# Benefits of Geographic Information Systems for State and Regional Ocean Management

FINAL REPORT
to the
Coastal Services Center
National Oceanic and Atmospheric Administration
Charleston, South Carolina

James W. Good
and
Derek Sowers

Oregon Sea Grant
and the
Marine Resource Management Program
College of Oceanic and Atmospheric Sciences
Oregon State University

October 1999

Mailing Address:

College of Oceanic and Atmospheric Sciences
104 Ocean Administration Building
Oregon State University
Corvallis, Oregon 97331-5503

Phone: 541/737-1339
FAX: 541/737-2064

E-mail: good@oce.orst.edu

Cite as: Good, J.W. and D. Sowers. 1999. *Benefits of Geographic Information Systems for State and Regional Ocean Management*. Final Report to the Coastal Services Center, National Oceanic and Atmospheric Administration. Corvallis, OR: Oregon State University

**Acknowledgments**

Many individuals contributed to the completion of this project and report. We especially thank the state coastal and ocean managers who spent time with us on the phone, providing much of the basis for our state profiles and subsequent analysis. Thanks also to those who attended the special interest group meeting at Coastal Geotools '99 conference in Charleston, SC. We got a great deal out of the face-to-face dialogue with the coastal and ocean managers and scientists present. To Rob Neely, Eric Treml, and Cindy Fowler, staff at the NOAA Coastal Services, we also owe a great debt of thanks for their support and advice throughout the project. We also appreciate the advice and critique provided by staff of the Federal Geographic Data Committee at the Portland conference.

This work was supported through a subcontract with the NOAA Coastal Services Center. The original source of funds was a U.S. Geological Survey, Federal Geographic Data Committee to the NOAA Coastal Services Center. The views expressed herein are those of the authors and do not necessarily reflect the views of NOAA, any of its sub-agencies, or the FGDC.

Jim Good and Derek Sowers
Oregon State University

# Table of Contents

# List of Figures and Tables

# Executive Summary

The principal goal of this study was to determine the potential benefits of using Geographic Information Systems (GIS) to manage marine resources and ocean space, emphasizing state ocean interests. We also wanted to know how these benefits might foster more integration in ocean management, as well as more equity, efficiency, and effectiveness in decision making. Another question was the perceived value and utility of the regional approaches, such as the Southeast Ocean Planning Information System (OPIS), versus less ambitious, more limited geographic area approaches. The role of the Internet in GIS data sharing was also of interest, given the exponential growth in its use over the last decade and expected growth in the future.

To answer these questions, we developed 23 coastal state “profiles” on ocean management activities and GIS use, based on literature review and interviews of key state personnel. Two states that illustrated a range of ocean management activism were selected for more in-depth cases (Maine and Florida), along with the regional Southeast OPIS. Because of its proximity to the researchers, Oregon was also examined in more depth than other states, but was not the subject of a full case study. In addition, a special workshop in conjunction with the conference, Coastal Geotools 99, was held to get face-to-face perspectives and examples to supplement the interview and case study process.

**PRINCIPAL FINDINGS**

<u>State Ocean Interests and Influence Increasing</u> - State interest in and influence over the management of marine resources and ocean space has increased in recent decades and this trend is likely to continue, albeit slowly.

<u>State and Federal Interests Offshore Differ</u> - State interests in ocean management have some inherent differences from federal agency interests, both in character and degree; consequently, the perceived roles of ocean GIS for information management and decision-support are different.

<u>State Management Capacity Growing Slowly</u> - Many coastal states are gradually improving their institutional capacity for participation in ocean management and virtually all claim interest in doing so—this trend will stimulate interest in state and regional ocean GIS.

<u>State GIS Technical Capacity Strong</u> - State coastal management agencies, and other sectoral management agencies with coastal and marine resource management responsibilities, have significant and growing technical capacity and resources to develop GIS applications and provide Internet information services.

<u>GIS Benefits Ocean Management</u> - The potential benefits of GIS for ocean management are deep and widespread, accruing to policy-makers, resource planners and managers from all marine sectors at all governmental levels, users of marine resources and ocean space, marine scientists of different disciplines, nongovernmental interest groups of every stripe, and the public at large, including youth.

Some benefits of GIS are:
- integrates scientific and technical, ocean use, and ocean governance data in one geo-referenced system.
- integrates scientific research planning with ocean management needs.
- centrally stores, organizes, documents, and makes accessible data from many sources.
- informs and empowers stakeholders and the public to be more knowledgeable and involved in decisions that affect them, a benefit much enhanced by Internet access to data and maps.
- clarifies and gives visual geographic representation to ocean jurisdictions, boundaries, and authorities.
- clarifies and helps resolve disputes and conflicts by allowing visualization of interactions, problems, and potential solutions.
- supports planning for complex, inter-jurisdictional issues at regional, limited-area, and site-specific scales by integrating diverse ecological, human use, and governance data.
- analyzes project-specific and cumulative environmental effects.
- monitors data on indicators of marine ecosystem health.
- evaluates outcomes to determine decision equity, efficiency, and effectiveness relative to policy goals and objectives.

GIS Fosters Integration, Equity, Efficiency, and Effectiveness – The use of GIS for ocean management, and the benefits it confers, will lead to more integrated marine policy and management. It will also increase equity, efficiency, and effectiveness in marine resource and ocean area management.

Barriers to Ocean GIS Implementation – Significant financial, institutional, scientific, technical, and cultural barriers and limitations impede the development and implementation of state and regional ocean GIS. These include:

- the significant initial cost of ocean GIS.
- the uncertainty about future maintenance and its costs.
- fragmentation in ocean management at state and national levels.
- a disjunction between the kinds of oceanographic and marine ecosystem data that scientists produce (often three- or four-dimensional) and the present technical capacity of GIS to integrate and display that data.
- difficulty gaining the attention of high-level managers and policy makers needed to win financial support for GIS development.
- limited technical training of coastal managers on marine science and issues.
- limited understanding within the science community of ocean management and ocean GIS information and research needs.
- low priority of ocean management and GIS for staff time and/or financial resources at the state level, relative to other coastal issues.

## RECOMMENDATIONS

1. National Framework for Regional Ocean GIS – The National Oceanic and Atmospheric Administration (NOAA) should develop a regional ocean GIS framework based principally on large marine ecosystems (LMEs).

   Forty-nine LMEs have been identified globally, with U.S. waters comprising all or parts of seven. Development of such a regional LME-based framework for ocean GIS (and ultimately ocean management) is logically a role for NOAA, as the nation's lead ocean agency. Such a framework might also have other benefits, such as focusing research efforts, fostering increased standardization of data collection and reporting protocols, providing a regional ocean framework for the National Spatial Data Infrastructure (NSDI), and better integrating the growing state ocean management community with existing ocean data and information agencies.

2. Expand Ecosystem and Human Use Components of Ocean GIS – The NOAA Coastal Services Center should more fully develop the *marine ecosystem* and *human use* components to the regional ocean GIS.

   The *ocean policy* or governance component of the Southeast OPIS is central to a regional ocean GIS designed to advance or support more integrated policy and management. However, the *marine ecosystem* and *human use* components are relatively weak and indistinct, being mainly focused on particular demonstration scenarios. To be truly useful for the range of area planning and policy applications one might envision, however, these latter two components need to be given equal weight and be more fully developed.

3. Regional GIS – NOAA should continue to develop Southeast region ocean GIS, market the concept broadly, and initiate a second demonstration project, either on the West Coast or Gulf Coast.

   Continued development of the Southeast ocean GIS is important, with additions or enhancements suggested here; a second regional ocean GIS should also be undertaken to increase the potential for learning that a very different region would provide, and to advance the concept generally.

4. Nested Local-Regional Ocean GIS – NOAA should further develop the "nested" ocean GIS concept and evaluate its technical feasibility and practicality.

   The interests and needs of state and federal ocean managers overlap, but there are clear differences as well. States find large-scale, high-resolution GIS applications more useful than small-scale, lower resolution regional applications (at least conceptually, since few have much experience with either). We recommend exploration of the concept of nesting large-scale GIS applications within regional-scale ocean GIS.

5. Marketing Regional Ocean GIS - NOAA should develop a strategic plan for marketing the regional ocean GIS concept to coastal states, its federal partners, and to policy makers at both levels.

   Despite its substantial benefits, regional ocean GIS needs "customers" to be viable. NOAA should continue its proactive marketing of the regional ocean GIS concept. However, to more sharply focus those efforts, NOAA should consciously develop a strategic plan for promoting and developing regional ocean GIS for *all* U.S. waters.

6. Incorporating Multi-dimensional Marine Data - NOAA should lead an effort to increase the capacity of GIS to incorporate and analyze multi-dimensional (x, y, z, time) oceanographic, marine resource, and human use data.

   For GIS to realize its potential as an ocean research, planning, and management tool, it must be able to incorporate and analyze data in three and four dimensions. NOAA should sponsor a workshop that brings together marine scientists and ocean managers to explore GIS needs and opportunities for incorporating multi-dimensional marine information. NOAA should also consider supporting needed research and demonstration projects in this arena.

“A dark, illimitable ocean without bound, without dimension, where length, breadth, height, and time and place are lost…”

John Milton, *Paradise Lost*, 1667

## INTRODUCTION

When Milton penned these words more than three centuries ago, he certainly could not have imagined the extent to which the ocean would be explored, measured, sounded, fought over, fished, mined, drilled, violated by wastes, and ultimately carved up and “managed” by the nation states of the world. Technological advances in the 20th century have taken us from the industrial era to the information age, bringing the depths of the ocean and its inhabitants into our living rooms, raising our harvest efficiency for some marine resources to near-extinction levels, and providing the capacity to tap ever-deeper ocean area reserves of oil, gas, and minerals. Technology is driving ocean research and knowledge to new heights and depths: satellites and other remote sensors are providing quality data in quantities never imagined just three decades ago, and submersibles are taking researchers to depths where new ocean crust being formed and to environments where they observe and sample hitherto unknown ecosystems.

As a result of these technological advances, we are learning more and more about the oceans—their bounty as well as their limits and vulnerabilities. At the same time, we are often awash in data and often not able to use it as efficiently and effectively as we might for managing ocean resources. Data translation and communication are at the heart of the problem. Two information age technologies that are just beginning to be used for ocean management and decision making—geographic information systems (GIS) and the Internet—are potential solutions.

GIS, with its capacity to store, organize, and analyze geographically-referenced data, has seen widespread use for land-based natural resource management, but only minor use offshore. This is in part because the ocean science community, dealing with research questions in four dimensions (x, y, z, time), has yet to see its utility for data visualization and analysis. This is changing slowly, however, as GIS researchers and oceanographers who are pioneering the use of marine GIS begin to address dimensionality issues. The ocean policy and management communities confront the same issues. GIS is being used for ocean management for relatively small areas (e.g., marine protected areas) and for management of single resources (e.g., groundfish), but these applications are limited by their geographic coverage or narrow focus.

One reason for the slow adoption of GIS and Internet delivery of ocean data and information in the United States is that we lack the national policy and institutional framework that would require it. Absent such a framework, federal and state agencies with management responsibilities for this resource or that activity operate within relatively narrow parameters, constrained by legal authority, financial resources, data availability, and tradition. The outlook for modernization of national ocean policy and institutions is uncertain. Great effort was made in 1998—the International Year of the Ocean—to pass legislation establishing a national commission to study policy integration needs, but it failed, as have similar efforts in recent years (Archer 1999). Blueprints for a new national ocean policy have been produced—the latest by a 1997 National Research Council panel on ocean governance (NRC 1997). Despite significant support, the inability of Congress to pass ocean policy legislation suggests that other avenues for rationalizing the complexities of ocean issues and management must be explored. Building on existing institutions where federal-state partnerships are strong and tested—one of the NRC study recommendations—is one such approach. Improving access to data and information useful for ocean governance and management is another, complementary, strategy.

This report examines the benefits (and potential benefits) of using GIS and Internet technologies as tools for improving the management of marine areas, resources, and activities. Improved access to ocean data and information, and increased efficiency and effectiveness in decision making are examples of such benefits. Although the federal government has primary jurisdiction over most of the United States Exclusive Economic Zone (EEZ) area, resources, and uses, the principal focus of this study was on state interests, activities, and initiatives in using GIS for ocean management. In part, this is because states have primary management authority for resources within the 3-nautical mile territorial sea, as well as the adjacent coastal lands and waters, areas rich in marine resources and strongly linked to offshore ecosystem health. States also have a large say in what happens in the EEZ, through their state coastal management programs and other federal laws that require state consultation and sometimes concurrence on EEZ activities.

The main impetus for this project comes from the National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center (CSC), who has been working for several years on a prototype regional Ocean Planning Information System (OPIS) for the Southeast United States—North and South Carolina, Georgia, and Florida are collaborators. The OPIS is supported in part by the by the Federal Geographic Data Committee (FGDC), as part of the development of the National Spatial Data Infrastructure (NSDI). FGDC also has a "benefits assessment" component to evaluate the efficacy of its various initiatives—improved equity, efficiency, and effectiveness are its goals. The FGDC benefits assessment program meets the CSC's need for an independent evaluation of the usefulness of the Southeast OPIS. Key questions for the OPIS include: How useful is it and is it worth the time and investment? Might similar efforts be warranted elsewhere in the U.S.? What improvements might make it more useful? However, because many other states and regions also have ocean interests and needs for improved ocean data and information sharing, all 23 coastal states bordering on the U.S. EEZ were included in the benefits study. The CSC subcontracted with Oregon State University to conduct the benefits assessment.

The overarching question we address in this report is whether GIS (and GIS data delivery via the Internet) can improve access to ocean data and information, increase efficiency and effectiveness in decision making, and thereby foster more integrated ocean management.

## BACKGROUND ON OCEAN MANAGEMENT AND GIS

Assessing the potential benefits of using GIS and innovative data delivery technologies for ocean management requires some context setting. How is GIS used for natural resource management generally? How are marine areas and resources managed today and how did we get to this point? What is the nature of resource management conflicts offshore? What do policy entrepreneurs mean when they say we need "more integrated management" and what specific proposals are being made? How are ocean data and information used now and who has access to that information? To what extent and how are GIS and new information-sharing technologies being used for ocean area and resource management today and what are future possibilities, given the nature of the marine environment and issues? Each of these questions are addressed below.

**GIS and Natural Resource Management**

GIS is widely recognized as a powerful tool for organizing and analyzing natural resource information. It has become an indispensable tool for coastal zone management, land use planning, regulatory program administration, resource inventories, and many other applications. Although marine applications have lagged behind for a variety of reasons, discussed later, a number of the general capabilities make GIS potentially attractive for offshore use:

- allows integration and storage of large diverse data sets and mapped information.
- assists area planning for various purposes at various scales.
- aids identification of conflicting uses, resource threats, and management opportunities enables assessment of environmental, social, and economic impacts of proposed development.
- supports regulatory and permitting activities by tracking geographically relevant information over time.
- provides a means by which to assess cumulative impacts and resource trends over time.
- enhances the effectiveness of public education and outreach efforts by representing scientific and regulatory information in a more comprehensible form (maps).
- fosters greater public involvement in resource planning and decision-making by making data available and understandable.
- improves conceptualization of spatial relationships between various ocean uses and resources.
- provides powerful analytical capabilities for better understanding or modeling interactions and processes of the marine environment .
- supports better informed decision making by resource managers.
- in conjunction with Internet and map-serving software, it provides a basis for improved user access to data and the means to independently analyze it.

Despite these many attributes of GIS and their potential utility in the management of marine areas, resources, and activities, the adoption of GIS for ocean management has been slow, particularly at the state level. States have limited resources and capacity, and do not perceive the need or benefits of investing now for some future benefit. The ocean management community in most states is small and relatively low profile. Land-based problems are perceived as more pressing and are certainly more visible than most ocean issues, barring the occasional oil spill, whale beaching, or beach closure due to pollution. The limited use of GIS by ocean scientists because of dimensionality problems is another factor, referred to earlier. Ocean managers deal with the same limitations, using GIS for limited area or single resource applications. Moving beyond these and other limitations is one of the objectives for the Southeast OPIS.

**U.S. Marine Resource Management and its Roots**

Marine resources and ocean space in the United States' territorial and EEZ waters are governed through a panoply of overlapping international, federal, state, and local authorities, institutions, and management regimes. Complexity and fragmentation are among the chief characteristics of these mostly single-purpose regimes, both among and within governmental levels (Cicin-Sain and Knecht 1985, NRC 1997). Resource management regimes, principal agencies involved at the U.S. federal level, and coastal and ocean jurisdictional and ownership boundaries begin to illustrate the problem (**Table 1** and **Figure 1**). Similar tables illustrating fragmentation of ocean decision-making could also be constructed for most coastal states. Policy goals and objectives, as well as decision-making criteria, where there are any, also vary and sometimes conflict. Complicating the management of marine areas and resources are a host of conflicted user groups and trade organizations, often aligned with and supporting the bureaucratic power structure of the agency managing "their resource" or "activity." Other interest groups and the public are also involved, with diverse avenues and strategies for pursuing their goals. Marine resource management over the last several decades has thus become increasingly fractious, contentious, litigious, and politically charged. Few winners have emerged; instead, distrust, strained relationships, and competing goals and programs characterize the ocean user and management communities today.

The roots of this fragmented, poorly coordinated ocean management system lie in decisions made more than a half century ago, nicely summarized by Armstrong and Ryner (1981). Prior to 1937, the territorial sea was the only offshore "zone", with state ownership of resources. Oil and gas development was underway offshore in California and the Gulf of Mexico and commercial fisheries were expanding. Federal interests were limited to protecting free commerce, navigation and national security. That began to change in 1937 when the Department of Interior, seeing an opportunity to tap into a large new revenue source in Outer Continental Shelf (OCS) oil and gas royalties, asserted federal authority over territorial sea resources. Concern over rapidly-expanding foreign fisheries near U.S. coasts also attracted federal attention—a fisheries management regime similar to what we have today was even proposed by Roosevelt, but the war intervened.

A *National Marine Resources Policy Study*, completed in 1945, settled a federal interagency conflict that had been brewing since the late 1930s (while ignoring state interests). The resource-oriented Department of Interior wanted greater control over offshore space and resources. The Departments of State and War, on the other head, were concerned about the foreign policy and security implications of such actions. The compromise laid out in the study established the two separate regimes that serve as the foundation for present-day ocean governance. Submerged lands of the continental shelf were to be managed under a "single management regime", with oil and gas and other submerged land resources under the "sovereign control" of the U.S. For ocean waters, the unit of management would be individual resources or activities—fisheries were to be managed separately. Waters would remain "high seas." This framework was implemented by the Truman Proclamations on the Continental Shelf and on Fisheries in September, 1945.

Between 1945 and 1953, states sought to get back some rights in ocean resources. Congress passed legislation returning control of the territorial sea resources to the states, but Truman vetoed it. Offshore control thus became an issue in the 1952 presidential election issue. The Republicans, who took up the states' cause, won in 1952 and subsequently passed two cornerstones of U.S. ocean policy in 1953—the *Submerged Lands Act* (SLA), which resolved the territorial sea control issue in favor of the states; and the *Outer Continental Shelf Lands Act* (OCSLA), which legislatively implemented the remainder of the Truman Proclamations.

