia and other states may encounter in the future disposal of radioactive waste, indicate that the global inventory of radioactive wastes requiring storage and disposal is large and growing.

The London Convention currently provides an indefinite moratorium on all radioactive-waste dumping at sea. Just how long-term this will be, however, is unclear. An Intergovernmental Panel of Experts on Radioactive Wastes—established by the London Convention—has produced a report listing seven future policy options. These range from lifting the moratorium to establishing a permanent ban on radioactive-waste disposal at sea. The options will be considered at the London Convention's 16th Consultative Meeting in November 1993.

Meanwhile, public resistance to any ocean disposal of radioactive waste is growing. In fact, the trend indicates a move toward zero tolerance in some areas. While some scientists have provided assurances that there is little danger of any regional scale radioactive contamination in the Arctic or North Atlantic, much of the evidence available to date remains inconclusive. Hence, future threats cannot be entirely discounted.

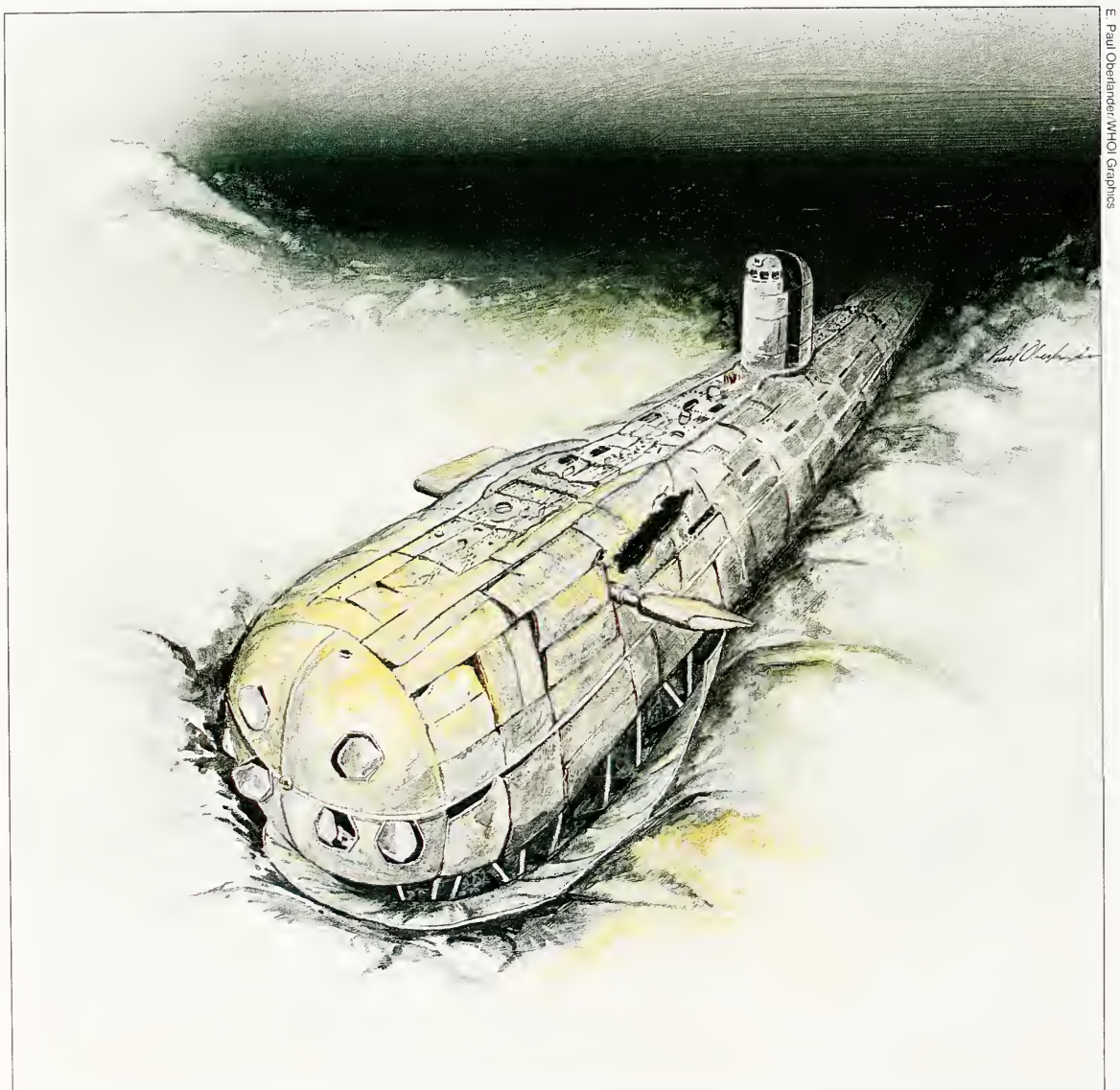
The legal framework for dealing with radioactive waste is almost nonexistent, and the financial resources are severely limited.

