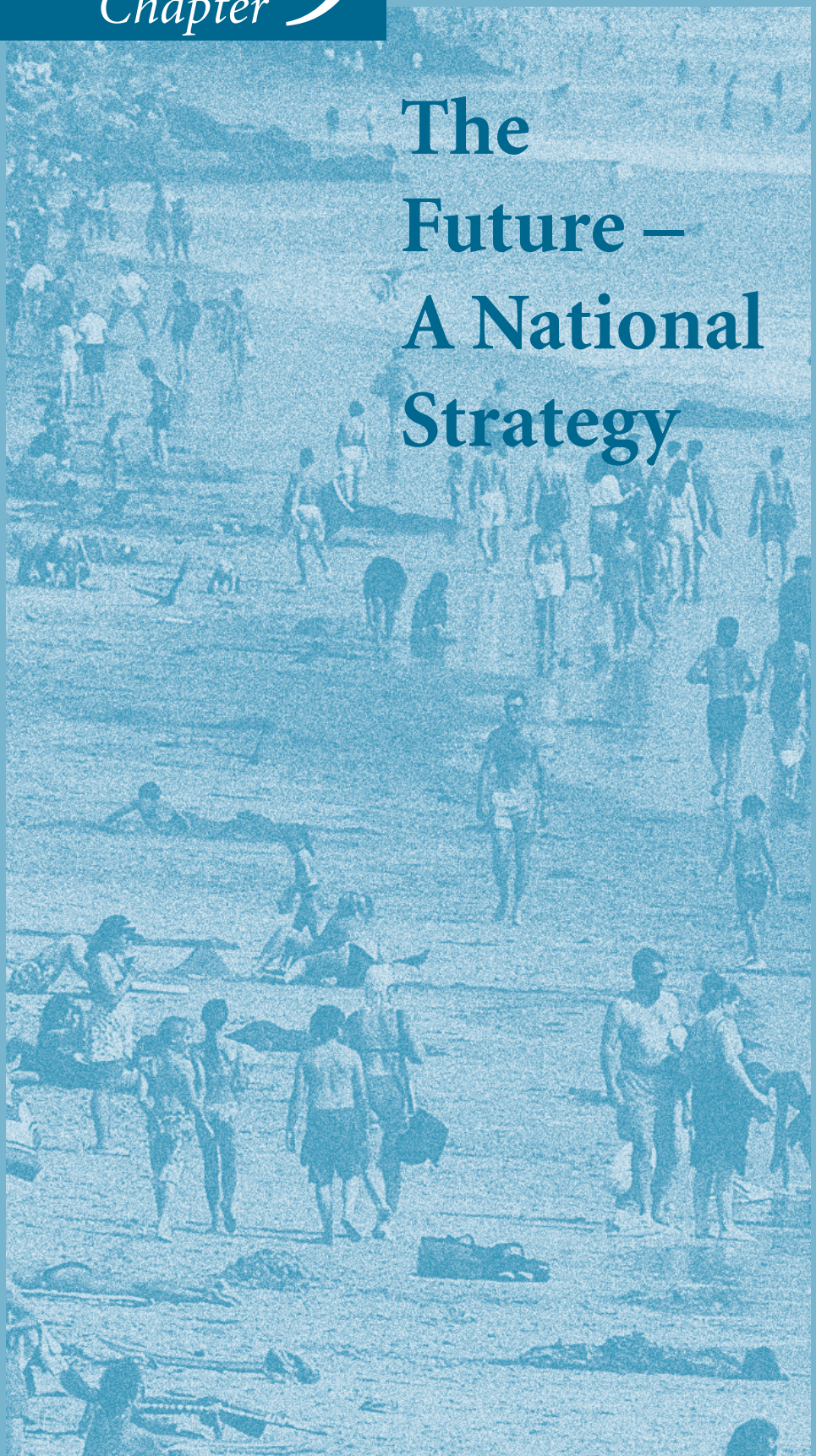
Chapter 9

The Future – A National Strategy



Chapter 9

The Future – A National Strategy

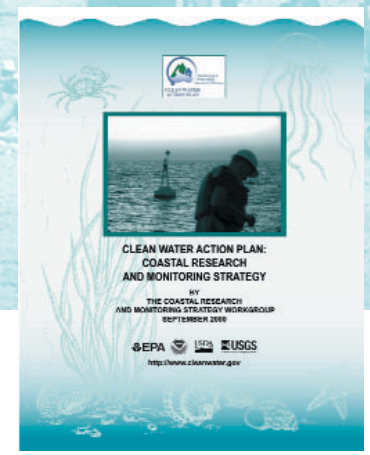
Coastal areas are among the most popular places to live and locate industry in the United States. The coastal zone, defined as all areas within 50 miles of the shoreline, constitutes 17% of the U.S. land area and is inhabited by more than 53% of the nation's population. Coastal populations continue to grow, a trend that could result in 75% of the U.S. population living in the coastal zone by 2020. The high density of people and industry in coastal areas is a potential threat to the ecological condition of our nation's coastal environments.

Currently, no single comprehensive monitoring program provides the data necessary to produce an integrated assessment of the ecological condition of the nation's coastal areas. Even when data are compiled from existing federal and state coastal monitoring programs, there are still large data gaps and data collection inconsistencies that make it

difficult to generalize about the condition of the nation's coasts as a whole. Competing objectives, levels of funding, and varying scopes of interest have resulted in a proliferation of data in some areas (like Chesapeake Bay), while data are sparse or nonexistent in other areas (like Alaska).

There are several national programs that can contribute information about the nation's coasts, but they cannot be used to formulate a complete picture of the nation due to limitations in the scope of parameters assessed or area monitored. EMAP's regional surveys provide consistent data for the mid-Atlantic, Southeast, and