The 1950s and 1960s saw dramatic expansion of U.S. oceanography, increased Cold War tensions, and in 1966, the formation of the Stratton Commission. That commission's recommendations, and the environmental movement that emerged soon after, led to the establishment of NOAA and passage of much of the legislation that provides the underpinnings for ocean management today—the Coastal Zone Management Act (CZMA), Marine Protection, Resource, and Sanctuaries Act (MPRSA), which established the ocean dumping and marine

Table 1. Federal governance regimes, principal authorities, and key agencies for U.S. marine areas and resources.

| Governance Regime | Laws and Authorities | Key Dates | Principal Agencies |
|---|---|---|---|
| State-Federal Relations and Offshore Jurisdiction | Submerged Lands Act (SLA) | 1953 | State agencies |
| | Outer Continental Shelf Lands Act (OCSLA) | 1953; 1978 | DOI (MMS, USGS) |
| | National Environmental Policy Act (NEPA) | 1969 | All federal agency actions |
| | Coastal Zone Management Act (CZMA) | 1972; 1980; 1990 | NOAA, State coastal agencies |
| Living Resources Management | Fisheries Conservation and Management Act (FCMA) | 1976 | NOAA-National Marine Fisheries Service (NMFS), Regional Fishery Management Councils |
| | Marine Mammal Protection Act (MMPA) | 1972 | NMFS |
| | Endangered Species Act (ESA) | 1973 | NMFS, USDOI-Fish and Wildlife Service [USFWS]) |
| Non-Living Resources Management | OCSLA Amendments (oil and gas) | 1978 | USDOI (MMS) |
| | Deep Seabed Hard Mineral Resources Act (DSHMRA) | 1980 | NOAA, Ocean and Coastal Resources Management (OCRM) |
| | OCSLA Section 8(k) (mining) [1] | 1978 | USDOI (MMS) |
| Waste Disposal and Management | Ocean Dumping Act (ODA) (transport and dumping) | 1972 | U.S. Environmental Protection Agency (EPA); US Army Corps of Engineers (USACE) |
| | Clean Water Act (CWA) (pipeline discharges) | 1972 | U.S. Environmental Protection Agency (EPA); US Army Corps of Engineers (USACE); State agencies |
| | MARPOL[2] (plastics and non-biodegradable wastes) | 1973/1978 | U.S. Coast Guard |
| Oil Spills | Oil Pollution Act of 1990 | 1990 | U.S. Coast Guard, states, shippers |
| Comprehensive Ocean Management[3] | National Marine Sanctuaries Act (MSA) | 1972; 1980 | NOAA-OCRM |
| | State Initiatives: CZMA and State coastal management programs (CMPs) | 1972; 1980; 1990 | NOAA-OCRM; State CMPs |

[1] National Seabed Hard Minerals Act was proposed in 1987 for continental shelf mining that mirrored the deep seabed regime in the DSHMRA .

[2] MARPOL is the International Convention on the Prevention of Pollution from Ships, and is implemented in separate U.S. legislation on disposal of plastics and other non-biodegradable wastes.

[3] There have been several EEZ management proposals introduced in Congress, but none have passed.

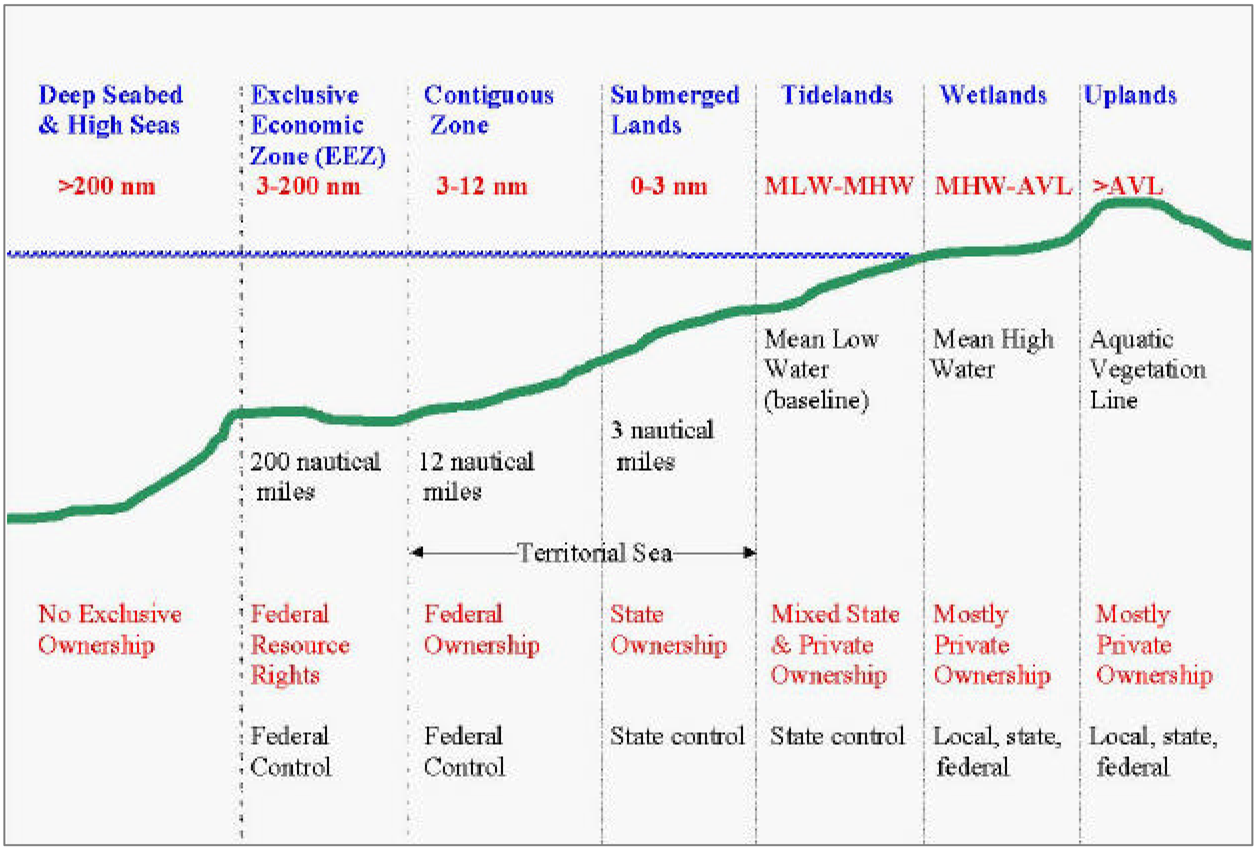


Figure 1. Ownership and jurisdiction in United States coastal and ocean areas.

sanctuary programs, Clean Water Act (CWA) amendments, and Fisheries Conservation and Management Act (FCMA). Each of the independent management regimes established by these laws worked fairly well early on, with significant bipartisan political and interagency cooperation. But political polarization and increasing conflicts among federal agencies with different missions, and among states and the federal government, better characterize the management of marine areas and resources in the 1980s and 1990s.

Since the 1983 presidential executive order proclaiming a 200-nautical-mile United States Exclusive Economic Zone (EEZ), policy specialists from academia, nongovernmental organizations, ocean interest groups, and NOAA have been calling for the establishment of a more comprehensive, integrated "national ocean policy" (see, for example, Cicin-Sain and Knecht 1985; Eichenberg and Archer 1987; Juda 1987; Archer 1989; Knecht, Cicin-Sain, and Archer 1988; Juda and Burroughs 1990; Hildreth 1991; NRC 1992; NRC 1997). The impetus for these calls comes from years of frustrations, conflicts, and inefficiencies generated by the system of ocean governance that has evolved, layer upon layer, over the last half century. Designed for a simpler era when ocean interests were relatively few and well-defined, this principally sector-based system of ocean governance is inefficient and ineffective for today's ocean decision-making situations. This patchwork system of ocean governance has few effective mechanisms for rationalizing the needs and interests of multiple users of renewable and nonrenewable resources; of national, state, and local governmental interests, and the concerns of conservationists and other nongovernmental organizations; and of a national citizenry that is both fascinated by and concerned about the future of both the world oceans and the marine environments just off their coasts.

**Conflicts in U.S. Marine Resource Management**

Growing conflicts and politicization of offshore decision making is one factor behind calls for a new national ocean policy. Specific classes and examples of these conflicts are discussed below. Given the primary goal of this report—to assess how GIS might facilitate more collaborative, integrated management—these examples begin to suggest some of the potential benefits for improved ocean management.

Archer (1989) characterized several state-federal intergovernmental examples of marine resource conflict: management of fisheries that span state-federal jurisdictional boundaries; lack of coordination between federal managers and state interests for marine mammal management; state-federal disputes over ocean incineration; and finally, oil and gas leasing, exploration, and development on the OCS. The latter has probably been the greatest area of conflict, with a number of state-federal disputes—mostly on the west coast—being decided by the nation's highest court. Lester (1994), in a study of OCS oil and gas decision making for offshore California, describes the situation as one of policy incoherence, process breakdown, and deadlock. **Figure 2** illustrates agency and interest groups interrelationships in offshore decision making, providing some insight into the complex relationships and entry points to the fractious offshore process. Because this process tends to create rather than resolve conflicts, Congressional moratoria, budget notes, and similar blunt policy tools have been the main "management" techniques for offshore oil and gas over the last decade.

This failure of single purpose management regimes affects other sectors as well—implementation of the Fisheries Conservation and Management Act (FCMA), first passed in 1976, is another example. Both regional fishery management councils and the National Marine Fisheries Service (NMFS) have been criticized for their often adversarial relationships, and for their failure to control overfishing and bycatch of nontarget species (NRC 1999). The vulnerability of the fishery management process to delays and political influence has also been cited. Other problems include conflicts between fishery harvest and NMFS responsibilities for implementing the Endangered Species Act, and failure to protect critical habitat for commercially important species (NRC 1999). Similar lists of conflicts and policy failure could be drawn up for virtually all the single-purpose regimes for U.S. marine resources management.

Competing management regimes within a single use sector are another problem—ocean mining, for example. The Department of Interior, Minerals Management Service (MMS) regulates mining *within* the EEZ under the authority of a single paragraph in Section 8 (k) of the 1978 OCS Lands Act Amendments, where all U.S. mining proposals have been. NOAA, on the other hand, has a robust, comprehensive authority—the 1980 Deep Seabed Hard Mineral Resources Act—for mining *outside* the EEZ. No such proposals have been put forward in the two decades that law has been in place.

A final set of disputes—those among different management regimes and agencies—can be even more intractable. Examples include regulation or exclusion of oil and gas exploration in marine protected areas, and the establishment of no-take fishery areas to protect habitat. There are few if any established mechanisms to resolve such disputes, other than the courts or legislative bodies.

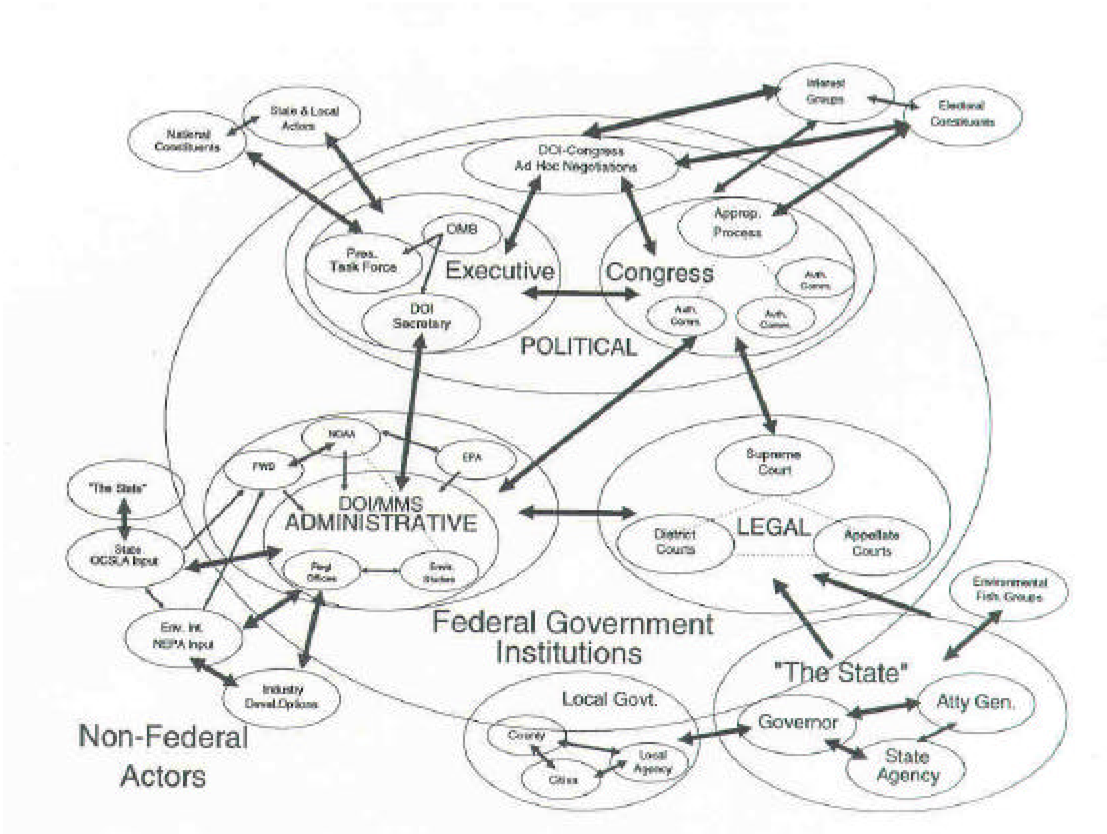



Figure 2. Complexities of the Outer Continental Shelf oil and gas policy system (Lester 1994).

**Increasing State Influence and Capacity for Ocean Management**

Another development relates to changes that have occurred in U.S. laws over the past three decades. States today have greater influence over ocean resources and uses than they did in the 1960s. They have also increased their capacity for ocean management through policy development and implementation activities (NRC 1997). Coastal zone management, oil pollution control, OCS oil and gas development, involvement in the governance of National Marine Sanctuaries, and fisheries management are all areas where states have growing influence (NRC 1997). Federal consistency, a provision of the 1972 Coastal Zone Management Act, is a prime example. Federal actions within the coastal zone (which in all cases extends to the limit of the 3-nm territorial sea) and federal activities outside the coastal zone (including the EEZ) that have a significant impact on the coastal zone must be consistent with state coastal policy to the maximum extent practicable. This provision has been largely responsible for the improvements in state-federal coordination that have developed, promoting early consultation and accommodation of state interests. The Oil Pollution Act of 1990, fallout from the 1989 Exxon Valdez oil spill, strengthened the states' hand in this arena as well, preserving states rights to enact even stricter controls to protect their waters and resources (Mitchell 1991). Another example is OCS oil and gas development; in all but a few areas, states, who were adamantly opposed to wholesale leasing efforts of the Reagan administration, won out, convincing Congress to block oil and gas development through moratoria and other means (Hershman et al. 1988). State influence in establishing National Marine Sanctuaries is cited as another example of increasing influence. Even though the NMS program is federal, state interests have used it to advance their goals, often increased environmental protection offshore. The “co-management” regime established for joint state-federal management of the Florida Keys NMS is cited as an example (NRC 1997).

In the past 15 years, some states have become actively engaged in independent ocean management efforts. The 1990 Coastal Zone Act Reauthorization Amendments (CZARA) provided additional impetus for this, requiring states to evaluate ocean resource issues, and if appropriate, develop strategies for improving their coastal programs to address these issues. Seven states identified ocean resources as a high priority issue in the CZARA-mandated process, five applied for project funding, and three (Massachusetts, Oregon, and North Carolina) actually received funding and carried out projects for ocean management program improvements (Bernd-Cohen et al. 1995). Oregon, for example, used these funds to conduct inventories and develop rocky shores management strategies for their Territorial Sea Management Plan (OPAC 1994). In their report on ocean governance, NRC (1997) listed ten states that can be considered “activists” because of efforts initiated to improve their capacity for ocean management—Alaska, California, Florida, Hawaii, Maine, Massachusetts, Mississippi, North Carolina, Oregon, and Washington.

The first and most important reason for state activism in ocean management was the threat of federal oil and gas leasing offshore—states used their powers under the OCSLA and the CZMA to force reconsideration of lease sales, mainly because of perceived threats to living resources and sensitive shoreline habitats, and the potential for adverse onshore impacts. State policy analyses of their ocean management capacity was another factor that was both a response to offshore development concerns and a stimulation for further activity. Proposals for mining strategic minerals in offshore placer deposits in state and federal waters were particularly galvanizing forces for Oregon (Good and Hildreth 1987). State legislative interest was high as well—the Western Legislative Conference, for example, appointed an Ocean Resource Committee, which in turn published *A Leadership Agenda: State Management of Ocean Resources* (Western Legislative Conference 1988). It is no accident that all five Pacific states are among the ten activists cited earlier.

Another explanation for increased state activism in ocean management is that it was part of a broader trend in the development of state capacity for environmental management (NRC 1997). This was stimulated in part by a several-decade trend toward a “new federalism,” wherein responsibility for administration of a variety of federal laws devolved to the states—state implementation of the Clean Water and Clean Air Acts are prime examples.

The results of these state ocean management efforts have been relatively modest. Several states have passed responsibility for ocean management among different agencies. Others have done little since initial policy studies. Oregon is one exception, having developed a legislatively-mandated ocean plan, and adopting it as part of state coastal management program, thus bringing federal consistency to bear with respect to plan policies for a “stewardship area” that encompasses the entire continental margin (ORMTF 1990). Interest in ocean management in Oregon has been sustained by issues surrounding tourism, nearshore rocky habitat degradation, a proposal for kelp leasing, poor ocean conditions for endangered salmon, and, most recently, severe constraints on groundfishing, associated community impacts, and proposals for marine reserves to protect the habitat of overfished species.

## Integrated Ocean Management and GIS

What do we mean by “Integrated Ocean Management” and what role might GIS play in fostering it? Marine policy specialists characterize today’s sectoral, resource- or activity-based controls as “marine resource management” to differentiate it from proposals for more comprehensive “ocean management” (Cicin-Sain et al. 1990). Ocean management in this sense is defined as area-based, multiple use, and integrated with respect to policy and institutions. The National Marine Sanctuary Program, particularly with regard to the large sanctuaries designated in the 1990s (e.g., Florida Keys, Monterey Bay, Olympic Coast) is sometimes cited as a model for this more integrated ocean management (Rote 1993).

What does “integration” mean in the context of marine policy and management? According to the *Random House Unabridged Dictionary*, it has to do with “the bringing together or incorporating the parts into a whole” (Flexner and Hauck 1993, 990). Underdahl (1980) defines integrated marine policy as policy that is comprehensive with respect to inputs—time, space, actors, and issues; aggregated with respect to decision making—evaluation considers all alternatives, interests, and perspectives; and consistent with respect to outputs—among and within policy levels. Considering the variety of actors, interests, space, issues, and interests offshore, policy and management integration can be seen to have at least five dimensions (Knecht and Archer 1993; Cicin-Sain and Knecht 1998):

***Intersectoral integration*** **–** between marine and coastal sectors (e.g., oil and gas development, fisheries, transportation, marine recreation, marine mammal protection), as well as between marine sectors and land-based sectors that directly and indirectly affect the ocean environment (e.g., agriculture, forestry, coastal development).

***Intergovernmental integration*** **–** within governmental levels (horizontally for sectoral agencies) and among levels (federal, state, local)

***Spatial integration*** **–** between the land and the ocean, from one part of coastal and ocean waters to others, and from the ocean surface to the seafloor—nature- and human-imposed boundaries, interactions across boundaries, and the fluidity of resources in space.

***Science-management integration*** **–** interdisciplinary science (physical, natural, social) and integration of science into policy-making processes and into management planning and decision making.

***International integration*** **–** the lack of correspondence between natural and human-imposed boundaries and ranges require integration at international borders as well as where states where boundaries integration of—common fisheries, transboundary pollution, ship passage are examples of international issues where disputes arise.

The potential of GIS to foster integration in virtually every one of these dimensions is clear. Whether it is interrelating various kinds of scientific data and information, examining political boundaries relative to resource distribution, seeing how jurisdictional boundaries interact among state management agencies or between state agencies and their federal counterparts, or seeing how different uses interact (e.g., crab pot fishing areas with ship transportation lanes or ocean dumping areas), GIS has the potential to clarify issues, display and communicate information, and analyze and illustrate the effects of different options. The social and behavioral implications of GIS use for decision making may also be significant (NRC 1997), helping to build working relationships, understanding, and appreciation for others’ perspectives, and more.