At the same time, the means for addressing potential problems are lacking. Technical options aimed at the storage and disposal of radioactive waste are under explored. The legal framework for dealing with such issues as national and international responsibility and liability relating to radioactive waste is almost nonexistent, and the financial resources available to governments for tackling these problems are severely limited.

The Policy Makers' Challenge

The challenge for policy makers is to mediate among these often-competing forces to determine priorities for investing scarce resources in response to the dumping problem. A variety of basic questions must inform decision making. For instance: Is society prepared to accept the contamination of certain parts of Earth and the extinction of certain maritime species, even if that contamination is shown to have a negligible direct impact on humankind? Should the burden of proof fall on those asserting that there is no significant impact on the environment and humans, or on those asserting that there is such an impact? Moreover, what time frame should be used to assess data on these issues?

Addressing these and other policy questions requires a precautionary approach. This holds that in light of the incomplete state of knowledge on these issues, and the relatively short period over which data has been



E. Paul Oberlander/WHOI Graphics

On April 7, 1989, the Soviet nuclear-powered submarine Komsomolets *caught fire and sank in the Norwegian Sea, taking 42 lives. Today the sub rests on the bottom, in approximately 5,500 feet of water. Whether or not the torpedo tubes (at the front of the sub) pose a radioactivity risk is currently being investigated by scientists from several nations.*

collected, caution must govern decision making, and irreversible remedial measures should be avoided.

Recommendations

A precautionary approach in no way implies inaction. It does imply that future policy decisions must not overstep our still-incomplete knowledge of the issues if we are to arrive at an effective approach to radioactive dumping. At present, a number of measures suggest themselves.

Access to additional information is crucial to the creation of sound policy. National governments should therefore disclose all existing data, including that currently classified, relating to arctic environmental contamination. Evaluations are needed of disposal, storage, and transport options for high-level radioactive waste of both military and civil origin. And a comprehensive inventory of existing radioactive waste disposal sites in the Arctic and other oceans should be prepared.

The growing self-awareness and political power of the 8 to 10 million people currently inhabiting the arctic region must also be considered. Northerners strongly oppose the disposal of any further nuclear materials in the Arctic Ocean, and press for the cleanup of existing sites. These people must be assured of effective and early involvement in the decision-making and implementation processes relating to radioactivity in the Arctic. Consideration should be given to the impact of radioactive waste and remediation options on indigenous peoples' subsistence lifestyle and culture. Furthermore, governments should make the results of all scientific research and monitoring available to them on a timely basis.

More generally, and in view of the limited resources available to tackle the problem, policy must be guided by the principle of economic efficiency. Attention should be given to spillover or multiplier effects (for example, the development of technologies that not only address the dumping problem, but have applications in other areas as well), hidden subsidies (policies and practices that promise indirect benefits from their adoption), environmental damages, cross-generational issues, etc. The triage concept should guide decision making, and a variety of criteria should be employed in determining priorities, including safety, comparative environmental impact, technical feasibility, social/political acceptability, and the reversibility of measures taken.

Other measures could be taken on the legal, institutional, and financial fronts. For instance, while the London Convention will remain the principal global institution governing radioactive waste disposal, it could be supplemented by regional measures specific to the Arctic. Legal principles of responsibility and liability for environmental damage could be clarified and developed further.