Gulf of Mexico coasts; however, budget constraints precluded the implementation of these regional surveys in other regions of the United States (e.g., the West Coast, Alaska). Data from the Coastal 2000 program will address many of these issues. NOAA's National Status and Trends (NS&T) Program provides information for representative locations across the United States on a specific set of environmental parameters focused on toxic contaminants. This program is designed only to monitor contaminant levels and trends in sentinel organisms and sediments. The NS&T Program is not designed to support probability-based estimates of the spatial extent of degraded versus nondegraded resources across regional to national scales.

EPA's Clean Water Act Section 305(b) water quality data for coastal resources are reported by coastal states, which use a variety of approaches for data collection. Data reported range from environmental parameters collected at specific locations with known problems to larger-scale characterization of state watersheds based on evaluations of existing data and professional judgment. Many states do not have the resources to conduct comprehensive coastal monitoring to collect data for their 305(b) assessments. States like Alaska, Washington (excluding Puget Sound), Oregon, California (north of San Francisco Bay), North Carolina, Georgia, and Maine have little or no coastal monitoring in place and receive little or no financial support to create comprehensive coastal monitoring programs. The lack of monitoring data for Alaska is particularly bothersome because Alaskan estuaries represent nearly 75% of all U.S. estuarine resources, yet very little