## Ocean Management in the Future—A Potential Model

Whether and how “marine resource management” is transformed to a more “integrated national ocean policy and management” regime remains to be see. The National Academy of Sciences panel that produced *Striking a Balance: Improving Stewardship of Marine Areas* (NRC 1997), provides a recent, compelling overview and synthesis of the many ocean policy critiques and ideas that have been put forward in recent years. More importantly, the panel, with a membership drawn from the full range of ocean stakeholders, developed consensus recommendations for a national ocean policy and institutional framework that addresses key problems. It called for:

- a National Marine Council to define national objectives and to coordinate public and private sector interests.
- regional councils, authorized where appropriate to deal with serious conflicts or valuable resources if existing regimes were inadequate.
- the maximizing of the potential of existing programs.
- improvement of resource management by using management tools more creatively, including access limitations where needed.
- assessment of the value of nonmarket goods and services the ocean provides to ensure their consideration in decision making.
- more inclusive decision processes and rule-making.
- improvement of existing coordination mechanisms.
- utilization a wider range of financing, similar to those used for land-based management.

These recommendations for a new ocean management model, together with some of the suggested objectives and operating principles the NRC panel proposed provides a useful "straw proposal" for consideration of GIS benefits.

**Data and Information for Ocean Management Today**

Marine scientific inquiry and the data and information that follow are of two basic genres today. The first is basic scientific research conducted by academic, government, and to a lesser extent, nongovernmental agencies and institutions. The second is applied scientific research to support decision making within a particular marine management regime, such as fisheries, water quality, or oil and gas resources, or to monitor long-term trends in environmental quality. Basic research focuses on fundamental questions and unknowns, whereas applied research and monitoring are designed to feed into resource management and allocation decisions. There is considerable overlap to be sure, and basic research of previous eras forms much of the foundation for both types of inquiry. Integrating scientific results of the two types of inquiry, however, is often difficult, even for managers trained in science. Basic science literature is generally inaccessible to those without specialized training. Much of the work reported is theoretical, is based on abstract modeling, and seems far removed from the day-to-day decisions resource managers must make.

Increased data volume and processing capability is another trend. High quality ocean environmental data are being collected at rates unimagined just a decade ago—satellites, other remote sensors, in situ data recorders, and other devices are continuously on the job. Computing capacity has increased apace, allowing scientists to store, organize, analyze, display, and publish these data. Often, however, results are in formats that are indecipherable or otherwise not useful to ocean users and managers. Advances in translation of ocean science for policy and management have not kept pace, despite awareness and interest in the problem. This trend is exacerbated by ever-changing technology.

In addition to the communication constraints imposed by data volume and technology, there are social and behavioral barriers to communication and utilization of scientific data and information for policy, and management. Some of these are based on cultural differences among the domains of individuals involved in science, policy and management—mutual lack of understanding, lack or misuse of others' products, competition, simple failure to communicate, and disdain are problems (Orbach 1996). Even within domains, there are serious communication barriers. For example, "science" is not a unitary structure or process. Each discipline relevant to ocean policy and management has its own language, scientific methods, and means of interpreting, displaying, and presenting data and information derived from data. Do the fisheries oceanographer and marine economist really understand and appreciate the other's basis for how much fish can be caught? The puzzle pieces offered up by different disciplines often do not fit well together, even where studies are interdisciplinary and scientists meet regularly to explore the others' results.

It is worthwhile to examine some of the problems regarding the development, sharing, and use of data and information for ocean management. This provides at least some insight into why GIS has yet to be widely used for ocean applications. Conceptually, many of the problems in data and information sharing and application to planning and decision making have their basis in the differences between those who generate data and information, those who use it for policy making, those who transform it for public planning and management, and those who use it for private purposes or to advance their agendas. Each has very different ends and means. Scientists, for example, are constantly building, tearing down, and rebuilding the body of knowledge created by predecessors and peers. Policymakers, on the other hand, just want the scientific facts…is it true or not? Scientists equivocate (often with good reason), frustrating policy makers. Managers want to know the implications of the information for long-term planning or for this or that specific decision. Differences in understanding, need for data generalization or specifics, methods of working (e.g., the policy process does not approximate the scientific method), and other factors create communication barriers that contribute to the fragmentation and incoherence in ocean management.

## METHODOLOGY

### Goal and Objectives

The goal of this project was to evaluate the efficacy and potential benefits of different approaches to the design and implementation of GIS for ocean management in the United States, with emphasis on the ocean management needs and responsibilities of coastal states. Of particular interest was the perceived value and utility of the regional approaches, such as the Southeast OPIS, versus less ambitious, more limited geographic area approaches.
Specific objectives set forth to achieve this goal were to:

1. Understand the principal issues and concerns of states regarding ocean use and management of their coasts or regions;
2. Assess use of GIS by individual states and regional organizations for ocean affairs, including methods and extent of data and information sharing.
3. Explore with the states how GIS might be used to facilitate more integrated ocean management at a variety of scales.
4. Identify the potential benefits of ocean GIS, particularly regional-scale, and how these benefits might increase equity, efficiency, and effectiveness in ocean management.
5. Identify barriers to effective development and implementation of ocean geographic information systems.

Study methodology to achieve these aims, described more fully below, included the development of coastal state "profiles" on ocean management activities and GIS use, based on literature review and interviews of key state personnel. Two states that illustrated a range of ocean management activism were selected for more in-depth cases (Maine and Florida), along with the regional Southeast OPIS. Because of its proximity to the researchers, Oregon was also examined in more depth than other states, but was not the subject of a full case study. In addition, a special workshop in conjunction with the conference, Coastal Geotools 99, was held to get face-to-face perspectives and examples to supplement the interview and case study process.

**Supplemental Research Questions**

Two sets of supplemental research questions were developed to guide the interview and case study process. The first set of questions was developed in collaboration with the CSC prior to initiation of the project. They respond to CSC interests regarding the utility of regional ocean GIS approaches and in part to the more general FGDC benefits program purposes. This set of questions was particularly important in initial study design:

- What are some examples of ocean management issues whose solutions, whether from a single-state or regional perspective, are contingent on regional approaches?
- What are some examples of ocean management issues that are unique to single states (e.g., issues whose solutions would not necessarily require regional approaches)?
- To what extent and how (if applicable) are targeted programs utilizing GIS to address ocean management concerns within their borders?
- How, if at all, does GIS complement existing intrastate and/or regional program objectives?
- Based on feedback from states and case study participants, what are the potential barriers (e.g., administrative, fiscal, technological) to the development of intrastate and regional marine GIS, and how can those best be overcome?
- Based on state interviews and case studies, what actions will maximize the potential of regional Ocean GIS and how will this approach help to obtain NSDI Benefits Program objectives of enhanced efficiency, effectiveness, and equity?

A second set of questions arose as the study interviews and case studies progressed. Many relate to perceived barriers to using GIS in the marine environment. These questions, raised by many state interviewees, strongly influenced the evolving interview process as well as the case studies. These questions, listed below, are addressed in the Results section of the report:

- Can the functions of GIS for terrestrial resource management be effectively adapted to the marine environment?
- Can GIS be used to examine the interactions between multiple ocean uses in order to recognize problems and identify management solutions?
- What is the appropriate scale or spatial scope of a GIS in order to address particular management issues?
- Is there enough political interest and financial support to develop and maintain effective marine GIS?
- How can GIS capacity be developed given current ocean governance and management structures?
- What ocean management issues are most suitable for addressing in a marine GIS and

what data is needed for useful analysis?

- What is the necessary resolution and accuracy of data within a GIS in order to be helpful as a state or regional management tool?
- How can the use of GIS help to overcome sectoral, governmental, spatial, and science-management fragmentation in ocean management?

**State Profiles**

State Ocean Management-GIS Profiles were developed for the 23 coastal states with salt water shorelines—Atlantic, Gulf, and Pacific. Although all five U.S. territories have approved coastal management programs and ocean areas for which they are responsible, they were not included in the study due to time and funding limitations.

The first step in state profile development involved collection and review of state coastal management program documents, state ocean policy studies and plans, state issue assessments and strategies for program improvement developed in response to the 1990 amendments to the federal Coastal Zone Management Act (ocean resources was one of the required assessment topics), and other literature on national ocean policy, state ocean activities, and GIS use in resource management. These proved useful starting points for state profiles.

A state data collection instrument was developed and tested in Oregon, and subsequently scaled back in detail and expectations. The revised data collection instrument, which was designed to feed into the template for state profiles, was used as the framework for telephone and/or personal interviews with individuals in all 23 states. The number of interviewees varied from state to state, but generally included at least one state ocean and/or coastal manager familiar with offshore issues, and at least one GIS specialist involved in supporting coastal and/or ocean management efforts in the state.

**Case Studies**

Compilation of data from state profiles provide a useful national perspective on state activity and interest in ocean issues and the use of GIS to catalog and share information. However, case studies are also valuable, providing a more in-depth look at state interests offshore, the role that GIS is playing and might play in the future, as well as the barriers and complexities that need to be addressed for effective implementation of marine GIS systems for state-level management purposes. Four case studies supplement the information in state profiles.

One case study examined the *Southeast Ocean Planning Information System* effort. States were selected for other case studies based on the range of ocean management activism and GIS use they illustrated: *Maine*, which has no state ocean management framework in place, but is involved in a regional ocean information network; and *Florida*, a state with its own ocean management GIS effort as well as a participant in the Southeast OPIS. In fact, the case of Florida is especially important because their State Ocean Resources Inventory (SORI) served in part as the model for Southeast OPIS. Although not subject to a full case study, *Oregon* was examined in more detail than most other states, in part because the state has a formal state ocean management program and has used GIS for specific projects, and because it does not have an active state ocean GIS to support its work. The case studies provided insight into the necessary attributes and potential benefits to state managers of a tool like the Southeast OPIS. They further underscored the idea to be useful, regional GIS need to be sufficiently flexible to link well with the common and unique elements of ocean management frameworks in coastal states, address the priority ocean issues there (some shared regionally, some not), and state capacity and use of GIS and Internet technology. Case studies are included as Appendices C to E of this report. Information drawn from them, however, is included in the Results section of this report.

**Workshops**

Face-to-face interactions also played an important role in this project. For example, many of the participants in the April 1999 NOAA-sponsored Coastal Geotools 99 conference in Charleston, South Carolina were state contacts for this study, providing a unique opportunity for direct interaction about the benefits of regional GIS, barriers and constraints, and opportunities for the future. To take full advantage of this gathering of ocean GIS specialists, a special interest meeting on ocean governance GIS was held, attracting 20 participants. The results of the discussions were particularly valuable and are reflected in our results, conclusions, and recommendations. Similarly, the May 1999 FGDC Conference in Portland, Oregon, provided an opportunity to present preliminary results and get input on methods and progress from others conducting benefits assessments. Finally, preliminary results were presented in close to final form at Coastal Zone 99 in San Diego, California in July 1999. This forum provided an opportunity to receive questions from a broader, critical audience.

**Caveats on Methods**

There are several important caveats regarding our methods. One is that the perception of GIS benefits, the importance of ocean issues, and so on, can be very different for different people working in the same state. Because most states do not have a designated ocean management agency, it was difficult in some cases to determine who we should be interviewing. In addition, as staff changes occur, agency perspectives can shift rapidly, changing results. Thus, the “data” in state profiles and summary tables should be recognized for what it is—subjective, and based on limited perspectives from a small fraction of those involved in state ocean management. Given the mostly sectoral management structure in states, it was difficult to get a comprehensive picture of issue importance, state governance structure, and GIS use. Also, the differentiation we made between ocean and coastal applications was largely artificial from the state perspective, so at least some of the data we collected related to both. We have tried to point this out in the report where appropriate.

Despite these caveats, we strongly believe that the data collection effort and results, taken in aggregate, suggest clear trends, GIS benefits and barriers, and other findings. So, you may read on with some confidence.

## RESULTS AND DISCUSSION

The principal bases for analyzing the potential benefits of GIS for ocean management were the 23 Ocean Management-GIS “profiles” for coastal states (Appendix B) and the more in-depth case studies of several particularly enlightening examples (Appendix C). State profiles include general descriptive information; a rating of ocean management-GIS activity in the state (High, Moderate, or Low), along with the rationale for that rating; a discussion and rating of ocean issue importance from a state perspective; regional ocean concerns; existing GIS capability; and perspectives on benefits, barriers, and usefulness of GIS and regional information sharing. Case studies have the same general format, but go into more detail through specific examples. Several tables in the sections below summarize profile and case study results across all states and provide a basis for discussion and findings.

Because we are especially interested in the geography of ocean management, the results presented here are organized by marine regions, following the large marine ecosystem (LME) framework presented by Sherman (1993) (**Figure 3**). Criteria used to delimit LMEs include consideration of distinct bathymetry, hydrography, productivity, and trophically-dependent populations. The seaward boundaries extend well beyond continental shelves to include at least continental slopes, as well as the major ocean current systems. Globally, the LMEs in **Figure 3** account for 95 percent of the annual yields of marine fisheries. Eight LMEs border the U.S. coastal states evaluated here.

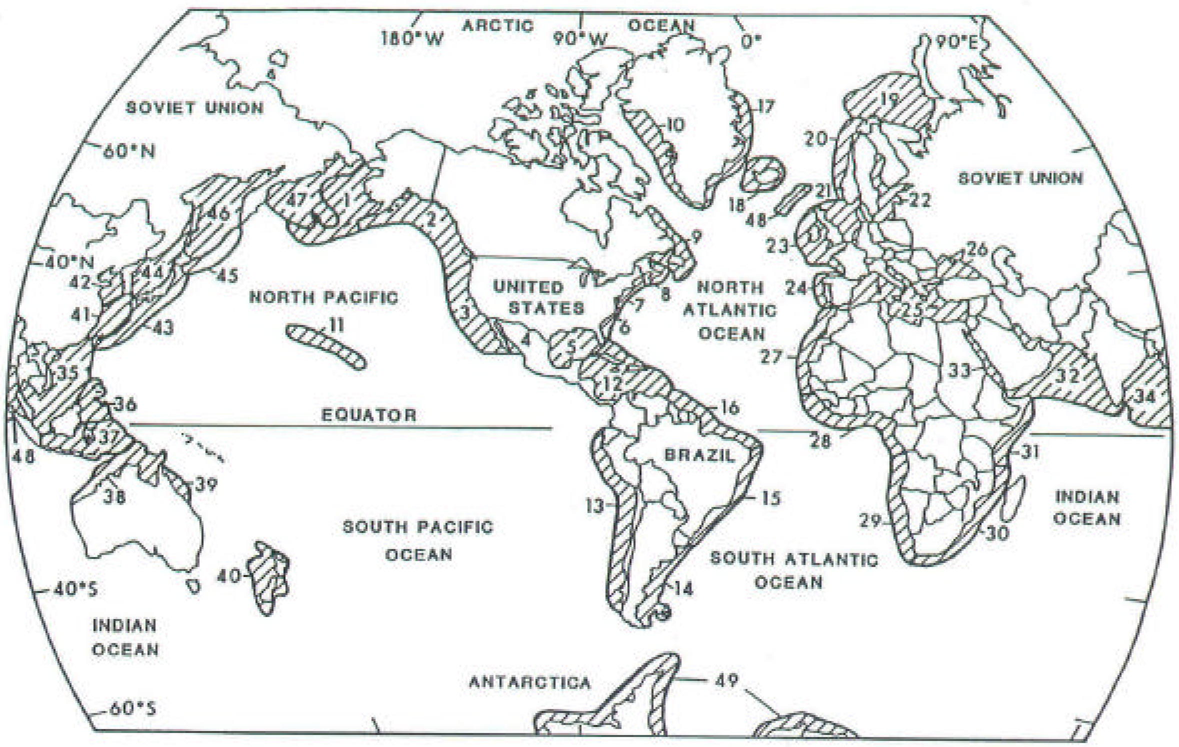
**Ocean Issues of State and Regional Importance**

States' interest in the waters off their coasts has grown substantially over the last several decades, motivated in part by the perceived threat of federal leasing and exploration plans for offshore oil and gas, and marine mineral development; conflicts over the management of marine fisheries and of marine mammals; and disputes over ocean incineration (Archer 1989). More recently, disputes have centered on the establishment and management of marine sanctuaries, Endangered Species Act listings, and the dramatic decline in some stocks of marine fisheries (NRC 1997).

Our survey of state governmental interests in offshore issues tracks these earlier findings (**Table 2**). However, given the limited sample of individuals we interviewed about issues (mostly staff from state coastal management programs), no statistically significant inferences can be drawn from the data. For example, had we interviewed a wider range of ocean interests in each state, we suspect that more issues would have been defined as important. Nevertheless, these results do suggest national trends and regional differences that are noted in the literature and being discussed in professional forums.

States had the choice of characterizing ocean issues as important locally (i.e., within state boundaries) or regionally (i.e., problems that were shared across boundaries). Most often (70 percent of the time), issues were seen as important regionally, requiring collaboration with adjacent states and the federal government. States had the opportunity to identify 17 different issues; the numbers of issues identified ranged from four to eleven, with an average of 5.8 issues per state. The ten "activist" ocean management states cited earlier averaged 6.9 issues. This small difference suggests that more states may be poised to join their fellow activists. Nationally, the five most important issues were:

- *Fisheries* – identified by all 23 states, with all but one characterizing it as a problem of regional significance; among specific problems cited were failure to protect declining stocks, severe harvest restrictions that have resulted, and associated community economic and social impacts.
- *Oil and gas development* – identified by 16 states (70 percent), with most characterizing it as an issue of both state and regional concern. Despite present moratoria on offshore development in most of the lower 48 states, and increased roles in offshore decisions through federal consistency, states still see the potential for future conflicts.
- *Water quality* – identified by 16 states (70 percent) as an important offshore issue, although nearshore pollution affecting estuaries, aquaculture, and beach recreation was most often mentioned, along with inland sources of pollution not under coastal state jurisdiction.




## LARGE MARINE ECOSYSTEMS OF THE WORLD

**1. Eastern Bering Sea**
**2. Gulf of Alaska**
**3. California Current**
4. Gulf of California
**5. Gulf of Mexico**
**6. Southeast U.S. Continental Shelf**
**7. Northeast U.S. Continental Shelf**
8. Scotian Shelf
9. Newfoundland Shelf
10. West Greenland Shelf
**11. Insular Pacific - Hawaiian**
12. Caribbean Sea
13. Humboldt Current
14. Patagonian Shelf
15. Brazil Current
16. Northeast Brazil Shelf
17. East Greenland Shelf
18. Iceland Shelf
19. Barents Sea
20. Norwegian Shelf
21. North Sea
22. Baltic Sea
23. Celtic-Biscay Shelf
24. Iberian Coastal
25. Mediterranean Sea
26. Black Sea
27. Canary Current
28. Guinea Current
29. Benguela Current
30. Agulhas Current
31. Somali Coastal Current
32. Arabian Sea
33. Red Sea
34. Bay of Bengal
35. South China Sea
36. Sulu-Celebes Seas
37. Indonesian Seas
38. Northern Australian Shelf
39. Great Barrier Reef
40. New Zealand Shelf
41. East China Sea
42. Yellow Sea
43. Kuroshio Current
44. Sea of Japan
45. Oyashio Current
46. Sea of Okhotsk
**47. West Bering Sea**
48. Faroe Plateau
49. Antarctic

Figure 3. Boundaries of the world's large marine ecosystems (U.S. LMEs in bold) (modified from Sherman 1993).