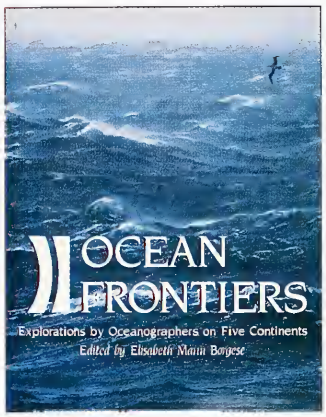
Finally, national governments, private funding agencies, and international bodies, such as the World Bank, might be encouraged to contribute financial resources to support the scientific, technical, and social research required for responsible decision making on the problem of radioactive waste in the North.

The continuing growth in quantities of radioactive waste requiring disposal, along with the failure of the London Convention to impose a permanent ban on its disposal at sea, strongly suggests that debate over ocean dumping will remain alive and, in fact, intensify. Whether policy makers will prove capable of responding effectively to these challenges will depend on their capacity to appreciate the myriad scientific, legal, political, social, and economic matters they raise. This and the adoption of a precautionary approach to decision making are key steps to developing sound policies on radioactive dumping.

John Lamb is Executive Director of the Canadian Centre for Global Security, Ottawa, Canada, and served as Chairman of the Working Group on Legal, Economic, and Policy Priorities of the Conference on Radioactivity and Environmental Security in the Oceans held at Woods Hole Oceanographic Institution June 7 to 9, 1993. Peter Gizewski is a Research Associate at the Centre, and teaches in the Department of Political Science, Carleton University, Ottawa, Canada. This article is based on the proceedings of the Working Group.

Ocean Frontiers

Explorations by Oceanographers on Five Continents



Edited by Elisabeth Mann Borgese, 1992. Harry N. Abrams, New York, NY. 288 pp. - $49.50.

Ocean Frontiers describes in detail the history and current programs of 12 oceanographic institutions around the world. Numerous photographs and other color illustrations convey a sense of excitement and immediacy to the scientific topics described.

This institutional view of ocean science complements the dry, bare-bones explanation of science found in most textbooks. To a large extent, personalities drive the founding of new institutions, and ocean science has been rich with strong men and women and their ideas about institutions.

It is fitting that the book is dedicated to Roger Revelle. Revelle had broad interests in ocean and earth science, and one of his lifelong concerns was the development of new oceanographic institutions. Under Revelle, Scripps served as a breeding ground for oceanographers who would become directors of new institutions.

The book provides short histories and descriptions of oceanographic institutions on five continents and in eleven countries: North and South America are represented by Canada, the US, Mexico, and Peru; Europe by Monaco and Germany; Africa by Kenya; and Asia by Japan, China, India, and Russia. Notably absent are some major institutions, such as the Institute of Oceanographic Sciences in the UK and several institutes in France and the US that are just as important as those reviewed; it would have been useful and interesting to have short accounts of those institutions as well. A second edition, focusing on other institutions, might well be considered.

But in spite of the limited coverage, the reviews, which in some cases are written by the principal and central figures themselves, offer a kaleidoscope of research activities and show why so many oceanographers love their profession. It is interesting to note the fisheries/marine biology origin of many institutions described, and how most of them have broadened to include other ocean-science disciplines.

Revelle's discussion of the name change from the Scripps Institution for Biological Research to the Scripps Institution of Oceanography by the first director, W.E. Ritter, is a good example of an early transition. Ritter felt strongly that the proper objects of biological research are whole organisms and their relationships with their environments. He envisioned that with its new name and aim, the Scripps Institution would concentrate on these relationships in the ocean realm, and it has indeed done so.

Not all the accounts can be described here, but a good example is the history of the Oceanographic Museum of Monaco, whose cornerstone was laid in 1899. It was officially inaugurated in 1910, when the museum had laboratories, a library, and display hall, and it gained prominence during Jacques-Yves Cousteau's directorship from 1957 to 1988. Gotthilf Hempel provides a lively description of the Alfred-Wegener Institute in Bremerhaven, which owes much to his personal interest and skills in institution building. Yunshan Qin tells the story of the State Oceanic Administration in Bejing, and there are striking photographs of the Institute of Oceanology at Quingdao and the Ocean Station at Xiaomai.