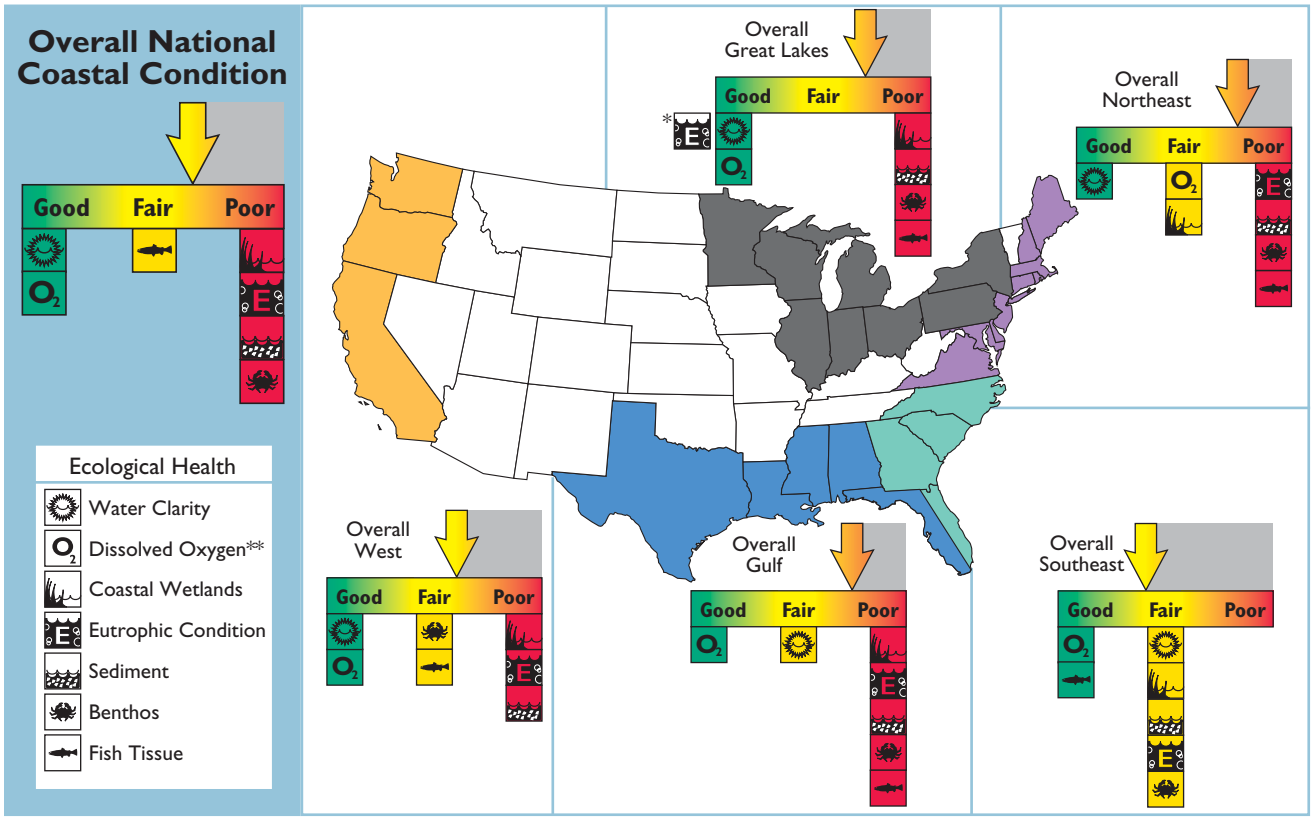
The CWAP Coastal Research and Monitoring Strategy outlines a plan to develop a comprehensive integrated framework for assessing the condition of the nation's coasts.

information to support the kind of analysis used in this report is available (i.e., spatial estimates of condition based on indicators measured consistently across broad regions).

Due to the current state of information, we are unable to characterize quantitatively the condition of all of the nation's coastal waters. Moreover, at present, the assessments must be based on a limited number of ecological indicators for which there are consistent data sets available to support estimates of condition over as broad an area as possible.

In this report, we have compiled existing information to provide a preliminary picture of the condition of estuarine waters in the United States. Although it may appear that this report accomplishes that goal, it falls short of the "comprehensive report on the condition of the nation's coastal waters" called for by the Clean Water Action Plan due to a lack of nationally consistent data. What has been accomplished is the best assessment of coastal condition that can be made with existing data. Figure 9-1 represents our best perspective of ecological condition in estuaries. It is based on substantial information on the Mid-Atlantic, Southeast, and Gulf of Mexico Coasts but scattered and sparse information from New England, the West Coast, Alaska, the Pacific Islands, and the Caribbean. One of our greatest needs for the 21st century is a coordinated, comprehensive, and integrated coastal monitoring program that examines all aspects of coastal condition at national, regional, state, and estuary-specific scales. The program should include estuaries, beaches, coastal wetlands, the Great Lakes, and coastal waters throughout the 24 coastal states and the Pacific and Caribbean commonwealths. The *Clean Water Action Plan: Coastal Research and Monitoring Strategy* (www.cleanwater.gov), established under authority of the Clean Water Action Plan (U.S. EPA, 1998), presents the conceptual framework for coastal monitoring

and research to be conducted in partnership among federal agencies, state resource agencies, and academia. The framework will guide the direction of coastal monitoring and research across federal agencies to address current and future environmental issues of the coast. The recommended coordination and collaboration of federal agencies will permit future coastal research and monitoring activities to benefit from the specific knowledge and experience of each agency—the resulting decision-making capability will be greater than the sum of the parts.