Table 2. Ocean management issues of state or state/regional importance.

| State | LME[1] | WQ | Spills | O&G | Min | Hab | MM | Fish | Aqua | R/T | Ship | DMD | Sand | Mil | Rsch | Leas | Gov | Reef |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ME | 7a | ● | | ● | | ❍ | | ● | ❍ | | | ● | | | | | | |
| NH | 7a | | | ● | | | | ● | | | | ❍ | | | | | | |
| MA | 7a | ● | | | | ● | ● | ● | ● | | | | | | | | | |
| RI | 7b | | | | | | | ● | | | | ❍ | | | | | ❍ | ❍ |
| CT | 7b | ● | | ● | ● | ❍ | | ❍ | | | | | | | | | | |
| NY | 7b | ● | ● | | | ● | | ● | | | ● | ● | ● | | | | | |
| NJ | 7b | ● | | | | | | ● | | | | ● | ● | | | | | |
| DE | 7b | ● | | | | ● | | ● | | | | | ● | | | | | |
| MD | 7b | ● | | ● | | | | ● | | | | | ● | | | | | |
| VA | 7b | ● | | ● | | | | ● | | | | | | | | ❍ | | |
| NC | 7b, 6 | | | ● | | ❍ | | ● | ❍ | | | ❍ | ● | | | | ● | |
| SC | 6 | | | ● | | ● | | ● | | | | ❍ | | | | | ● | |
| GA | 6 | ❍ | | | | ● | | ● | | ❍ | | ● | ● | | | | ● | |
| FL | 6,5 | ● | ● | ● | | | | ● | | ❍ | | | ● | | | | ● | |
| AL | 5 | ❍ | | ● | | ❍ | | ● | | | | | ❍ | | | | | |
| MS | 5 | ● | ● | ● | | | | ● | | | | | | | | | | |
| LA | 5 | ● | | ● | ● | | | ● | | | ● | | ● | | | ❍ | | ❍ |
| TX | 5 | ● | | ● | | ● | | ● | | | | | | | | | | |
| CA | 3 | ❍ | ❍ | ● | | ❍ | | ● | | ❍ | ● | | ❍ | | | | | |
| OR | 3 | | ❍ | ● | ❍ | ❍ | ● | ● | | ❍ | ❍ | ● | | | | ❍ | ❍ | |
| WA | 3 | | ❍ | | | ● | ● | ● | | ❍ | ❍ | | | | | | | |
| AK | 2,1,47 | | ❍ | ❍ | | ● | ● | ● | | | | | | | ❍ | | | |
| HI | 11 | ● | | ● | ● | ● | ● | ● | | ● | ● | | ● | | | ● | | |
| State | | 16 | 7 | 16 | 3 | 15 | 5 | 23 | 3 | 6 | 6 | 9 | 11 | 0 | 1 | 4 | 6 | 2 |
| Reg | | 13 | 3 | 15 | 3 | 9 | 5 | 22 | 1 | 1 | 4 | 5 | 9 | 0 | 0 | 1 | 4 | 0 |

[1] Large Marine Ecosystems (LME) numbers cross-referenced to Figure 3; LME 7 (Northeast U.S. Continental Shelf) is subdivided into Gulf of Maine and Middle Atlantic Continental Shelf (after Sherman 1993).

❍ Important issue within state boundaries (based on document review and state coastal/ocean manager interviews).

● Important issue of state *and* regional concern (based on document review and state coastal/ocean manager interviews).

**Key to Table 2 Abbreviations:**

**Ocean Issues of State and/or Regional Concern**

**WQ** – water quality and pollution, including debris and land-based sources.
**Spills** – oil/hazardous material spills.
**O&G** – oil and gas exploration/development.
**Min** – marine mineral mining.
**Hab** – protection of marine ecosystems, especially essential fish habitat and seabirds.
**MM** – protection and/or management of marine mammals.
**Fish** – depletion of fisheries and need for more effective management.
**Aqua** – marine aquaculture opportunities and conflicts.
**R/T** – marine recreation and tourism growth, management, and use conflicts.
**Ship** – navigation and transportation versus other uses and activities.
**DMD** – siting and dumping of dredged material from harbor improvements.
**Sand** – location of offshore sand resources for beach nourishment.
**Mil** – military use of ocean areas.
**Rsch** – research in state and/or offshore waters.
**Leas** – seabed leasing for cables, aquaculture, and other uses.
**Gov** – governance issues, jurisdiction, gaps and overlaps, boundaries.
**Reef** – siting and impacts of artificial reefs.

---

- *Habitat protection* – identified by 15 coastal states (65 percent), the need to define and protect essential fish habitat was a principal concern, as was seabird protection. This connects to increasing interest in strategies such as marine protected areas.
- *Sand resources for beach nourishment* – identified by 11 states (48 percent), locating appropriate offshore sand bodies that could be used for onshore beach nourishment projects was viewed primarily as a regional or shared problem.

There were both regional similarities and differences in issue importance. In virtually all regions, fisheries and oil and gas development are priority ocean management issues driving state interests offshore. Another similarity is the almost uniform lack of concern about ocean management issues arising from military operations (no states), offshore research (one state), artificial reefs (two states), and offshore aquaculture (four states). Military use, of course, is mostly hidden from public view, until site-specific problems emerge. Offshore marine research is viewed as mostly benign, and aquaculture, while important to some states, is more of an inland waters issue.

Regional differences in issue importance are striking. Regions identifying the greatest numbers of issues, in rank order, included Hawaii (10 issues), West Coast (8 issues on average), the Southeast (6.5 issues), Alaska (6 issues), and Gulf Coast states (5.2 issues). The Northeast (4.7 issues) and Middle Atlantic states (4.6 issues) identified the fewest issues. Numbers of issues do not tell the full story, however. *Water quality*, for example, was uniformly important for the Northeast, Middle Atlantic, and Gulf Coast states (the three regions identifying fewest issues), but not that important for much of the West Coast or the Southeast (recent severe pollution associated with hurricane-related precipitation and flooding may change this perception). *Oil and other hazardous material spills*, on the other hand, were important issues in all three West Coast States and Alaska, but not as important regionally in other areas. This may be a function of where spills and related damage have occurred in recent years, rather than an accurate perception of risk. *Marine mining* was identified as important by all West Coast states, Alaska, and Hawaii, related to both territorial sea resources and federal mining proposals farther offshore. As might be expected, *marine recreation and tourism* was an important ocean management issue for warm-water states like Hawaii and Florida, but also for all West Coast states who are grappling with issues such as personal watercraft-caused disturbance of seabirds and marine mammals. Few states identified *governance* as an important issue, the exception being the entire Southeast contingent involved in the Southeast OPIS project. Perhaps collaboration in the ocean GIS project has raised awareness of potential governance and jurisdictional issues that states *should* be concerned about, but may not be aware of at present. Also evident from regional analysis of issue importance is that future ocean GIS initiatives, including governance elements, must be tailored to regional (and state) differences and interests.

**Maturity of State Ocean Management Efforts**

Interviews of state coastal managers, supplemented by a review of the literature, were the basis of an assessment of the status and maturity of state ocean policy and institutional frameworks (**Table 3**). Our findings tend to support recent evaluations (e.g., NRC 1997), in part because our assessment was based on similar factors.

The main finding is that most state involvement in offshore decision making is carried out through sectoral policies and institutions, mirroring the fragmentation in decision making prevalent at the federal level. Every state, for example, is involved in nearshore fisheries management. Even those states with relatively mature ocean management programs are adverse to tinkering with the existing federal-regional-state fisheries management regime, a finding that echoes the recent NRC (1997) study on ocean governance. The rising importance of essential fish habitat protection as a state ocean issue may signal a change in this trend, however, at least for this issue. Most states, at least in the view of coastal managers interviewed, simply see no compelling need for focusing their limited resources on ocean issues and management. Their agendas, they assert, are already overflowing with pressing onshore concerns—coastal hazards mitigation, management of development, wetland protection, and more. This in part may be an artifact of the kinds of staff expertise in coastal management agencies—most hire land planners or coastal environmental specialists; few coastal programs have marine science or management specialists, that being the realm of other sectoral agencies at the state level, such as fisheries.

High ratings in overall maturity and capacity for state-level ocean management were assigned to just three states (California, Hawaii, and Oregon), and moderate ratings to another five states (Maine, Massachusetts, North Carolina, Florida, and Washington). The remaining states rated low in the maturity and capacity of ocean policy and institutions. Just one state, Oregon, has adopted an ocean plan as part of the state coastal management program (ORMTF 1990), giving its policies additional force through federal consistency. California (Resources Agency of California 1997) and Hawaii (Hawaii Ocean and Marine Resources Council 1988) have adopted plans, but policies are advisory rather than enforceable. Most of the remaining

Table 3. Status and maturity of state policy and institutional frameworks for integrated ocean management (IOM).

| **State** | **LME**[1] | **Policy Framework** | | | | | | | **Institutional Framework** | | | | **Overall IOM Maturity Assessment** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Initial Interest | CZM §309 priority[2] | Mainly Sectoral Policy | Ocean Policy Study | Comp. Ocean Legis. | Ocean Plan – advis. | Ocean Plan – author. | Mainly Sectoral Mgt. | Ocean Planning body | Perm. advisory body | Perm. authority body | |
| ME | 7a | ❍ | High | ❍ | ❍ | | | | ❍ | | | | Moderate |
| NH | 7a | ❍ | Low | ❍ | | | | | ❍ | | | | Low |
| MA | 7a | ❍ | High | ❍ | | | | | ❍ | | | | Moderate |
| RI | 7b | ❍ | High | ❍ | | | | | ❍ | | | | Low |
| CT | 7b | | Low | ❍ | | | | | ❍ | | | | Low |
| NY | 7b | ❍ | Low | ❍ | | | | | ❍ | | | | Low |
| NJ | 7b | ❍ | Low | ❍ | | | | | ❍ | | | | Low |
| DE | 7b | ❍ | Low | ❍ | | | | | ❍ | | | | Low |
| MD | 7b | ❍ | Medium | ❍ | | | | | ❍ | | | | Low |
| VA | 7b | | Low | ❍ | | | | | ❍ | | | | Low |
| NC | 7b, 6 | ❍ | Low | ❍ | ❍ | | | | ❍ | ❍ | ❍ | | Moderate |
| SC | 6 | ❍ | Medium | ❍ | | | | | ❍ | | | | Low |
| GA | 6 | ❍ | N/A | ❍ | | | | | ❍ | | | | Low |
| FL | 6,5 | ❍ | High | ❍ | ❍ | | | | ❍ | ❍ | | | Moderate |
| AL | 5 | ❍ | Medium | ❍ | | | | | ❍ | | | | Low |
| MS | 5 | ❍ | Low | ❍ | ❍ | | | | ❍ | | | | Low |
| LA | 5 | ❍ | Low | ❍ | | | | | ❍ | | | | Low |
| TX | 5 | ❍ | N/A | ❍ | | | | | ❍ | | | | Low |
| CA | 3 | ❍ | Medium | ❍ | ❍ | ❍ | ❍ | | ❍ | ❍ | | | High |
| OR | 3 | ❍ | High | ❍ | ❍ | ❍ | | ❍ | ❍ | ❍ | ❍ | | High |
| WA | 3 | ❍ | Low | ❍ | ❍ | ❍ | | | ❍ | | | | Moderate |
| AK | 2,1,47 | ❍ | High | ❍ | ❍ | | | | ❍ | | | | Low |
| HI | 11 | ❍ | High | ❍ | ❍ | ❍ | ❍ | | ❍ | ❍ | ❍ | | High |

[1] Large Marine Ecosystems (LME) numbers cross-referenced to Figure 3 map; LME 7 (Northeast U.S. Continental Shelf) is subdivided into Gulf of Maine and Middle Atlantic Continental Shelf (after Sherman 1993).

[2] Priority assigned by state to *Ocean Resources* in response to state issue assessment requirements of the 1990 amendments to the Coastal Zone Management Act (subsequent CZM funding for program enhancements stimulated ocean management activities for some states); Georgia and Texas CZM programs had not been approved yet.

states rated “moderate” have conducted a detailed state ocean policy study and one, Florida, is poised to embark on a new, more sophisticated planning effort (FGOC 1998).

Regionally, ocean management policies and institutions are relatively mature on the West Coast and Hawaii, somewhat less mature in Southeast and Northeast, and uniformly immature in the Middle Atlantic and Gulf Coast regions. States in regions with more mature ocean policy and institutions are probably the best candidates for new regional ocean management GIS initiatives, especially since many ocean issues in these regions are shared among states. Oregon and California, for example, are beginning discussions for such collaboration (Robert Bailey, pers. comm., August 1999).

**State Use of GIS for Ocean Management**

Virtually all coastal states use GIS in their coastal management programs, but the extent of use and the sophistication of applications vary widely. GIS use for marine applications is less common than use for coastal lands or estuarine analysis, mirroring the relatively low importance that many states assign to ocean issues (see **Table 2**). The level of sophistication and maturity of ocean area and resource management policy and institutions (see **Table 3**) also seems to be a factor in whether and how GIS is used for marine applications. Further, most marine applications of GIS by states are for nearshore, state-managed waters rather than federal waters farther offshore. But this is changing somewhat as some states explore more comprehensive management of ocean resources and seek a greater role in ocean decision making and experiment with more comprehensive approaches to handling data and information.

Another finding is that state coastal management agencies are often not the principals in state marine GIS applications. Instead, marine resource management agencies with specific sectoral responsibilities such as fisheries and wildlife management, parks and recreation operation, or state lands leasing are leaders. One of the more common state ocean applications is oil spill contingency plans, generally undertaken by the state environmental quality agency, and nearshore-focused. Generally, the narrow focus and tailored approaches that states are taking to ocean GIS suggests that different applications may be difficult to integrate for more comprehensive planning and analysis purposes.

We have classified the approaches states use to organize, store, and analyze ocean area and resource information into three categories: state-level GIS applications, regional GIS efforts;,and other types of information systems (**Table 4**). “State-level ocean GIS” refers to marine GIS applications that are maintained by coastal management or other state resource agencies and are generally limited to state jurisdictional waters. The “regional ocean GIS” category refers to GIS tools that are interstate/intergovernmental collaborative projects and include multiple state territorial sea areas and adjacent EEZ waters. The “other information system” category includes spatial data clearinghouses and networked ocean-related data sets. Existing information systems are further characterized based on their area of coverage, type of application, and accessibility. **Table 5** describes the primary management purposes and uses of GIS with specifics detailed in individual state profiles (Appendix B).

***State Ocean GIS Applications*.** Fifteen states (65 percent) use GIS in state-level marine management activities; of these, 11 focus solely on state waters, while the other five have applications that extend in federal waters. Most states employ GIS for multiple marine applications, and two have relatively comprehensive systems either developed or underway. One of these, Florida, is discussed below and in detail in Appendix D. Regional trends are apparent—

Table 4. Summary of GIS and other IS use by states for marine resource or comprehensive ocean management.

| State[1] | LME[1] | State Ocn GIS | Area/ Type | Data Access | Regional Ocn GIS | Area/ Type | Data Access | Other Info Sys | Area/ Type | Data Access | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ME | 7a | Y | TS/MUL | LTD | N | - | - | Y | LME/MUL | WWW | LME networked IS |
| NH | 7a | N | - | - | N | - | - | Y | LME/MUL | WWW | LME networked IS |
| MA | 7a | Y | TS/COM | MIN | N | - | - | Y | LME/MUL | WWW | LME networked IS |
| RI | 7b | N | - | - | N | - | - | N | - | - | Inshore GIS |
| CT | 7b | Y | TS/MUL | LTD | N | - | - | Y | TS/MUL | LTD | OLISP Project |
| NY | 7b | N | - | - | N | - | - | Y | EEZ/ISS | LTD | Dredged Material |
| NJ | 7b | N | - | - | N | - | - | N | - | - | Coastal GIS |
| DE | 7b | Y | TS/MUL | LTD | N | - | - | Y | TS/MUL | LTD | Nearshore only |
| MD | 7b | N | - | - | N | - | - | N | - | - | Inshore GIS |
| VA | 7b | N | - | - | N | - | - | N | - | - | Inshore GIS |
| NC | 7b, 6 | Y | EEZ/MUL | LTD | Y | EEZ/GOV | WWW | N | - | - | Reg-NOAA-CSC |
| SC | 6 | Y | EEZ/MUL | LTD | Y | EEZ/GOV | WWW | Y | EEZ/MUL | LTD | Reg-NOAA-CSC |
| GA | 6 | N | - | - | Y | EEZ/GOV | WWW | N | - | - | Reg-NOAA-CSC |
| FL | 6,5 | Y | EEZ/COM | WWW | Y | EEZ/GOV | WWW | N | - | - | Reg-NOAA-CSC |
| AL | 5 | Y | EEZ/RES | LTD | Y | EEZ/RES | LTD | N | - | - | Reg-CORIS (MMS) |
| MS | 5 | Y | TS/MUL | MIN | Y | EEZ/RES | LTD | N | - | - | Reg-CORIS (MMS) |
| LA | 5 | Y | TS/ISS | LTD | Y | EEZ/RES | LTD | N | - | - | Reg-CORIS (MMS) |
| TX | 5 | Y | TS/MUL | WWW | Y | EEZ/RES | LTD | N | - | - | Reg-CORIS (MMS) |
| CA | 3 | Y | EEZ/MUL | WWW | N | - | - | Y | EEZ/MUL | WWW | CalOCEAN; fisheries |
| OR | 3 | Y | TS/ISS | LIM | N | - | - | Y | EEZ/RES | LTD | Rocky shore; fisheries |
| WA | 3 | Y | TS/MUL | LTD | N | - | - | N | - | - | Fisheries |
| AK | 2,1,47 | N | - | - | N | - | - | Y | SMA | WWW | CIIMMS (Cook Inlet) |
| HI | 11 | Y | TS/MUL | LTD | N | - | - | Y | EEZ/MUL | LTD | Plan for compreh, GIS |

[1] Large Marine Ecosystems (LME) numbers cross-referenced to Figure 3 map; LME 7 (Northeast U.S. Continental Shelf) is subdivided into Gulf of Maine and Middle Atlantic Continental Shelf (after Sherman 1993).

**Area (Coverage)**

LME – large marine ecosystem (regional)
EEZ – Exclusive Economic Zone (state)
TS – Territorial sea (state)
SMA – special management area (size varies)

**Type (Application)**

COM – comprehensive ocean management
ISS – single issue (e.g., oil spill contingency)
RES – single-resource (e.g., fisheries harvest)
MUL – multiple issues and/or resources
GOV – governance GIS

**Data Access**

WWW – internet access to data, maps, etc.
LTD – Limited data access through gatekeeper
MIN – minimal access; may be archived

Table 5. Current primary uses of GIS by coastal states for coastal and ocean management.

| State | Data Storage | Mapping and Outreach | Issue-specific Analysis | Comprehensive Analysis | Routine Decision Support | Other |
|---|---|---|---|---|---|---|
| ME | ❍ | ❍ | ❍ | | | Planning |
| NH | | | | | | |
| MA | ❍ | ❍ | ❍ | | | Regulatory |
| RI | | | | | | |
| CT | ❍ | ❍ | ❍ | ❍ | ❍ | |
| NY | ❍ | | | | | |
| NJ | ❍ | ❍ | ❍ | ❍ | ❍ | |
| DE | ❍ | ❍ | ❍ | ❍ | ❍ | |
| MD | ❍ | ❍ | ❍ | ❍ | ❍ | |
| VA | ❍ | ❍ | ❍ | | ❍ | |
| NC | ❍ | ❍ | ❍ | | | |
| SC | ❍ | ❍ | ❍ | | | |
| GA | ❍ | ❍ | | | | |
| FL | ❍ | ❍ | ❍ | ❍ | | |
| AL | ❍ | ❍ | ❍ | | | |
| MS | ❍ | ❍ | ❍ | | | |
| LA | ❍ | ❍ | ❍ | ❍ | ❍ | |
| TX | ❍ | ❍ | ❍ | | ❍ | |
| CA | ❍ | ❍ | ❍ | | ❍ | Regulatory |
| OR | ❍ | ❍ | | | ❍ | |
| WA | ❍ | ❍ | | | | |
| AK | ❍ | ❍ | | | | |
| HI | ❍ | ❍ | | | | |
| Total | 21 | 20 | 15 | 6 | 9 | |

all Gulf Coast and West Coast states use GIS for at least limited ocean management purposes, mostly in nearshore waters. Only three states provide Internet access to state-level ocean GIS data—Florida, Texas, and California. Most other states claim to make data available on request, but its availability is not widely publicized or known. Two states are discussed further below—Florida, because of their status as the leader in the use of GIS for ocean management, and Oregon, because of their leadership in ocean planning and management.