This book provides a vivid evocation of the evolution of oceanographic institutions and of the way ocean science is done throughout the world. I would say it should be required reading for all new graduate students in oceanography and for many professionals in the field as well.

—D. James Baker
Undersecretary of Commerce for Oceans and Atmosphere and Administrator, NOAA

On the Surface

By Randy Olson, 1993. Prairie Starfish Productions, Lake Quivira, KS. 40 minute video - $39.95.

"Do what sets you on fire," Ruth Turner said. And I said to myself, "Aha, that's right!"

I was watching, totally fascinated, Randy Olson's latest video about the sea, *On the Surface*. Turner, one of three women marine biologists featured in the video, was responding to a question about what advice she would give students contemplating a career in scientific research.

Randy Olson has done it again. Already a successful marine biologist (Assistant Professor of Zoology, University of New Hampshire) and award-winning videographer, Olson has created another stimulating and intriguing account of his passion, the sea. This time he turns his attention to the deep sea, and the work of three deep-sea specialists, who happen to be women.

Ruth Turner, now professor emeritus at Harvard University, was the first woman to make a deep dive in *Alvin*, Woods Hole Oceanographic Institution's research submersible. Clearly highly motivated and determined in her youth, she is still vigorous in her late seventies, and continues to share her excitement about science with her colleagues and students. Thanks to Olson, Turner has a chance to share her wisdom with us, too.

Colleen Cavanaugh was one of her most exemplary students: Brilliant and exuberant, her work in graduate school showed that the vent animals, such as giant tube worms, depend on their symbiotic chemosynthetic bacteria for energy, rather than on food from sunlight. A former music major, Cavanaugh mentions being inspired by a college professor who encouraged her to do her own thinking. "I never knew I could do that," she remarks candidly.

What a gift Randy has given us, particularly young people contemplating career choices and lifestyles. His gentle, yet probing inquiries prompt fascinating comments, and leave the audience wanting to hear and learn more about just what's "on the surface." Why is Colleen so passionate about lowly bacteria, which she says "keep everything going?" What were the political hoops she needed to jump through in her struggle to convince skeptics of her radical scientific beliefs? How does she juggle a time-consuming, successful career at Harvard and marriage to another equally successful research scientist?

The third participant in the video discussion is another especially wonderful choice, showing not only the range of possibilities for career paths in science, but also the range of personalities in scientists. Cindy Van Dover, a researcher at the Woods Hole Oceanographic Institution and the only woman ever to pilot *Alvin*, earned certification despite the grueling training required. Although her style is calm and reserved, she vividly conveys the excitement she has experienced firsthand, diving and driving into the dangerous depths of a volcanic rift, right where the plates are actually parting! Unpretentiously perched on a couch, barefoot and with her knees curled up, her style obliterates any possible misconceptions about dull, arrogant, and creepy scientists in white lab coats.

No dull, creepy scientist himself, Olson demonstrates his knack for bridging the gap between scientist and nonscientist. He

ingeniously intersperses the 11 different segments of the video discussion (such as "Scientific Tediousness," "Future Discovery," and "Homelife") with thought-provoking facts about the submersible (such as vent temperature of 350°C, but window-melt temperature of 80°C) and remarkable footage (such as black smokers and vent creatures—one typical sequence shows the dancing descent of a deep-sea crab, accompanied by Olson's original and whimsical musical score).

It is obvious that these three women are Olson's friends as well as his highly respected colleagues; his style and presence allow us to get close to them too. He makes it possible for them to show their curiosity about life, their love for their work, their genuine interest in future exploration, and their obvious affection for one another. Although it is clear that success in any career, whether for women or men, whether in science, tennis, Afro-Brazilian dance, or koto-playing, truly requires fire and determination, it is also clear that there can be lots of help and encouragement along the way.

This video is sure to spark interest among high school and college students, educators, professional women—anyone interested in the deep sea and marine biology. Olson has taken a potentially difficult subject and made it accessible. Even more importantly, it appeals to teenagers! I worry as I watch young girls in my Boston neighborhood still trying to be dumber than their boyfriends, still worrying about being pretty enough, still worrying about fitting in. I showed this video to a neighbor, and her heart-warming comment to me was, "Gee, I'd really like to meet one of them."