* No indicator data available.
** Does not include the hypoxic zone in offshore Gulf of Mexico waters.

Figure 9-1. Overall national coastal condition.

Due to the unique marine environment surrounding the Channel Islands, the Channel Islands National Marine Sanctuary (CINMS) is home to a diverse array of marine life, making the region highly valuable to scientific research. The CINMS routinely conducts research to monitor, preserve, and protect the Sanctuary's rich resources. In 1998, the CINMS participated in a regional monitoring survey of the Southern California Bight coordinated by the Southern California Coastal Water Research Project (SCCWRP). Trawl and sediment samples from randomly selected sights around the islands were collected to measure the distribution and health of the island's marine life (Photo: Channel Islands NMS).

Objectives of Research and Monitoring within an Integrated Assessment Framework

The complex and changing nature of the coastal waters, bays, estuaries, and wetlands often requires the integration of physical, chemical, biological, and ecological data to assess coastal environmental conditions and often requires the integration of research with monitoring to improve or extend our assessment capabilities. For the past decade, academic, federal, state, and private sector scientists have been working on new approaches to this integration (Messer et al., 1991; NSTC, 1997). These integrated assessment efforts appear to have roughly the same common goal:

> *Provide the national, regional, and local capabilities to measure, understand, analyze, and forecast ecological change (natural and anthropogenic) that can affect coastal economies, public safety, and the integrity and sustainability of the nation's coastal ecosystems.*

Integrated assessments provide an effective format for bridging science and policy and, therefore, are the appropriate context for designing a research and monitoring strategy. Integrated assessments have the following objectives:

- Document status and assess trends in environmental conditions at the necessary scales for scientific investigation and policy development.
- Evaluate the causes and consequences of changes in environmental status and trends.
- Assess environmental, economic, and sociological impacts of alternative policies for dealing with these changes.

Research is necessary to improve both the assessment techniques and the monitoring done to support these assessments. The research necessary to support these activities includes

- **Predict change and create an early warning detection system.**
- **Analyze environmental, economic, and sociological impacts of coastal policy.** A large number of national, state, and tribal policies direct the expenditure of billions of

dollars of public and private money to protect the coastal zone. It is important to understand if these investments are well spent—if the coastal zone has been protected or restored.

- **Understand coastal physical and ecological processes.** An understanding of the physical and ecological processes of the coastal zone underlies all of the other objectives. Investments in research to improve this understanding are paid back directly or indirectly by our increasing ability to truly understand current status, predict future trends, and determine the significance of change.
- **Improve or enhance monitoring and assessment tools.** Our ability to perform the above objectives rests on our ability to use federal investments wisely. Advancements in field monitoring and observation, remote sensing, and data management and display technology have created opportunities to acquire, manage, and disseminate coastal environmental data more efficiently and economically than was thought possible 10 years ago. The challenge is to select wisely from or improve upon the traditional, new, or emerging technologies that will provide information needed for policy or management decisions.

The effective integration of monitoring and research will enable comprehensive assessments of the nation's coastal resources and eventual remediation of the problem. This approach is essential to differentiate between actual and perceived environmental issues in the coastal zone so that (1) we address all major coastal environmental issues appropriately and in a timely manner and (2) we avoid unnecessary environmental regulation or environmental damage. It follows that an integrated monitoring and research strategy focused on supporting the comprehensive management of our coastal resources requires an integration of key assessment and management elements with monitoring and research objectives (Figure 9-2). Monitoring is crucial to documenting status and assessing trends, determining associations between stressors and impacts, and assessing the effectiveness of management actions. Research is an important part of environmental monitoring and is particularly important for improving our ability to interpret monitoring data and improve our assessment capability. Additionally, research is key to predicting impacts as a result of emerging trends and to forecast and assess the impacts and benefits of management actions.