One of our case study states and also a key player in the Southeast OPIS, Florida is clearly the most active and advanced state nationally in use of GIS to support ocean resources management. There are many reasons for this—the importance of the ocean and its resources to the state economy; tangible threats to Florida's marine environment, early work on ocean policy and management issues in the state (e.g., Christie 1990); significant investment in ocean and coastal management; the need for information to support those efforts; and finally, an institution—the Florida Marine Resources Institute—that had both the technical know-how, marine science expertise, and links to management agencies needed to establish and support a marine GIS capability.

Florida actually has two complementary state-wide ocean GIS efforts. The first is the Marine Resources GIS, developed to store and integrate scientific data and information about

Florida's marine environment and resources. UNIX-based, this system is not accessible for public use, but is very valuable to marine management agencies and academics. The second GIS system, the Statewide Ocean Resources Inventory (SORI), contains much of the same data as the first system, but is publicly available through an Internet-based map server. SORI also served as the model for the Southeast OPIS. SORI is an excellent resource for marine educators in schools and outreach organizations, as well as for managers who want to get easy, Internet-based access to data and maps. However, because Florida has not developed a formal ocean management program (recommendations for the same have yet to be legislatively implemented), SORI does not really have a principal client to ensure long-term support and maintenance.

Oregon has a formal ocean management program covering both the territorial sea and an offshore *stewardship area* that includes the entire continental margin (ORMTF 1990). The plan was legislatively implemented in 1991 and subsequently approved by NOAA as part of the Oregon Coastal Management Program, maximizing federal consistency powers offshore. But Oregon has no statewide ocean GIS effort analogous to that of Florida. See the Oregon profile in Appendix B for details. GIS is used by a number of Oregon state agencies with sectoral ocean resources responsibility for data storage, map-making, and limited decision support. The Ocean Resources Management Task Force used GIS maps to present an ocean inventory in its *Oregon Ocean Plan* (ORMTF 1990) and its *Territorial Sea Management Plan* (OPAC 1994), but has no separate, ongoing GIS effort to support the work of that group. Establishing such a system through coordination of GIS activities of individual members of the Ocean Policy Advisory Council—the state's ocean management institution—would provide an ocean GIS that is more robust than the sum of its separate agency parts. There is some interest on the part of state ocean managers in exploring such a strategy, as well as regional coordination of GIS activities to address shared issues with California and Washington (e.g., oil spill planning, protected areas, and fisheries). Financial and human resources and expertise are the principal barriers at present.

***Regional Ocean GIS*.** Eight states (35 percent) are involved in regional ocean GIS activity with state and federal waters covered. Five Gulf of Mexico states—Texas, Louisiana, Mississippi, Alabama, and Florida—are included in the federal Mineral Management Service (MMS) Coastal and Ocean Resources Information System (CORIS). This GIS is utilized by the MMS primarily for evaluation of oil and gas related management decisions. Although data from the five "participating" states are utilized in the GIS, the states have very little active involvement in the development, use, and maintenance of the system. Direct access to the CORIS is limited to the MMS.

The Southeast OPIS is the only bona fide regional, state-focused GIS effort in the U.S. See Appendix E. First conceived by North Carolina and the federal NOAA Office of Ocean and Coastal Resources Management, the Southeast OPIS is being developed through federal leadership of the NOAA Coastal Services Center, in partnership with Florida, Georgia, South Carolina, and North Carolina. This GIS uses both state and federal data sets and is unique in its inclusion of extensive ocean planning and governance data, including boundaries, jurisdictions, and direct links to relevant laws and polices governing ocean areas and resources (**Figure 4**). It also includes selected marine environmental data coverages, but this component of the GIS is relatively weak, limiting its utility. Nevertheless, easy access to the data through the Internet, a map-serving capability, and other features make it the prototype for a more useful regional ocean GIS of the future. See http://www3.csc.noaa.gov/gisprojects/ocean/index.htm for more information.

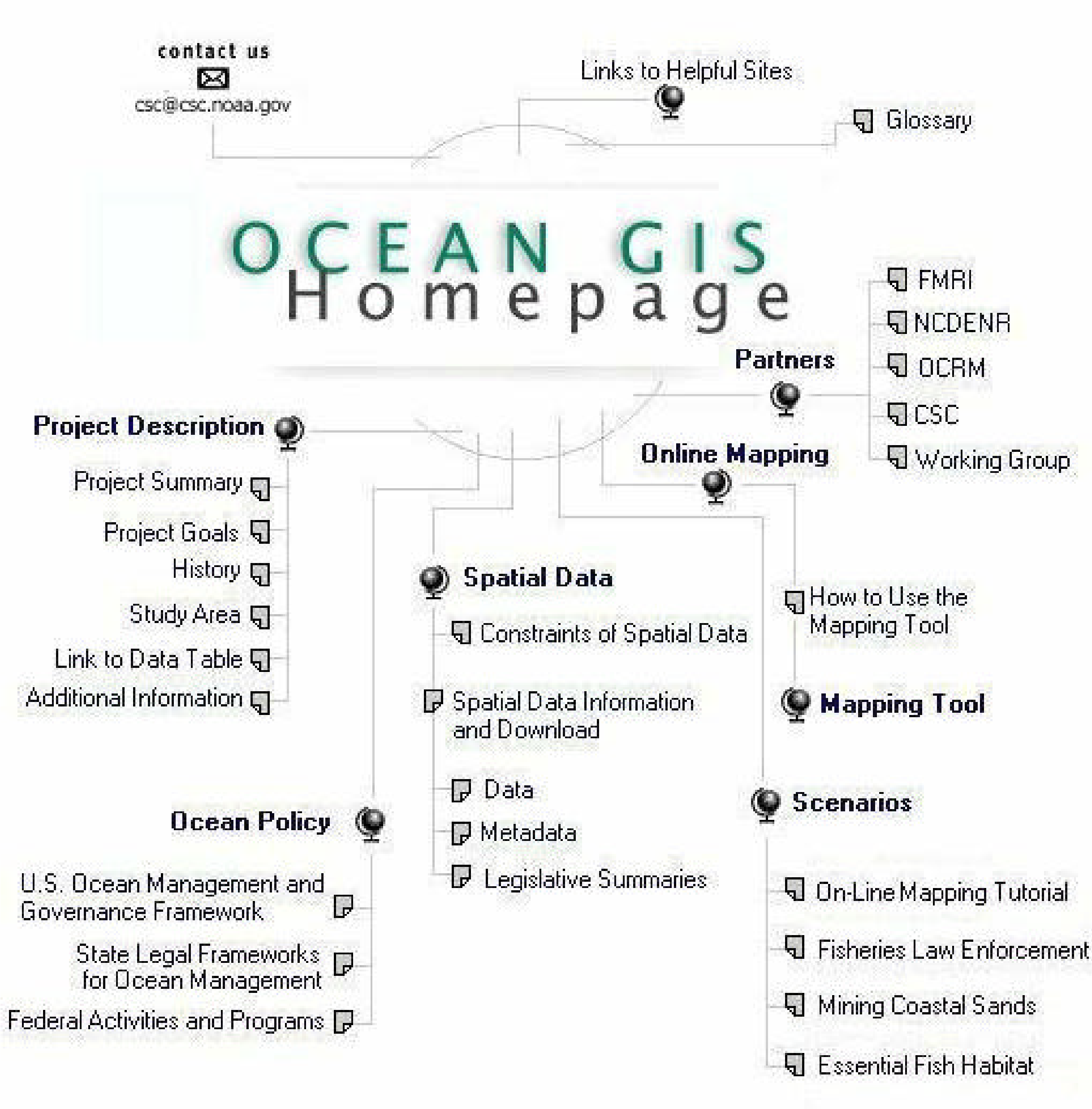



Figure 4. Site map for the Southeast Ocean Planning Information System, illustrating the variety of data and services available (See http://www3.csc.noaa.gov/gisprojects/ocean/index.htm).

***Non-GIS Ocean Information Systems.*** Eleven states (48 percent) are involved in other-than-GIS information system activity. One of these is California. That state is developing the California Ocean Information Network (CalOcean) in support of its active ocean management and planning effort (Resources Agency of California 1997). CalOcean includes data on water quality, coastal hazards, coastal habitats, marine managed areas, oil and gas facilities, fisheries, and land-based information. An experimental GIS mapping system called the California Atlas, featuring an Internet map server, is being developed as well, although atlas data are sparse thus far.

Maine, one of our case study states, uses GIS for limited, area-specific or issue-specific applications (oil spill contingency planning, water and sediment quality monitoring, aquaculture, and harmful algal blooms). See Appendix E for details. However, there is little interaction among these various efforts and certainly no comprehensive, state-wide effort in ocean GIS.

Maine does participate in a regional ocean forum—the Gulf of Maine Council on the Marine Environment (GOMCME)—which also includes Massachusetts, New Hampshire, and two Canadian provinces, Nova Scotia and New Brunswick. The GOMCME, which focuses on environmental concerns in the Gulf that affect all members, has established a data repository and information-sharing mechanism through the Environmental Data and Information Management System (EDIMS) (see http://www.gulfofmaine.org/index.html). Although not a GIS, EDIMS in theory provides links to many sources of state, regional, federal, and academic institution data. However, the practical utility of EDIMS has been limited due to the lack of an Internet data-serving capability and other difficulties in accessing data (Evans 1997). As with Florida, the lack of any clear state or regional legislative mandate for GOMCME, as well as the lack of intrastate ocean management program, provides little impetus and support for an integrated information system.

***Sophistication of State Use of GIS***. GIS is a powerful tool, but most users and most applications do not take full advantage of its capabilities. This is certainly true in the case of ocean GIS applications by the states. The purposes for which GIS is used by states for *coastal and ocean management* tends to be limited (**Table 5**). GIS is most prominently identified as an effective means of storing data (21 states) and mapping resources (20 states). GIS use to conduct issue-specific analyses is also relatively common (15 states). Nine states claim they routinely use GIS as a basis for management decisions, and six states use GIS to examine the interactions between multiple marine resources and ocean uses. These more sophisticated uses are generally for onshore or estuarine applications, rather than for offshore waters. GIS is also identified as a primary planning aid and regulatory tool by several states, again, mainly for onshore activities such as wetlands management. Clearly, the simpler functions of GIS are the ones most commonly used for marine management, namely to organize spatial data and generate maps. Higher-order functions, such as complex spatial analysis and modeling are rare, particularly for ocean area or resource management. The emphasis on relatively simple GIS functions is not surprising given the stage of development of marine applications, as well as the fact that most GIS efforts are undertaken by sectoral agencies for limited purposes. More complex functions are often associated with more comprehensive problem solving.

**Benefits of GIS for State and Regional Ocean Management**

Several approaches were used to identify the actual and potential benefits of GIS use for state and regional management of ocean areas, resources, and activities. First, in open-ended interviews, we asked knowledgeable state ocean and coastal management and GIS professionals how their present use of GIS benefited coastal and ocean management efforts, prompting with some generic categories. We queried the same professionals about the benefits or potential benefits of regional GIS that would cover multiple states and the adjacent EEZ. Details for each state are provided in profiles (**Appendix B**) and case studies (**Appendices C-E**). Finally, we perused the ocean management literature for specific examples of GIS use or management issues that might have benefited from the improved organization, analysis, visualization, and communication of information that GIS offers. Given the significant overlap among these three sources, we also summarize the potential GIS benefits with respect to our objectives: how can GIS foster more integrated ocean management; and how might GIS increase equity, efficiency, and effectiveness in ocean management?

***Current Benefits of State GIS.*** Responses to our open-ended interviews regarding present benefits of using GIS for state coastal and ocean management varied, but most fell into the following general categories: (1) multiple-use management and conflicts; (2) policy options and issue analysis; (3) multidisciplinary science integration for management; (4) interagency collaboration and communication; (5) centralization of and access to data; and (6) stakeholder and public education (**Table 6**).

- The capacity of GIS to provide visual representations of multiple use interactions and conflicts was identified by 22 of 23 states (96 percent) as an important benefit (category 1).
- Another important benefit identified by 18 states (78 percent) was the analytical power of GIS to examine policy issues and options in a variety of contexts—area planning, environmental assessment, and spatial analysis of monitoring data (category 5).
- Sixteen states (70 percent) noted the high value of data centralization inherent in GIS, as well as the relative technical ease of making those data sets widely available through the Internet or on CDs (category 4).
- Thirteen states (57 percent) identified the ability of GIS to integrate multiple, related scientific data sets within an ecosystem management framework (category 2).
- The role of GIS in fostering intergovernmental coordination and communication, thus reducing (or at least elucidating) conflicts or barriers to cooperation, was noted by 13 states (57 percent) (category 3).
- Just nine states (39 percent) identified the role of GIS in educating stakeholders and the general public (category 6).

These results say more about the present use of GIS by state coastal and ocean programs than about the actual potential of ocean GIS. For example, the most-often identified benefits of GIS were multiple-use management and conflict resolution, and policy analysis (categories 1 and 5). These uses of GIS are mainly the province of the resource managers and GIS professionals we interviewed, so the importance attributed to them might be expected. However, we expect some other areas to be at least equally important in the future. For example, stakeholder and public education was the least important benefit currently being realized, yet the use of GIS for real-time mapping and analysis in stakeholder processes is just beginning to come of age, as resource managers and planners develop confidence in their own GIS expertise and begin to share it with others. Because information is the currency of decision making, GIS is likely to contribute to the democratization of ocean decision making in the future. Similarly, with schools and the "average citizen" rapidly becoming "connected" and computer savvy, the potential audience for ocean GIS expands with it.

The integration of scientific information for more robust analysis of marine ecosystems was identified by just over half of the states, although problems with the use of GIS in the multidimensional ocean environment is one of the chief limitations of GIS, as well as a barrier to its more common use in the ocean science community (as discussed in the next section). Despite these limitations, we believe that four-dimensional GIS software will soon be widely enough available that marine scientists will embrace GIS as a tool that can reveal ecological relationships not otherwise apparent.

Table 6. Benefits of using GIS for state-level coastal and ocean management efforts, as suggested by state coastal managers and GIS specialists.

| State | Multiple-use management and conflict | Policy and issue analysis | Multidisciplinary science integration for management | Interagency collaboration/ communication | Centralization of, and shared access to data | Stakeholder and public education |
|---|---|---|---|---|---|---|
| ME | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| NH | ❍ | | | ❍ | | |
| MA | ❍ | ❍ | | | | ❍ |
| RI | | ❍ | ❍ | ❍ | | ❍ |
| CT | ❍ | ❍ | ❍ | | ❍ | |
| NY | ❍ | ❍ | | ❍ | ❍ | |
| NJ | ❍ | ❍ | | | ❍ | |
| DE | ❍ | ❍ | ❍ | ❍ | ❍ | |
| MD | ❍ | ❍ | | ❍ | | |
| VA | ❍ | | ❍ | ❍ | ❍ | |
| NC | ❍ | ❍ | | | | ❍ |
| SC | ❍ | ❍ | | ❍ | ❍ | ❍ |
| GA | ❍ | | | ❍ | ❍ | |
| FL | ❍ | ❍ | ❍ | ❍ | ❍ | |
| AL | ❍ | ❍ | | | | ❍ |
| MS | ❍ | | ❍ | | ❍ | |
| LA | ❍ | ❍ | ❍ | | | |
| TX | ❍ | | ❍ | | ❍ | |
| CA | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| OR | ❍ | ❍ | ❍ | ❍ | ❍ | |
| WA | ❍ | ❍ | | | ❍ | ❍ |
| AK | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| HI | ❍ | ❍ | ❍ | | ❍ | |
| Total | 22 | 18 | 13 | 13 | 16 | 9 |

**Key to Table 6 columns:**

**Multiple-use management and conflict** – GIS integrates data and information across multiple ocean use and activity sectors, allowing visualization of multiple ocean uses interactions, as well as interactions between ocean uses and the marine environment.

**Policy and issue analysis** – GIS is a powerful tool for analyzing ocean issues in a variety of institutional settings—long range planning for resource development, conservation, preservation, or protection (e.g., marine protected area design); for assessing the impacts of specific resource development proposals; resolving conflicts among uses or among use and non-use; assessing the cumulative environmental impacts of human activities.

**Multidisciplinary science integration for management** – GIS is increasingly able to incorporate scientific data from many sources and sensors about the character, resources, and variability of marine ecosystems.

**Interagency collaboration and communication** – GIS helps integrate interagency and intergovernmental communication and collaboration by standardizing data formats, information sharing protocols, and by an improved capacity to identify gaps, overlaps, and conflicts in authority or responsibilities.

**Centralization of, and shared access to data** – GIS provides for centralized storage, organization, documentation, and access to data and information from multiple research groups and management authorities.

**Stakeholder and public education** - GIS communicates information powerfully and equally (with appropriate explanation) to multiple stakeholders in many issue settings by providing an intuitive visual representation of the marine environment, resources, boundaries, uses, and policies. Internet-based mapping and information tools provide broad access to marine resource information and can serve as a mechanism for public education.

***Potential Regional Benefits.*** When we asked states about the benefits or potential benefits of regional ocean GIS, we used the Southeast OPIS as an example. But we also suggested that a regional GIS would include more robust marine ecosystem and human use information, which are relatively undeveloped features in the Southeast prototype. Overall, features of a model regional ocean GIS include coverage of multiple states and the adjacent EEZ, generally corresponding to large marine ecosystems; state, federal, and nongovernmental data sets, data on the location and intensity of ocean uses and activities, and governance. The governance component is one of the unique features of the Southeast regional GIS and includes legal and jurisdictional boundaries, and "geo-regulations"—policy summaries and direct links to relevant laws governing ocean areas and resources. Easy access to the data through the Internet and a map-serving capability is another feature of the model.

State responses to our queries about the actual or potential benefits of a *regional ocean GIS* fell into the following general categories, some of which overlapped with the state-level benefits noted above: (1) jurisdictions, boundaries, laws; (2) regional planning; (3) environmental change and impact assessment; (4) design of SMAs; (5) centralization of, and shared access to data; and (6) stakeholder and public education (**Table 7**).

- State interest in participating in regional GIS, as suggested by our conceptual model, was high for six states (26 percent), moderate for 11 states (48 percent), low for five states (22 percent), and mixed moderate/high for one.
- The utility of ocean GIS for regional planning applications was identified by 20 states (87 percent) as an important potential benefit (category 2).
- Fourteen states (61 percent) identified centralization of data and shared access to a wider variety of academic, federal, other state, and NGO data as a tangible benefit of regional GIS (category 5).
- The utility of the governance element in a regional GIS was recognized by 13 states (57 percent) as a real benefit of regional GIS (category 1).
- Twelve states (52 percent) cited the strengthened environmental assessment capacity of regional GIS as a significant benefit, both for individual projects and for examining long-term cumulative effects (category 3).
- Six states (26 percent) specifically mentioned the usefulness of regional GIS in designing and establishing marine reserves and protected areas, citing as rationale the growing capability of GIS to model the regional, dynamic nature of marine ecosystems (category 4).
- Just four states (17 percent) identified the use of regional ocean GIS to educate stakeholders and the public about ocean uses and activities (category 6).