Thank you, Randy Olson, for doing what sets *you* on fire!

—Katy Muzik
Marine Biologist/Tropical Octocorals
On Leave from Harvard Museum of Comparative Zoology

Dangerous Aquatic Animals of the World: A Color Atlas

By Bruce W. Halstead, MD, in collaboration with Paul S. Auerbach, MD, 1992. The Darwin Press, Inc., Princeton, NJ. 283 pp. - $60.00.

Anyone who has ever set foot into the earth's aquatic environment, whether marine or freshwater in nature, has probably had visions of unknown peril lurking beneath the water's surface. Whether the concern is warranted or not, the perception that dangers exist, especially among beachgoers or occasional sport divers, is real and it is important that these fears be addressed.

In *Dangerous Aquatic Animals of the World: A Color Atlas*, author Bruce W. Halstead provides a very readable means to educate ourselves about the potential risks posed by aquatic animals when we enter their world. The book is bountifully illustrated with 521 plates (mostly in color), numerous figures and diagrams, and 11 color maps depicting distributions of some of the more globally occurring aquatic animal hazards. The bulk of the text is devoted to descriptions of aquatic animals that are able to inflict a wound, those that sting by injecting a venom or releasing a stinging poison, those that are poisonous to eat, and those that emit electrical discharges.

If all this sounds familiar, it should, for this is the most recent of several books by the author on essentially the same topic. Beginning in 1959 with *Dangerous Marine Animals*, followed by the classic three volume *Poisonous and Venomous Marine Animals of the World* (Vol. 1, 1965; Vol. 2, 1967; Vol. 3, 1970) encompassing more than 1,000 pages per volume, Halstead unquestionably established himself as a leading authority in the field. By 1978, the

author had condensed three volumes of information to a single-volume revised edition of some 1,043 pages, and, by 1988, a second revised edition of 1,168 pages of text, plus 288 pages of plates. Shorter versions of approximately 200 pages appeared as *Dangerous Marine Animals* in 1980 and as *A Color Atlas of Dangerous Marine Animals* in 1990.

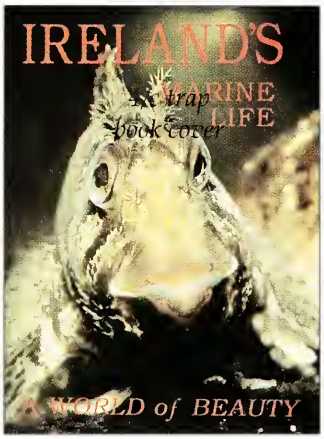
Much of the text and many of the diagrams and plates found in this newest book are taken directly from the earlier works. However, by expanding to aquatic animals instead of limiting the scope to the marine arena, the current title allows for the inclusion of animals not considered previously. As a result, the reader is reminded that freshwater rivers, streams, and lakes of the world can be home to venomous snakes, ferocious crocodilians, toxin-laden toads, frogs, and salamanders, and poisonous waterbugs, not to mention sting rays, catfish, and piranhas. Also included are fascinating sections addressing the little-publicized dangers of the duck-billed platypus and human parasitic catfish.

Perhaps the most useful section is an expanded appendix dealing with prevention, first aid, and emergency treatment procedures, assembled in collaboration with Paul S. Auerbach, MD. This appears to be one of the most comprehensive attempts presently available at addressing the practical aspects of what to do when bitten, stung, or poisoned by one of many aquatic denizens.

The splendid blend of informative text, stunning photographs, practical measures for dealing with actual encounters, and suggested readings (rather than exhaustive reference lists) makes this book a desirable acquisition for a broad range of potential buyers.

—Carl A. Luer
Senior Scientist and Coordinator
Marine Biomedical Research
Mote Marine Laboratory

Ireland's Marine Life— A World of Beauty



trap book cover

Paul and Susan Murphy, 1992. Sherkin Island Marine Station Publishers, County Cork, Ireland. 158 pp. - $17.99.