State interest in participating in a regional GIS is relatively high, with more than three-quarters indicating at least moderate interest. This reflects, we believe, the growing state interest and technical capacity for ocean resources management, and the expressed desire of states for becoming a more equal partner with the federal government in EEZ, and territorial sea decision making.

Support of regional planning, one of the chief functions of the professionals we interviewed, was rated an important GIS benefit by most states, whereas stakeholder education was rated important by very few. The multiple actors involved in regional planning (recall **Figure 2**), and the information-intensive nature of such efforts suggests to us that the educational

Table 7. State interest and potential benefits of regional ocean GIS.

| State | State LME[1] | State Interest | Jurisdiction, boundaries, laws | Regional Planning | Environmental change/impact assessment | SMA Design | Centralization of, and shared access to data | Stakeholder and public education |
|---|---|---|---|---|---|---|---|---|
| ME | 7a | Moderate | | ❍ | | ❍ | | |
| NH | 7a | Moderate | ❍ | ❍ | | | | |
| MA | 7a | High | ❍ | ❍ | | ❍ | | |
| RI | 7b | Moderate | ❍ | ❍ | ❍ | | | ❍ |
| CT | 7b | Low | | | | | | |
| NY | 7b | Moderate | | ❍ | | | ❍ | |
| NJ | 7b | Low | ❍ | ❍ | ❍ | | | |
| DE | 7b | Low | | | | | ❍ | |
| MD | 7b | Moderate | | ❍ | ❍ | | | |
| VA | 7b | Low | | ❍ | | | | |
| NC | 7b, 6 | High | ❍ | ❍ | ❍ | | ❍ | |
| SC | 6 | High | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| GA | 6 | Moderate | ❍ | ❍ | | | ❍ | |
| FL | 6,5 | High | ❍ | ❍ | ❍ | ❍ | ❍ | |
| AL | 5 | Moderate | | ❍ | ❍ | | ❍ | |
| MS | 5 | Low | | | ❍ | | ❍ | |
| LA | 5 | Moderate | ❍ | ❍ | ❍ | ❍ | | |
| TX | 5 | Moderate | | ❍ | ❍ | | ❍ | |
| CA | 3 | Moderate | ❍ | ❍ | ❍ | | ❍ | ❍ |
| OR | 3 | High | ❍ | ❍ | | | ❍ | ❍ |
| WA | 3 | Moderate | ❍ | ❍ | | | ❍ | |
| AK | 2,1,47 | Mod/Hi | | ❍ | ❍ | ❍ | ❍ | |
| HI | 11 | High | ❍ | ❍ | | | ❍ | |
| Total | | | 13 | 20 | 12 | 6 | 14 | 4 |

**Key to Table 7. Columns:**

**Jurisdictions, boundaries, laws** – Regional ocean GIS clarifies jurisdictions and boundaries, visualizes gaps and overlaps, links to legal authorities and regulations, and integrates these data with ocean uses and activities for jurisdictional determinations.

**Regional planning** – Regional ocean GIS helps identify problems and opportunities shared among multiple jurisdictions, supports collaborative and integrated planning for inter-jurisdictional issues such as migratory species protection, marine transportation, oil and gas development, oil spill contingency planning, fisheries conservation, cable right-of-ways, military operations, and so on.

**Environmental change/impact assessment** – Regional ocean GIS is a tool for storage, organization, and analysis of marine geographic data to assess natural variability in ocean and climate conditions, such as sea surface temperature, nutrients, chlorophyll, winds, and currents; it also is a powerful tool for assessing the impacts of new ocean use or development proposals, as well as the cumulative effects of human use.

**Design of SMAs** – Regional ocean GIS integrates marine ecological and ocean use and activity data to help design special geographic areas to protect species, habitats, or resource uses or development.

**Centralization of, and shared access to data** – Regional ocean GIS provides for centralized storage, organization, documentation, and access (through Internet map and data serving capabilities) to data and information from multiple research groups and management authorities.

**Stakeholder and public education** – Regional ocean GIS communicates information powerfully and equally (with appropriate explanation) to multiple stakeholders in any given issue or policy setting by providing an intuitive visual representation of the marine environment, resources, boundaries, uses, and policies. Internet-based mapping and information tools provide broad access to marine resource information and can serve as a mechanism for public education.

value of GIS and its ability to level the playing field is an undervalued benefit. Public availability of ocean GIS data through the Internet should also be an equalizer, not only in regional planning, but also in site-specific decision making.

Just six states identified the role of regional GIS in designing special management areas. Interestingly, California, a state undertaking an extensive protected area planning effort along its coastline, was not among them. With the federal mandate to protect essential fish habitat (1996 Sustainable Fisheries Act), continuing concerns about certain marine mammal populations (e.g., sea otters and Stellar sea lions on the West Coast), and growing scientific interest—an entire supplemental issue of the journal *Ecological Applications* was devoted to the subject in 1998 (Volume 8, No. 1, Supplement), the perceived benefits and use of regional ocean GIS for SMA design are likely to increase greatly over the next decade.

***The Sum Benefits of Ocean GIS*.** There are some clear overlaps in categories and definitions of state benefits (**Table 6**) and potential regional benefits (**Table 7**). For example, the last two categories for each group are identical (*data centralization/access* and *stakeholder education*). The state category *interagency collaboration* is similar in some respects to the regional *jurisdictions, boundaries, and laws*, although the latter is more specific. The remaining categories overlap as well, suggesting that collapsing benefit categories into a single, perhaps more elaborate list is needed. Consolidation of benefits and the addition of other benefits based on our literature review leads to 10 benefits, although the list could probably be longer or shorter depending on lumping or splitting. Using GIS and Internet tools, ocean managers can:

1. Integrate the physical, natural, and social sciences, and engineering data and information with ocean use and ocean governance information.
2. Identify scientific research needs to address ocean management questions, and help generate research hypotheses.
3. Centrally store, organize, document, and provide access to data and information from multiple research groups and management authorities.
4. Provide Internet-based access to ocean information that educates and empowers stakeholders and the public to be involved in decision making.
5. Clarify ocean jurisdictions and boundaries, visualize gaps and overlaps, and provide issue and area-relevant links to authorities and regulations.
6. Identify and resolve disputes at multiple scales, and provide for visualization of ocean use interactions, as well as interactions between ocean uses and the marine environment.
7. Support planning for complex, inter-jurisdictional issues at regional, limited-area, and site-specific scales by integrating diverse ecological, human use, and governance data.
8. Assess environmental impacts of specific ocean management decisions and cumulative effects.
9. Monitor and evaluate indicators of marine ecosystem health.
10. Evaluate outcomes to determine equity, efficiency, and effectiveness in achieving ocean policy goals and objectives.

***Ocean GIS—Does It Foster More Integrated Ocean Management?*** Earlier we described present ocean management and decision-making regimes as largely fragmented—within and among sectors; within and among governmental levels; with respect to the geography of coastal lands and waters; and with respect to the types and quality of disciplinary information utilized. Improved integration, we suggested, means policy and decisions that are comprehensive with respect to inputs—time, space, actors, information; aggregated with respect to decision making—all options, interests, and perspectives considered; and consistent within and among sectors and governmental levels. Each of the ocean GIS benefits above has some potential to confer improvement in one or another dimension of integration (**Table 8**). As we suggested earlier, virtually every dimension of integrated ocean management benefits significantly from application of GIS and Internet technologies. This is because information is the currency of decision making, whatever the issue.

Differences appear to be small, but the *intergovernmental* dimension of integrated management seems to be most positively benefited by ocean GIS, particularly those functions associated with multi-jurisdictional planning and assessment. There are many examples of benefits in this area. For example, the NOAA Coastal Services Center, in developing the governance elements of the Southeast OPIS, identified numerous marine boundary and point location inconsistencies and generalizations in federal and state laws and regulations. This precipitated a more concentrated effort to develop marine cadastral standards. Another example is the influence of GIS modeling of the potential impacts of alternative dredged material disposal sites in New York harbor (Pace Wilber, pers. comm. 1998).

The *intersectoral* dimension is affected next most strongly. An example of the benefits associated with GIS for intersectoral aspects of ocean management was the inadvertent discovery by the Minerals Management Service that a major Gulf of Mexico tanker shipping lane was located next to an out-of-production oil platform that was being used to store major quantities of oil pumped from wells throughout the area (Norman Froomer, pers. comm., April 1999).

An example from the *disciplinary* dimension turned up in the Oregon review. Several species of groundfish have been severely overfished, effectively closing the entire multi-species fishery because of fish intermingling. One controversy concerning groundfishing is the possible adverse impacts of trawl gear on bottom habitat necessary for fish recruitment and rearing. Research on the issue is limited and none has been conducted in Pacific Northwest waters. GIS data on trawl effort (**Figure 5**) is being used as a starting point to frame hypotheses about the effects of bottom trawling (Wakefield and Bailey, unpublished data, 1999). There is hope that this kind of research might lead to efforts to protect the most important, sensitive areas. A *spatial* integration example is a West Coast-wide, five-year study just getting underway to monitor larval dispersal, recruitment, and nutrient levels in nearshore rocky intertidal and subtidal environments (Renee Davis-Borne, pers. comm., 1999). GIS is being used to organize and interpret data, and then communicate information about spatial patterns and trends, and their implications for ocean management, particularly the establishment of nearshore marine reserves.

***Ocean GIS—Does It Increase Equity, Efficiency, and Effectiveness in Ocean Management?*** Increasing the equity, efficiency, and effectiveness of decision-making processes that include a spatial dimension is one of the goals of the National Spatial Data Infrastructure in the United States. Virtually all ocean management activity has a spatial dimension and thus we

Table 8. GIS benefits and their potential to foster improved integration in ocean management.

| | Potential Benefits of GIS for Ocean Management | Benefit Improves Integration[1] | | | |
|---|---|---|---|---|---|
| | | Sectoral | Intergov. | Spatial | Disciplinary |
| 1 | Integrates the physical, natural, and social sciences, and engineering data and information with ocean use, and ocean governance information. | ❍ | ❍ | ● | ● |
| 2 | Identifies scientific research needs to address ocean management questions, and help generate research hypotheses. | | | ❍ | ● |
| 3 | Centrally stores, organizes, documents, and provides access to data and information from multiple research groups and management authorities. | ❍ | ● | ❍ | ● |
| 4 | Informs and empowers stakeholders and the public to be more knowledgeable and involved in decisions that affect them, a benefit much enhanced by Internet access to data and maps. | ● | ● | | |
| 5 | Clarifies ocean jurisdictions and boundaries, visualizes gaps and overlaps, and provides issue and area-relevant links to authorities and regulations. | ❍ | ● | ● | ❍ |
| 6 | Helps identify and resolve disputes at multiple scales, and provides for visualization of ocean use interactions, as well as interactions between uses and the marine environment. | ● | ● | ❍ | ❍ |
| 7 | Supports planning for complex, inter-jurisdictional issues at regional, limited-area, and site-specific scales by integrating diverse ecological, human use, and governance data. | ● | ● | ❍ | ❍ |
| 8 | Analyzes project-specific and cumulative, long-term environmental effects. | ❍ | ● | ❍ | ● |
| 9 | Stores, organizes, and analyzes monitoring data on indicators of marine ecosystem health. | ❍ | ❍ | ● | ● |
| 10 | Evaluates outcomes to determine decision equity, efficiency, and effectiveness in achieving ocean policy goals and objectives. | ❍ | ❍ | ❍ | |

[1] See text for definitions of the dimensions of integrated ocean management.

● Benefit has potential to confer significant improvement or function
❍ Benefit has potential to confer some improvement or function

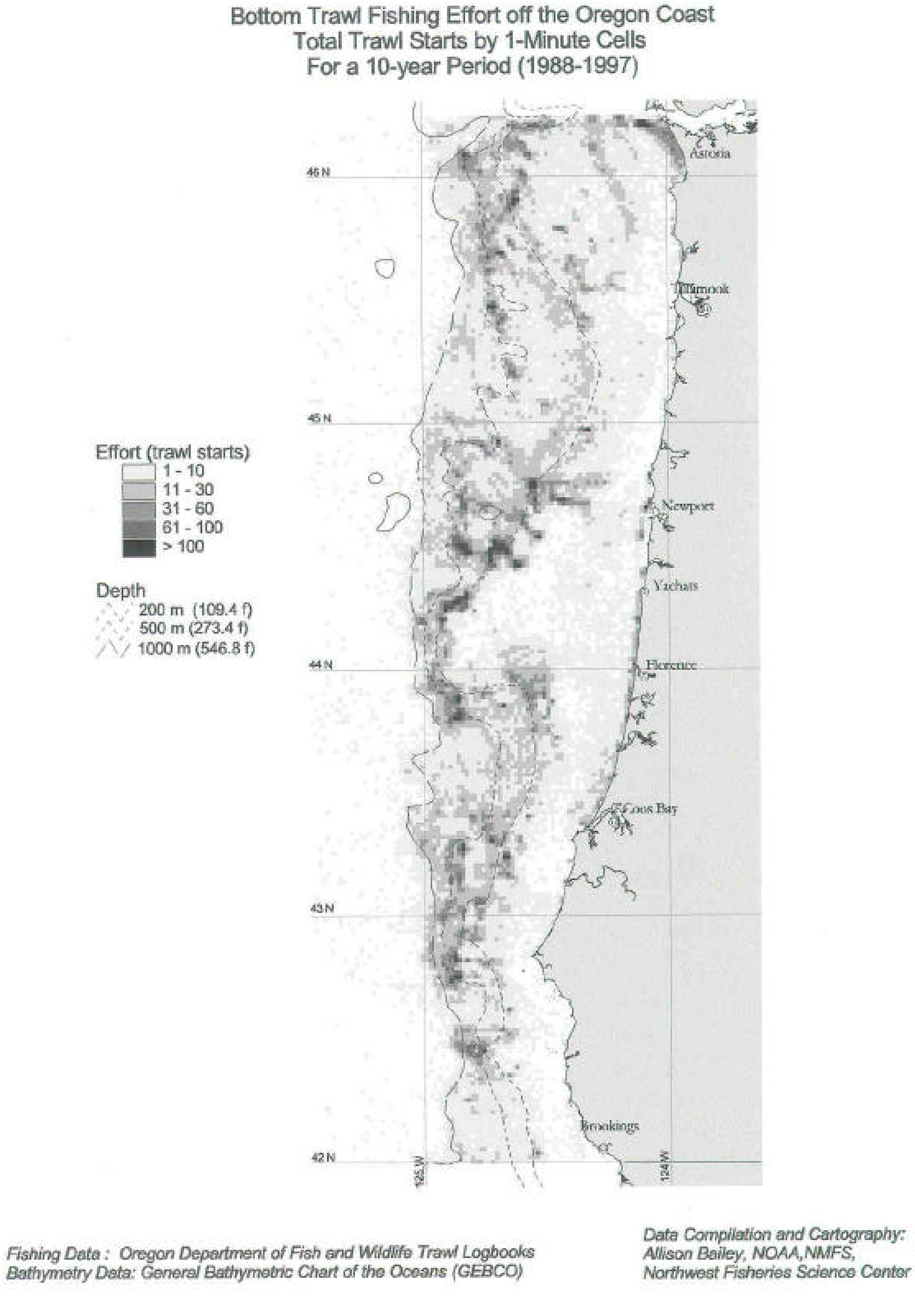



Figure 5. Bottom trawl fishing effort of the Oregon coast, and example of ocean use data that can be coupled with substrate and other data to generate hypotheses about trawl impacts.

are interested in whether and how the use of GIS in this context can increase equity, efficiency, and effectiveness. With respect to ocean GIS, we defined these three terms simply:

*Equity* – means easy, low-cost or no-cost access to the best available scientific and other ocean data and information by all ocean stakeholders and the public in a form that is easy to use, interpret, and understand; if information is power, equity is about the free sharing of power.

*Efficiency* – means developing needed spatial data and information for ocean management at the lowest cost possible; efficiency presumes wide data sharing and reduced duplication of effort.

*Effectiveness* – has to do with the impact of ocean management policy and decision making outcomes with respect to policy goals and objectives, and the role of GIS in fostering effectiveness and documenting outcomes.

Although we did not query state managers and GIS professionals directly on this issue, their responses on other questions provided us with an intuitive basis for assessing how each benefit identified might increase equity, efficiency, and effectiveness, as defined above (**Table 9**). The benefits we ascribe to ocean GIS fit our definitions rather neatly, since some relate to improved, more democratic information access (equity), others to avoiding duplication through improved data integration and sharing (efficiency), and still others to improved decision making and policy outcomes (effectiveness). Although it was unclear at the outset of the study how we might answer questions about increased equity, efficiency, and effectiveness, they emerged with unexpected clarity, as **Table 9** illustrates. Application of GIS and Internet data sharing to ocean management has a significant positive effect on equity, efficiency, and effectiveness of processes employed and outcomes achieved.

**Barriers to State-Level Development of State or Regional Ocean GIS**

If ocean GIS makes so much sense and offers so many benefits, why are states not taking it up, investing their own resources in developing ocean GIS for their waters and adjacent EEZ, as well as collaborating across state marine boundaries on shared issues? This was one of the questions we asked state coastal and ocean managers and GIS professionals. The simple answer is that the perceived benefits are overwhelmed by the institutional, financial, technical, and data integration barriers (**Table 10**).

***State Perceptions of Barriers*****.** The lack of financial resources to develop and maintain an ocean GIS was named by 22 of the 23 states we interviewed (96 percent) as a important barrier (**Table 10**). Competition for limited funds among natural resource agencies at the state level is fierce, and although GIS and related technologies are rapidly being integrated into coastal management processes, investments in applications and data development for land-based issues like wetlands management, coastal hazards, and growth management take priority over offshore applications. The much greater expense of collecting some kinds of marine environmental data as compared to collecting land data is also a factor.

Eighteen states (78 percent) cited problems with marine data availability. Even basic data sets, like detailed bathymetry, habitat and related attribute data (e.g., key species associations) are not readily available for many ocean areas. Also, much of the data available from the ocean science community is not suitable for use in a GIS, much of it being too fine or coarse in resolution, too narrowly or broadly focused geographically, or beyond the capability of GIS to integrate in meaningful ways.

Table 9. GIS benefits and their potential to foster increased equity, efficiency, and effectiveness in ocean management.

| | Potential Benefits of GIS for Ocean Management | Benefit Increases[1] Equity | Efficiency | Effectiveness |
|---|---|---|---|---|
| 1 | Integrates the physical, natural, and social sciences, and engineering data and information with ocean use, and ocean governance information. | | ● | |
| 2 | Identifies scientific research needs to address ocean management questions, and help generate research hypotheses. | | ● | ❍ |
| 3 | Centrally stores, organizes, documents, and provides access to data and information from multiple research groups and management authorities. | ● | ● | |
| 4 | Informs and empowers stakeholders and the public to be more knowledgeable and involved in decisions that affect them, a benefit much enhanced by Internet access to data and maps. | ● | | |
| 5 | Clarifies ocean jurisdictions and boundaries, visualizes gaps and overlaps, and provides issue and area-relevant links to authorities and regulations. | | ● | ❍ |
| 6 | Helps identify and resolve disputes at multiple scales, and provides for visualization of ocean use interactions, as well as interactions between uses and the marine environment. | ● | ❍ | ● |
| 7 | Supports planning for complex, inter-jurisdictional issues at regional, limited-area, and site-specific scales by integrating diverse ecological, human use, and governance data. | ● | ❍ | ● |
| 8 | Analyzes project-specific and cumulative, long-term environmental effects. | ❍ | ❍ | ● |
| 9 | Stores, organizes, and analyzes monitoring data on indicators of marine ecosystem health. | | ❍ | ● |
| 10 | Evaluates outcomes to determine decision equity, efficiency, and effectiveness in achieving ocean policy goals and objectives. | | ❍ | ● |

[1] See text for definitions of equity, efficiency, and effectiveness.

● Benefit has potential to confer significant improvement or function
❍ Benefit has potential to confer some improvement or function

Table 10. Barriers to the state-level development of state or regional ocean GIS capacity.

| State | Data availability | Data access | Staff | Technology | Financial | Leadership | Priority | Other barriers |
|---|---|---|---|---|---|---|---|---|
| ME | | ❍ | ❍ | | ❍ | ❍ | ❍ | Not high state/agency priority |
| NH | | | | | | | ❍ | |
| MA | ❍ | | ❍ | ❍ | ❍ | | | |
| RI | | | ❍ | | ❍ | ❍ | | Limited GIS support staff |
| CT | ❍ | | | | ❍ | | ❍ | Ocean issues not a priority |
| NY | ❍ | | | | ❍ | ❍ | ❍ | |
| NJ | ❍ | | | | ❍ | | ❍ | Little academic collaboration |
| DE | ❍ | | ❍ | | ❍ | | | |
| MD | ❍ | | | | ❍ | | ❍ | Limited GIS support staff |
| VA | ❍ | ❍ | | | ❍ | ❍ | ❍ | |
| NC | ❍ | | ❍ | | ❍ | | ❍ | |
| SC | ❍ | | ❍ | | ❍ | | | |
| GA | | | ❍ | | ❍ | ❍ | | Not high state/agency priority |
| FL | ❍ | | | | ❍ | | | |
| AL | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | | |
| MS | ❍ | | ❍ | | ❍ | | | |
| LA | ❍ | ❍ | ❍ | | ❍ | ❍ | ❍ | |
| TX | | ❍ | | | ❍ | ❍ | | |
| CA | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | | |
| OR | ❍ | ❍ | ❍ | | ❍ | ❍ | ❍ | Lack time, staff, funds for GIS |
| WA | ❍ | | ❍ | | ❍ | | ❍ | Ocean issues low priority now |
| AK | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | All barriers important |
| HI | | | ❍ | | ❍ | ❍ | | Digitizing-integration issues |
| Total | 18 | 8 | 15 | 4 | 22 | 12 | 12 | |

Key to column headings:

Data availability: Data necessary for basic or specialized ocean coverages not available
Data access: Difficulties in acquisition, conversion, or compatibility of data sets
Staff: Lack needed staff, expertise, training, or time for ocean GIS development
Technology: Lack necessary hardware and/or software to support ocean GIS
Financial: Lack necessary financial resources to develop and maintain ocean GIS
Leadership: Lack high level political and/or management support/commitment for ocean GIS
Priority: Ocean GIS not high relative priority given issues and mostly federal control offshore

Staffing issues—lack of GIS positions, lack of training or expertise, or pressure from competing demands for use of existing GIS resources—were cited by 15 states (65 percent) as a major stumbling block to ocean GIS development. Given the focus on coastal issues opposed to ocean issues in most state coastal management programs, few staff have the requisite training to integrate much of the data and information available about marine ecosystems.

Twelve states (52 percent) noted that there was probably insufficient support from political or high level management for ocean GIS to be a high priority financial or human resource investment.

Twelve states (52 percent) said that the incentives or payoff for developing comprehensive state or regional ocean GIS were not sufficient to make the necessary initial investment. This is true even in some of the states now most engaged in ocean management—North Carolina and Oregon, for example. For others, ocean issues were once a priority but no longer are, at least now. Washington State is a good example of the latter case—in the mid-1980s, federal offshore oil and gas leasing appeared imminent and ocean management activity was high, including collaboration with neighboring states and British Columbia. When a moratorium on offshore leasing was imposed by President Bush and 2,700 square miles of offshore waters were set aside as the Olympic Coast National Marine Sanctuary, Washington State's attentions shifted to other more pressing issues. Washington's coastal program today is highly sophisticated in its use of GIS, but the focus is on watershed management, wetlands restoration, and coastal hazards, not ocean management.

Problems accessing needed data for ocean GIS were noted by eight states (35 percent), a lower number than we expected, perhaps reflecting states where interest has been piqued, but then dampened by perceived enormity of the task. Certainly, a good proportion of ocean data is proprietary (oil and gas exploration data), classified (military information), or developed by agency or academic scientists who must publish it first. Getting timely access or any access to these data presents a major challenge. Extracting data from sectoral governmental agencies is often difficult as well, even though it was created with tax dollars and is in the public domain. Because data and information confer power and advantage, getting access to available data useful for management is sometimes difficult.

Only four states (17 percent) identified technological barriers to development of ocean GIS, suggesting that the lack of hardware and software is not a major barrier, especially in comparison to other factors.

***Other Barriers and Limitations.*** A number of barriers noted above deserved more in-depth comment, as do some of the inherent limitations of GIS for application in the complex, dynamic marine environment. Among these are questions about:

- scale and resolution of ocean GIS data and applications
- data availability, compatibility, and quality
- upper management level understanding of what GIS can and can not do
- inherent limitations of GIS in a fluid, three-dimensional environment such as the ocean
- extent of understanding of ocean dynamics by most coastal and ocean managers
- cultural differences among data developers, integrators and analyzers, and decision makers
- fragmentation of ocean area and resources management regimes
- long-term maintenance of ocean GIS

*Scale and Resolution Issues.* One of the primary challenges in developing a GIS for a large ocean area is defining the geographic coverage of the system and necessary data resolution. Generally, the larger the area mapped, the poorer the resolution of included data. A large-scale map that covers a small geographic area can display far greater detail than a small-scale map that covers a much larger geographic area. However, the issue of scale is slippery with GIS, because the user can zoom in and out of a map, often well beyond the resolution limits of the data it contains. An indicator of resolution is the minimum mapping resolution (MMR)—the smallest area that can be described as one thing (Berry 1995). The MMR changes according to what is being mapped (boundary lines, benthic habitat, oil platforms, etc.), but is still limited by overall map scale. The finest image resolution that can be represented in a GIS is limited to the minimum cell size (in a raster coverage) or the minimum size of a point representation (in a vector coverage) (Berry 1995). Resolution of raw data is determined by the data collection technique. For instance, if bathymetry data were collected using side-scan radar with a resolution of 100 meters, then no finer resolution of bathymetry data is possible in the GIS. GIS users who do not have an appreciation for these points run the risk of misinterpreting analyses, drawing incorrect conclusions, and making poor management decisions.

The question of determining the most appropriate scale and resolution for GIS data can only be answered after careful consideration of the intended use of the GIS. We suggest that the concept of *decision scale and resolution* be used to address this issue. We define decision scale and resolution as the smallest acceptable scale and resolution of data that is needed to make a decision, be it the better of several broad policy options, site-specific zoning decision, or a single permit decision as compared to technical standards. This requires that the design of a GIS be preceded by identification of the range of decisions it is being built to support, and the types and smallest acceptable scale of data needed to make those decisions, assuming appropriate levels of risk and uncertainty. The concept of decision scale and resolution is useful for planning and using a GIS within its limits to yield accurate results, but it is an idealized one. In most cases, choices of data available for the marine environment are limited by available data collection techniques and the great expense of specialized data generation, particularly for large areas. Unless significant time and funding are available for the collection of new information, the use of existing data is the only option.

Based on our interviews of state coastal and ocean managers, most see a greater need for large-scale GIS applications (small area, high resolution), because management decisions and conflicts they deal with require that kind of detail for analysis. Small-scale ocean GIS (large area, lower resolution) have lower perceived utility at the state level, although many states were also interested in the possible benefits associated with a large area coverage GIS to aid in regional planning, particularly for areas under state control (the territorial sea). State perspectives on the scale-resolution issue are summarized in **Table 11**.

The question of large-scale versus small-scale GIS is not an either-or proposition. Conceptually, two related ocean GIS systems of different scale and resolution could be linked, with the large-scale GIS “nested” within the small-scale, regional GIS. Nesting of GIS applications in this manner would facilitate many of the benefits identified in this report for both state-level and regional ocean GIS. Development of a regional framework GIS within which large-scale applications might be nested would serve as a basis for improved data compatibility and integration across multiple spatial scales and management jurisdictions. This concept is currently being explored through collaborative meetings between GIS specialists from the Florida Marine Research Institute and NOAA Coastal Services Center (Eric Treml, pers. comm., September 1999). Currently, however, issues of scale and resolution pose substantial technical, conceptual, and practical limitations to effective ocean GIS development.

Table 11. Characteristics and potential benefits of large-scale GIS versus small-scale GIS applications.

| GIS Scale | General Characteristics | Potential Benefits |
|---|---|---|
| Large Scale/ High Resolution | • Relatively small coverage extent (limited scope).<br>• High to moderate resolution.<br>• Robust in state-level data.<br>• Developed and maintained by State.<br>• Most directly useful for state-level agencies. | • Useful for state-level regulatory, permitting and enforcement efforts.<br>• Visualization of local management issues.<br>• Useful in supporting day-to-day management decisions.<br>• Potential for conducting robust analyses. |
| Regional-Small Scale/Low Resolution | • Large coverage extent (broad scope).<br>• Low resolution.<br>• Sparse in state-level data.<br>• Developed and maintained by federal government or regional council.<br>• Most directly useful for federal or regional-level groups. | • Useful for regional-level planning and policy analysis.<br>• Visualization of interstate and international management issues.<br>• Provides a broad conceptual scope of marine issues.<br>• Useful for mapping state and federal ocean governance and management jurisdictions. |

*Data Availability, Compatibility, and Quality.* Data from many sources are used in all geographic information systems. The availability and quality of data, as well as its internal compatibility, can be powerful limitations for ocean GIS. Data about the marine environment is collected in many different forms; for it to be used in GIS, it must be collected or converted into digital data. Data capture—locating, digitizing, and integrating appropriate data sets—is generally accepted at the most time- and cost-consuming aspect of GIS development (Clarke 1997).

In order to generate useful GIS coverages, spatial data from a variety of sources must be standardized and geo-referenced to the same projection. The need to integrate multiple data sets can pose difficult technical challenges and makes it difficult to transfer data between different GIS programs. Current efforts to increase standardization of metadata information and data exchange protocols as part of the National Spatial Data Infrastructure (NSDI) framework could help to address this difficulty (NSDI 1999).

Another important data limitation for many marine GIS applications is a lack of existing data suitable to support the types of analysis that would be most useful for state marine resource managers. For instance, new requirements of the 1996 amendments to the Magnuson-Stevens Fishery Conservation and Management Act stipulates that regional fisheries management councils must identify essential fish habitat (EFH) for managed species (Coleman 1999). In order to utilize GIS to map and/or predict likely locations of EFH, high resolution bathymetric, substrate, habitat type, and species distribution information is needed. Because some of these data are not available digitally, the great potential of GIS to assist with necessary ecological analyses is not realized.

Data quality is a major issue for ocean GIS. Some marine environmental data is collected with great care and scientific precision, but other less so. Once merged in a GIS, however, the relative quality of data used for particular analyses becomes masked. This, of course, suggests the need for quality ocean GIS metadata, standards for which are just beginning to be developed.

*Understanding GIS Capabilities and Limitations.* The limited understanding by many policy makers and resource managers of the utility and benefits of GIS for ocean management are another barrier to its elevation to a state agency priority. Lacking champions at influential levels, it is unlikely that ocean GIS will get the needed funding, commitment, and technical support necessary for effective development and implementation. We suspect, based on our interviews, that this is one of the reasons for limited state interest thus far. Conversely, a lack of understanding of the limitations of GIS can result in the use of data for inappropriate analyses resulting in misleading or faulty results, as discussed earlier. Analyses based on poor data can make good-looking, but inaccurate, maps. Management decisions based on these types of analyses are likely to lead to unforeseen outcomes. In practice, however, managers typically do not have the time to learn about GIS in sufficient depth to appreciate its limits.

*Limitations of GIS in the Fluid Ocean Environment.* Most GIS applications, even in the marine environment, are two-dimensional (x, y). Yet much of the available data and information needed for ocean decision making has at least three dimensions (x, y, z) or even four (time). Although many two-dimensional analyses are useful in ocean management (e.g., separating towboat shipping lanes from crab fishing areas), the two-dimensional nature of GIS significantly limits its utility. Further, this inherent limitation has led to a rejection of GIS by many marine scientists as an inadequate tool for oceanographic data analysis.

The ability of GIS to handle 3-D and 4-D data is very limited at this time, although there is increasing research on multidimensional modeling (Mason et al. 1994). A recent GIS software application developed by researchers at the Wrigley Institute for Environmental Studies at the University of Southern California is an example of how GIS can effectively analyze 3-D and time-stamped data. This Environmental Assessment System (EASY) GIS is particularly well suited to analysis of oceanographic and satellite data for the modeling of coastal water quality (USC Wrigley Institute 1998).

*Limited Understanding of the Marine Environment by Managers*. One dimension of the “fragmentation” problem in ocean management is the distinct break in management that occurs at the shoreline. One reason for this is the “managers” of the coast are likely to be differently trained than those who deal with marine resources. Coastal management agencies employ planners, geographers, policy analysts, and perhaps coastal scientists or engineers, but few marine scientists. This makes sense given the bulk of issues coastal agencies deal with, but it limits their capacity to know what questions need to be answered in ocean decision-making situations, to know what information or data are needed, and whether and where it is likely to be available. As a consequence, coastal management agencies—often the only “sectoral integrators” at the state level—tend to operate within their geographic comfort zone, namely the shore, the bay, the upland. Conversely, many marine science-trained specialists do not know what the management questions are and what kinds of new knowledge or data might be most useful.

*Social and Behavioral Barriers to Ocean GIS Development.* In the background section of this report, we noted that culture differences among and within the science, management, and policy-making communities—how each works, what they work with, and how they communicate, are very different. The consequence, we suggested, is mutual lack of understanding, lack or misuse of others’ products, competition, simple failure to communicate, and even disdain for one another's work. This means that relationships are uneasy at best. GIS has the potential to either bridge some of these differences or deepen them. Careful use of data and information provided by scientists, interaction on interpretations, and improved communication are needed to build bridges and avoid deepening these problems. One outcome of communication barriers among those who develop, interpret, and use ocean information is that policy makers and resource managers are often unaware of the work of academic marine scientists, and scientists are unaware of societal need for their expertise and data. Much scientific endeavor, particular in academic institutions, is typically not conducted with consideration for how it might be used for ocean management. Sometimes scientists even fear that possibility. Efficiency in ocean management demands that these kinds of barriers be bridged. Awareness of this barrier is the first step in overcoming it, but increased opportunities for meaningful interaction and collaboration are needed to overcome them.

*Lack of Integration in Current Ocean Governance.* The fragmented nature of ocean governance, particularly between state and federal levels, and among sectoral management agencies poses a difficult obstacle to the implementation of regional ocean GIS. Lacking coordinating mechanisms and institutions (e.g., a regional ocean council) and dispute resolution authorities, regional ocean GIS has difficulty in building and maintaining a primary client base. Some states are very interested, but adjacent states less so, and some have necessary institutions developed (a state ocean council), but others do not. Existing fragmentation makes demand and interest in regional GIS very soft.

Sectoral management also hinders the process of locating and accessing appropriate data from multiple resource management agencies. Multiple management authorities for ocean management also make it challenging to secure funding for development and implementation of a regional GIS. Thus, although regional GIS has the potential to better integrate ocean management at a regional scale, actual changes in governance structures are likely to be necessary for the full realization of its potential.

*Questions About the Development and Maintenance of Regional GIS.* One of the basic questions that must be addressed in process of developing a regional ocean GIS framework is: Who should build, pay for, update, and maintain the system and how will this affect the utility and longevity of the resulting GIS? Many of the state GIS applications our interviewees noted were developed, used for a single project or decision, and then archived. If a regional GIS is funded and developed almost exclusively by the federal government, the danger exists that a sense of ownership will be lacking from state interests. Maintenance of the system, without a financial or personnel buy-in from the state, may lag or be eliminated, negating the value of the initial investment. In addition, without substantial participation from state representatives, a regional GIS is not likely to be directly useful to state management efforts. In either case, the system would fall short of providing the intended benefits of more integrated ocean management. Thus, an effective regional GIS framework must be founded upon both a stable federal coordinating mechanism and active participation from constituent states through data sharing, complementary development of large-scale marine GIS, and interest in developing interstate and intergovernmental solutions to regional marine problems.

## CONCLUSIONS

The principal goal of this study was to determine the potential benefits of using GIS to manage marine resources and ocean space, emphasizing state ocean interests. We also wanted to know how these benefits might foster more integration in ocean management, as well as more equity, efficiency, and effectiveness in decision making. Another question was the perceived value and utility of the regional approaches, such as the Southeast OPIS, versus less ambitious, more limited geographic area approaches. The role of the Internet in GIS data sharing was also of interest, given the exponential growth in its use over the last decade and expected growth in the future. The principal findings and conclusions follow.

**1. State Interest and Influence Increasing - State interest in and influence over the management of marine resources and ocean space has increased in recent decades and this trend is likely to continue, albeit slowly.**

States have strong interest in a number of key ocean issues—the management of declining fishery stocks; identification and protection of habitat for marine species; future oil and gas development; coastal water quality; oil spills; and, on the east coast, identification of sand resources for beach nourishment (**Table 2**). These issues, they say, have both local and regional attributes and thus require collaborative approaches.

At the same time interest is growing, new vehicles give states more influence in ocean decision making. One key example is the 1990 amendment of the "federal consistency" provisions of the CZMA, which clarified state authority to review federal activities for consistency with state coastal policies, whether or not the activities occurred inside or outside the coastal zone. Just as federal consistency was an important incentive for state participation in the federal coastal program, it is also likely to be a chief impetus for state ocean management program initiation. Other examples of vehicles for increased state involvement offshore include regional fishery management regimes that involve states, state authority to strictly enforce oil spill prevention and cleanup rules, and oil and gas leasing and development consultation procedures.

Having ready access to GIS data on marine boundaries and federal and state authorities (as in the Southeast OPIS) has obvious value to states desiring to assert their interests and influence in these and other ocean decision processes.

**2. State and Federal Interests Offshore Differ - State interests in ocean management have some inherent differences from federal agency interests, both in character and degree; consequently, the perceived roles of ocean GIS for information management and decision support are different.**

State ocean management is likely to benefit substantially from the improved information management and mapping GIS provides. Given the fragmentation of state marine resource management regimes, and the more local focus of their interests, they generally need higher resolution, larger-scale, sector-specific data as opposed to regional-scale data. States do concede that regional ocean GIS would be useful for area planning and policy analysis, particularly for issues they share across state and federal boundaries, or with adjacent states. Nevertheless, until state and national ocean policy and institution-building catches up with technical GIS capacity, single issues will drive state ocean management activities. In such an environment, it is unlikely that groups of states will initiate regional ocean GIS efforts on their own.

**3. State Management Capacity Growing Slowly - Many coastal states are gradually improving their institutional capacity for participation in ocean management and virtually all claim interest in doing so—this trend will stimulate interest in state and regional ocean GIS.**

State-level ocean management policy and institutions are beginning to emerge (**Table 3**). As they do, the need for improved ocean data and information, data access, and information sharing will follow.

States with more mature ocean management efforts tend to be more engaged in ocean GIS and other information system activities. Generally, policy and institutional development precede interest in ocean GIS and information sharing, simply because the need becomes apparent as issues are addressed. Maine, Massachusetts, North Carolina, Florida, California, Oregon, Washington, and Hawaii all have at least some policy basis and institutional structure for state ocean management and represent the beginning "market" for the regional ocean GIS concept. It is also possible that exposure to regional ocean GIS and appreciation of its utility may stimulate informal (and perhaps formal) policy and institutional improvements at the state level. The interest of Georgia and South Carolina in the OPIS suggests this may be the case.