This work portrays the uncommon talents of underwater photographer Paul Kay, and is edited by Sherkin Island Marine Station's Director, Matt Murphy, and his daughter, Susan. The array of colorful close-up photographs of marine animals in their natural environment along Ireland's coast should be a delight to all who have an interest in nearshore marine organisms, particularly a photographic interest. While the fishes and invertebrates depicted are native to Ireland's shores, and the book is therefore a bonus for Ireland's readers, each species has its counterpart in the temperate waters of other Northern Hemisphere countries. Thus, the volume is likely to have a wider, international appeal.

Aside from the scientific and common names of animals pictured, along with an occasional comment regarding a particular creature's habitat or habits, the book is free of narrative. As a result, the "reader" need experience only its pure pictorial pleasure. A number of the photographs appear to have been taken at night and within inches of their living subjects, which presents the viewer with a host of detail not ordinarily available. The reader would do well to keep in mind that photographer Kay did his work in cold waters of the North Atlantic that ordinarily lack the

ginlike clarity of the Caribbean, a factor that renders the pictures that much more remarkable. In addition, I'm certain that some will attach anthropocentric values to the "expressions" notable on several of the fishes and invertebrates; I was tempted...almost.

This book deserves to be seen by young readers as well as adults, and should find a home on many coffee tables or easily accessed bookcases. I recommend it as an excellent and unique gift for anyone inquisitive about the ocean's living secrets.

—David Crestin
Deputy Director
National Marine Fisheries Service, NOAA

Coming Up Next...

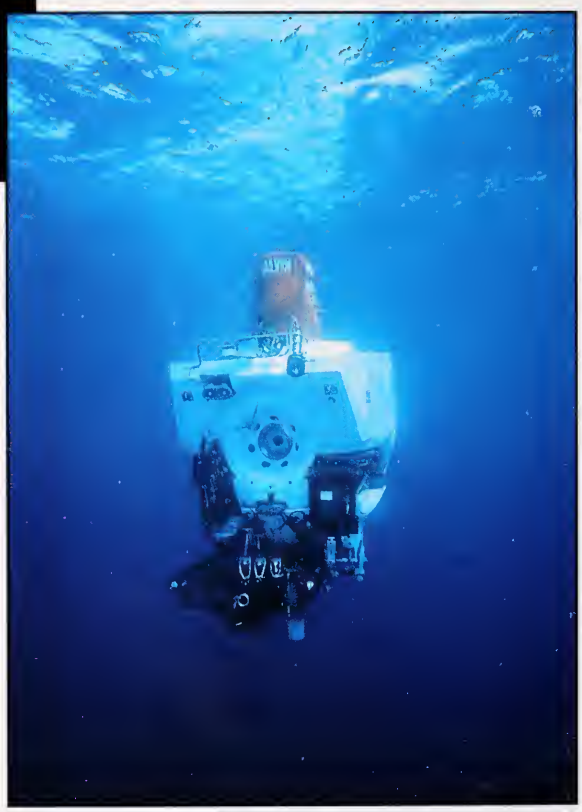
25 Years of Ocean Drilling

(Volume 36, Number 4, Winter 1993/94)

More than 35 Ocean Drilling Program scientists share the excitement and the advances of this program and its predecessor, the Deep Sea Drilling Program. Join us for intriguing glimpses of new knowledge gleaned from deep beneath the seafloor.

Explore Educational Programs at Woods Hole Oceanographic Institution

Applied Ocean Sciences & Engineering, Biology, Chemistry, Geology & Geophysics, Physical Oceanography... Postdoctoral Awards, Summer Student Fellowships, Research Fellowships, Summer Study and more...



With a commitment to the future, the Woods Hole Oceanographic Institution, one of the world's leading oceanographic centers, offers unique experiences in graduate and post-graduate studies. WHOI sponsors numerous fellowship and traineeship programs, and offers graduate degrees through a Joint Program with the Massachusetts Institute of Technology, providing a first-rate education through both hands-on experience and classroom instruction by many of the world's leading oceanographers. WHOI also offers select educational outreach programs for the K-12 grades. Find out today what WHOI can do for you.

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