Nevertheless, fragmentation in marine resource management at the state level impedes the development of comprehensive ocean GIS, just as it does at the federal level. Investments being made are issue- or resource-specific, and apply to limited geographic areas. Thus, although regional GIS has the potential to foster more comprehensive ocean management, the sectoral nature of current management can also *impede* its development. Until more integrated state and federal institutional arrangements for ocean management are established (national and regional marine councils, dispute resolution mechanisms, etc.), the demand for regional ocean GIS will continue to be soft.

**4. State GIS Technical Capacity Strong - State coastal management agencies, and other sectoral management agencies with coastal and marine resource management responsibilities, have significant and growing technical capacity and resources to develop GIS applications and provide Internet information services.**

State use and sophistication of GIS use for coastal and ocean management today varies, with most applications being site- or project-specific, for limited geographic areas, and focused on coastal lands and waters, as opposed to offshore areas (**Tables 4** and **5**). Florida is the undisputed national leader in developing ocean GIS, and the Southeast OPIS is the only bona fide regional GIS focused primarily on state interests. Internet data and information sharing is rare, but beginning to be used by states including Florida, California, and Maine. Sectoral state agencies (e.g., fisheries and wildlife) are just as likely to be the principal developers of marine GIS applications as the formally-designated coastal management agencies. Overall, the growing GIS and Internet technical capacity and resources of states provide a good foundation for expanding use of GIS for state and regional ocean management. However, limited financial resources pose a significant barrier to integrating existing digital data, generating additional data sets, investing in GIS technology, and hiring needed GIS technical staff.

**5. <u>GIS Benefits Ocean Management</u> - The potential benefits of GIS for ocean management are deep and widespread, accruing to policy-makers, resource planners and managers from all marine sectors at all governmental levels, users of marine resources and ocean space, marine scientists of different disciplines, nongovernmental interest groups of every stripe, and the public at large, including youth.**

Ocean GIS:

1. integrates scientific and technical, ocean use, and ocean governance data in one geo-referenced system.
2. integrates scientific research planning with ocean management needs.
3. centrally stores, organizes, documents, and makes accessible data from many sources.
4. informs and empowers stakeholders and the public to be more knowledgeable and involved in decisions that affect them, a benefit much enhanced by Internet access to data and maps.
5. clarifies and gives visual geographic representation to ocean jurisdictions, boundaries, and authorities.
6. clarifies and helps resolve disputes and conflicts by allowing visualization of interactions, problems, and potential solutions.
7. supports planning for complex, inter-jurisdictional issues at regional, limited-area, and site-specific scales by integrating diverse ecological, human use, and governance data.
8. analyzes project-specific and cumulative environmental effects.
9. stores, organizes, and analyzes monitoring data on indicators of marine ecosystem health.
10. evaluates outcomes to determine decision equity, efficiency, and effectiveness relative to policy goals and objectives.

It is apparent that this list somewhat restates the classic benefits of GIS for resource management we outlined in the background section. There are some unique aspects associated with use of the Internet as a distribution mechanism, but it is clear that the general utility of GIS for resource management applies equally to ocean management.

**6. <u>GIS Fosters Integration, Equity, Efficiency, and Effectiveness</u> – The use of GIS for ocean management, and the benefits it confers, will lead to more integrated marine policy and management. It will also increase equity, efficiency, and effectiveness in marine resource and ocean area management.**

Use of GIS to support regional and state management of ocean resources and space would benefit each dimension of integration discussed here—sectoral, intergovernmental, spatial, and disciplinary (**Table 8**). Benefits 1 to 3 above—dealing with data handling and integration—have the greatest impact on disciplinary and spatial integration; whereas the sectoral and intergovernmental integration are most positively affected by benefits 4 through 8, which involve the use of data for problem solving. Benefit 9, indicator monitoring, would affect integration in all dimensions, but most strongly in the spatial and disciplinary areas. Finally, benefit 10, evaluation, has the most positive impact on sectoral and intergovernmental integration.

Increased equity, efficiency, and effectiveness in ocean management will also be outcomes of increased GIS use for ocean management (**Table 9**). Benefits 1 to 3 and 5 above will increase efficiency by reducing duplication, more sharply focusing management-related research, and by improving information management. Equity will be increased by improved data availability and access—benefits 3 and 4, and by GIS applications with multiple stakeholder interests—benefits 6 and 7. Effectiveness in decision making, relative to goals, will be increased mainly through benefits 6 to 10, which deal with planning, results monitoring, and evaluation.

**7. <u>Barriers to Ocean GIS Implementation</u> – Significant financial, institutional, scientific, technical, and cultural barriers and limitations impede the development and implementation of state and regional ocean GIS. These include:**
(1) the significant initial cost of ocean GIS.
(2) the uncertainty about future maintenance and its costs.
(3) fragmentation in ocean management at state and national levels, which makes it difficult to
   (a) identify and obtain available data,
   (b) integrate disparate data developed by different methods for different purposes, and
   (c) identify enthusiastic, supportive clients for ocean GIS products.
(4) a disjunction between the kinds of oceanographic and marine ecosystem data that scientists produce (often three- or four-dimensional) and the present technical capacity of GIS to integrate and display that data.
(5) difficulty gaining the attention of high-level managers and policy makers needed to win financial support for GIS development.
(6) limited technical training of coastal managers on marine science and issues.
(7) limited understanding within the science community of ocean management and ocean GIS information and research needs.
(8) low priority of ocean management and GIS for staff time and/or financial resources at the state level, relative to other coastal issues.

## RECOMMENDATIONS

**1. <u>National Framework for Regional Ocean GIS</u> – NOAA should develop a regional ocean GIS framework based principally on large marine ecosystems.**
As the lead ocean agency for the United States, NOAA should undertake a collaborative effort to develop a regional ocean GIS framework based on distinct large marine ecosystems (LMEs). The LME concept has been the subject of a series of symposia sponsored by the American Association for the Advancement of Science (Sherman and Alexander 1986; 1989; Sherman, Alexander and Gold 1990; 1993), and so has been well developed and evaluated. Forty-nine LMEs have been identified globally, with U.S. waters comprising all or parts of seven (**Figure 3**). The logic and rationale for LMEs as natural regions for ocean management were also examined in these symposia (see, for example, Knecht and Cicin-Sain 1993; Bottom and others 1993). Some global LMEs would logically be subdivided for U.S. ocean management purposes. For example, the Northeast U.S. Continental Shelf is now believed to be composed of four subsystems: Gulf of Maine, Georges Bank, Southern New England, and the Mid-Atlantic Bight (Alexander 1993).

Development of such a regional LME-based framework for ocean GIS (and ultimately ocean management) is logically a role for NOAA, as the nation's lead ocean agency. Such a framework might also have other benefits, such as focusing research efforts, fostering increased standardization of data collection and reporting protocols, providing a regional ocean framework for the National Spatial Data Infrastructure (NSDI), and better integrating the growing state ocean management community with existing ocean data and information agencies, such as the National Environmental Satellite, Data, and Information Service (NESDIS).

**2. Expand Ecosystem and Human Use Components of Ocean GIS – The NOAA Coastal Services Center should more fully develop the *marine ecosystem* and *human use* components to the regional ocean GIS.**

The *ocean policy* or governance component of the Southeast ocean GIS is central to a regional ocean GIS designed to advance or support more integrated policy and management. However, the *marine ecosystem* and *human use* components are relatively weak and indistinct, being mainly focused on particular demonstration scenarios. To be truly useful for the range of area planning and policy applications one might envision, however, these latter two components should be given equal weight and be more fully developed. The shared, regional issues identified by states (see **Table 2**) bordering common LMEs (see Recommendation 1) should be examined to determine what ecosystem and human use characteristics must be represented at the regional scale. An effort to incorporate existing data sets and to develop new essential sets should also be undertaken.

**3. Regional GIS – NOAA should continue to develop Southeast region ocean GIS, market the concept broadly, and initiate a second demonstration project, either on the West Coast or Gulf Coast.**

Continued development of the Southeast ocean GIS is important, with additions or enhancements suggested elsewhere in these recommendations. Given the differences in ecological, use, and state-level governance characteristics of different parts of the United States, and the unlikely continued development of regional ocean GIS without federal leadership, a second regional ocean GIS should also be undertaken to increase the potential for learning that a very different region would provide, and to advance the concept generally. One potential candidate is the Gulf of Mexico LME (**Figure 3**), where the MMS already has developed many of the components of a regional ocean GIS. Another is the California Current LME, or one of its subdivisions, such as the Northern California Current LME. The rationale for the latter as a discrete ocean management area is outlined in detail by Bottom and others (1993).

**4. Nested Local-Regional Ocean GIS – Further develop the "nested" ocean GIS concept and evaluate its technical feasibility and practicality.**

The interests and needs of state and federal ocean managers overlap, but there are clear differences as well. States find large-scale, high-resolution GIS applications more useful than small-scale, lower resolution regional applications (at least conceptually, since few have much experience with either).

We recommend exploration of the concept of nesting large-scale GIS applications within regional-scale ocean GIS. A first-order nesting of sub-LMEs within larger LMEs discussed in Recommendation 1 above should be feasible. An example of a nested GIS system for the marine shoreline environment was developed by Schoch (1999) and is now being used for a broader West Coast-wide monitoring program. It may be a model that could be adapted. Florida, given their relatively advanced SORI GIS, is a logical test bed for this concept, or the Southeast region more generally.

**5. <u>Marketing Regional Ocean GIS</u> - NOAA should develop a strategic plan for marketing the regional ocean GIS concept to coastal states, its federal partners, and policy makers at both levels.**

Despite its substantial benefits, regional ocean GIS needs "customers" to be viable. NOAA should continue its proactive marketing of the regional ocean GIS concept. However, to more sharply focus those efforts, NOAA should consciously develop a strategic plan for promoting and developing regional ocean GIS for *all* U.S. waters.

Continued improvement and strengthening of the Southeast ocean GIS and development of a second demonstration project, as suggested elsewhere in these recommendations, is one sound strategy. Ocean GIS should also be marketed to potential users through informal demonstrations, at conferences and other meetings on ocean issues or science, and through tailored presentations to specific sectoral, disciplinary, or governmental groups. All groups that have the potential to foster more integrated ocean management need to have demonstrated first-hand the utility of information sharing and collaboration that ocean GIS has the potential to provide. National and state legislators and their staff are part of this audience because they have the power to appropriate funds for GIS development and maintenance, but also because they have the authority to create the more integrated governance regimes that are needed to give ocean GIS a clear, committed client.

**6. <u>Incorporating Multi-dimensional Marine Data</u> - NOAA should lead an effort to increase the capacity of GIS to incorporate and analyze multi-dimensional (x, y, z, time) oceanographic, marine resource, and human use data.**

For GIS to realize its potential as an ocean research, planning, and management tool, it needs to be able to incorporate and analyze data in three and four dimensions. The University Consortium of GIS institutions has identified this topic as a priority research area for geographic information science and some progress is being made (UCGIS 1996). Leading software providers are also making progress on these issues.

NOAA should join this process by sponsoring a workshop that brings together marine scientists and ocean managers to explore GIS needs and opportunities for incorporating multi-dimensional marine information. NOAA should also consider supporting needed research and demonstration projects in this arena.

## REFERENCES


Alexander, L.M. 1993. Regional approach to large marine ecosystems. P. 225-226 In: *Large Marine Ecosystems: Stress, Mitigation, and Sustainability,* Ed. K. Sherman, L.M. Alexander, and B.D. Gold. Washington: AAAS Press.

Archer, J.H. 1989. Resolving Intergovernmental Conflicts in Marine Resource Management: The US Experience. *Ocean & Shoreline Management* 12:253-269.

Archer, J.H. 1999. Notes on Legislation. *Ocean and Coastal Policy Network News*. 1(2):8-9.

Armstrong, J.M. and P.C. Ryner. 1981. *Ocean Management: A New Perspective*. Ann Arbor Science Publishers Inc., Ann Arbor, MI.

Bernd-Cohen, T., P. Pogue, V. Lee, and R. Delaney. 1995. A Review of the 309 Coastal States Enhancement Grants Program. *Coastal Management 23*(3):173–194.

Berry, J.K. 1995. *Spatial Reasoning for Effective GIS*. GIS World Books, Fort Collins, Colorado.

Bottom, D.L., K.K. Jones, J.D. Rogers, and R.F. Brown. 1993. Research and management in the Northern California current ecosystem. P. 259-271 In: *Large Marine Ecosystems: Stress, Mitigation, and Sustainability,* Ed. K. Sherman, L.M. Alexander, and B.D. Gold. Washington: AAAS Press.

Butts, R. 1988. Management of the Marine and Ocean Resources of the Washington Coast: An Interim Report to the Washington State legislature. Joint Select Committee on Marine and Ocean Resources. Olympia, Wash.: Washington State legislature.

Catena, J. 1992. Policy Options for Maine's Marine Waters: A Report of the Marine Policy Committee of the Land and Water Resources Council. Augusta, Me.: Maine Coastal Program, State Planning Office.

Christie, D. 1989. *Florida's Ocean Future: Toward a State Ocean Policy*. Tallahasse, Fla.: Environmental Policy Unit Report for the Governor's Office of Planning and Budgeting.

Cicin-Sain, B. and R. Knecht. 1985. The problem of governance of U.S. ocean resources and the new exclusive economic zone. Ocean Development and International Law 15:289.

Cicin-Sain, B. M.J. Hershman, R. Hildreth, and J. Issacs. 1990. *Improving ocean management capacity in the Pacific Coast region: State and regional perspectives*. NCRI-W-91-004. Portland, OR: National Coastal Resources Research and Development Institute.

Cicin-Sain, B. and R.W. Knecht. 1998. *Integrated Coastal and Ocean Management: Concepts and Practices*. Washington, DC: Island Press.

Clark, W.F. and S.E. Whitesell. 1994. *North Carolina's Stewardship Area: A Management Study*. UNC-SG-94-10. North Carolina Department of Environment, Health and Natural Resources.

Clarke, K. 1997. *Getting started with geographic information systems*. Prentice Hall Publishing, New Jersey.

Coleman, E. 1999. Essential Fish Habitat: can we sustain our fisheries and our industries? Louisiana Sea Grant Publication. *Coast and Sea*: 7(1).

Evans, J.D. 1997. *Infrastructures for sharing geographic information among environmental agencies*. Ph.D. diss., Department of Urban Studies and Planning, Massachusetts Institute of Technology.

Federal Geographic Data Committee. 1999. Homepage URL: http://www.fgdc.gov/

Flexner, S.B. and L.C. Hauck (eds.). 1993. *Random House Unabridged Dictionary*. 2nd Edition. New York: Random House.

Florida Governor's Ocean Committee. 1998. *Florida's Ocean Challenges*. Interim Progress Report to the Governor.

Froomer, N. 1999. Minerals Management Service, Personal Communication, April, 1999.

Good, J.W., and R.G. Hildreth. 1987. *Oregon Territorial Sea Management Study*. Salem, Ore.: Oregon Department of Land Conservation and Development.

Hawaii Ocean and Marine Resources Council. 1988. Hawaii Ocean Resources Management Plan. Honolulu: State of Hawaii.

Hershman, M., D. Fluharty, and S. Powell. 1988. *State and Local Influence Over Offshore Oil Decisions.* Seattle: Washington Sea Grant Program, University of Washington.

Hildreth, R.G. 1991. Managing Ocean Resources: United States. *International Journal of Estuarine and Coastal Law* 6(4): 313-363.

Juda, L. 1987. The Exclusive Economic Zone and Ocean Management. *Ocean Development and International Law,* 18(3):305-331.

Juda, L. and R.H. Burroughs. 1990. The Prospects for Comprehensive Ocean Management. *Marine Policy*, January 1990.

King, J., and B. Olson. 1988. Coastal state capacity for marine resource management. *Coastal Management* 16:305.

Knecht, R.W. 1994. A commentary on the institutional and political aspects of regional ocean governance. *Ocean and Coastal Management* 24:39-50.

Knecht, R.W. and J.A. Archer. 1993. "Integration" in the US Coastal Zone Management Program. *Ocean and Coastal Management* 21:183-199.

Knecht, R.W. and B. Cicin-Sain. 1993. Ocean management and the large marine ecosystem concept: Taking the next step. P. 237-241 In: *Large Marine Ecosystems: Stress, Mitigation, and Sustainability*, Ed. K. Sherman, L.M. Alexander, and B.D. Gold. Washington: AAAS Press.

Knecht, R.W., B. Cicin-Sain, and J.H. Archer. 1988. National Ocean Policy: A Window of Opportunity. *Ocean Development and International Law* 19:113-92.

Lester, C. 1994. Contemporary federalism and new regimes of ocean governance: lessons from the case of outer continental shelf oil and gas development. *Ocean and Coastal Management* 23:7-47.

Mason, D.C., M.A. O'Conaill, and S.B.M. Bell. 1994. Handling four-dimensional geo-referenced data in environmental GIS. *International Journal of Geographic Information Systems* 8(2): 191-215.

McLaughlin, R., and L. Howorth. 1991. *Mississippi Ocean Policy Study*. University, Miss.: Mississippi-Alabama Sea Grant Legal Program, University of Mississippi Law Center.

Mitchell, F. 1991. *Preservation of State and Federal Authority under OPA*. Environmental Law 21:237.

National Research Council. 1992. *Working Together in the EEZ: Final Report of the Committee on Exclusive Economic Zone Information Needs*. Washington, DC: National Academy Press.

National Research Council. 1997. *Striking A Balance: Improving Stewardship of Marine Areas*. Washington, DC: National Academy Press.

National Research Council. 1999. *Sustaining Marine Fisheries*. Washington, DC: National Academy Press.

Neely, R. 1999. NOAA Coastal Services Center, Personal Communication. August, 1999.

NOAA Coastal Services Center. 1999. Ocean Planning Information System URL: http://www3.csc.noaa.gov/gisprojects/ocean/index.htm

North Carolina Marine Science Council. 1984. *North Carolina and the Sea: An Ocean Policy Analysis*. Raleigh, NC: Office of Marine Affairs, North Carolina Department of Administration.

Ocean Policy Advisory Council (OPAC). 1994. *State of Oregon Territorial Sea Plan.* Oregon Ocean Policy Advisory Council. Portland, Oregon.

Ocean Resources Management Task force (ORMTF). 1990. *Oregon Ocean Plan.* Oregon Coastal Management Program, Department of Land conservation and Development. Portland, Oregon.

Orbach, M.K. 1996. Science and policy in the coastal zone. In: J. Taussik and J. Mitchell (eds.), *Partnership in Coastal Zone Management*. Samara Publishing Limited: Cardigan, UK.

Resources Agency of California. 1997. *California's Ocean Resources: An Agenda for the Future*. Sacramento, CA.

Rote, J.W. 1993. *The Monterey Bay National Marine Sanctuary: A model for "ocean management*." Paper from the Ocean Governance Study Group Conference, Berkeley, CA.

Sherman, K. 1993. Large marine ecosystems as global units for marine resources management—an ecological perspective. P. 3-14 In: *Large Marine Ecosystems: Stress, Mitigation, and Sustainability*, Ed. K. Sherman, L.M. Alexander, and B.D. Gold. Washington: AAAS Press.

Schoch, G. C. 1999. *Untangling the complexity of nearshore ecosystems: Examining issues of scaling and variability in benthic communities.* PhD Diss., College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, OR.

Underdal, A. 1980. Integrated Marine Policy: What? Why? How? *Marine Policy* 4(3): 159-169.

University Consortium for Geographic Information Science. 1996. Research priorities of geographic information science. Cartography and Geographic Information Systems, 23(3). American Congress on Surveying and Mapping. http://www.ucgis.org

University of Southern California Wrigley Institute for Environmental Studies. 1998. Too much data? Wrigley scientists develop an EASY solution. *WAVES Quarterly Newsletter* : 2(2).

Western Legislative Conference. 1988. *A Leadership Agenda: State Management of Ocean Resources*. Report and Recommendations of the Ocean Resource Committee. The Council of State Governments.