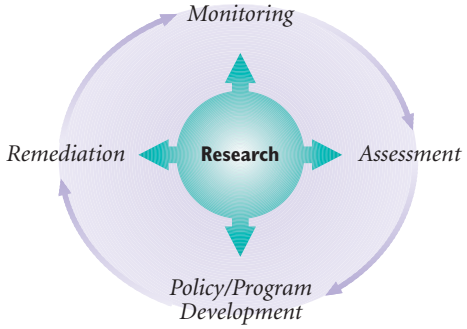


Figure 9-2. Monitoring-research-assessment-remediation cycle that gauges coastal ecological condition and the effectiveness of remediation policies and programs.

These objectives capture the intent of the *Coastal Research and Monitoring Strategy*—to observe coastal status and to differentiate between real and perceived coastal water issues and to provide informed and expert judgment

necessary for coastal policy and management. The objectives are, to a large extent, derived from national environmental monitoring and research objectives presented in *Integrating the Nation's Environmental Monitoring and Research Networks and Programs*, the national framework established by the National Science and Technology Council (NSTC, 1997). The NSTC objectives, as modified to address specific issues of coastal waters, overlap with charters of the departments and agencies represented in the Coastal Research and Monitoring Strategy Workgroup.

To be effective, an integrated assessment strategy for monitoring and research activities must be designed to accomplish all of these objectives. Only by addressing all components can the effectiveness of management actions be tracked.

The Gulf of the Farallones has over 100 dedicated volunteers for the BEACH Watch program. BEACH Watch volunteers survey their designated sanctuary beaches once a month and receive 80 hours of classroom and field training (Photo: Gulf of the Farallones NMS).

Monitoring

The Coastal Research and Monitoring Strategy addresses the physical, chemical, biological, and ecological conditions of coastal waters, bays, estuaries, beaches, wetlands, and the Great Lakes. A national coastal monitoring strategy must simultaneously meet the needs of the nation, the coastal states, and tribal nations. This strategy is the most effective way to satisfy needs at these scales, but it is also essential to receive the necessary cooperation from the coastal states and tribes. Only through this cooperation can the longevity of any national coastal monitoring effort be assured. The mechanisms to achieve this interaction are beyond the scope of this strategy. However, key attributes of the proposed approach should include cofunding by federal and state programs, nested designs to allow state-specific issues to be addressed in a national context, a uniform reporting protocol to facilitate data and information exchange, and further attention to specific state issues, collective reporting, and cross-system comparisons.

The coastal ecosystems addressed by this strategy include estuaries, coastal waters, beaches, wetlands, and the Great Lakes. Because the scale and dimensions of these systems vary considerably, the "optimal" monitoring design is one that allows adaptation to each ecosystem while maintaining a similar core design that would allow intercomparison and tiered estimates of condition. Attempts to design one program that fits all cases generally fail because all temporal and spatial scales are pertinent and important. Therefore, the design proposed

here incorporates a flexible, nested strategy that uses a base design (common to all), with details designed by the appropriate stakeholders at each level.

The strategy for a national coastal monitoring design is based on the three-tiered approach developed by EPA (Messer et al., 1991) and recommended by NSTC (1997). The three-tiered monitoring strategy addresses several of the major attributes of an integrated assessment:

- Characterization of the problem
- Diagnosis of causes
- Remediation actions
- Assessment of effectiveness of actions
- Reevaluation of causes
- Continued assurance of effectiveness of actions.

These attributes, in combination with the formulation of management actions, create the cycle of monitoring and attendant research necessary to identify, solve, correct, and manage environmental problems. The proposed three-tiered national coastal monitoring design features:

- **Characterization of the Problem (Tier I)**—Broad-scale ecological response properties as a base determined by survey, automated collection, and/or remote sensing.
- **Diagnosis of Causes (Tier II)**—Issue- or resource-specific surveys and observations concentrating on cause-effect interactions.
- **Diagnosis of Interactions and Forecasting (Tier III)**—Intensive monitoring and research index sites with higher spatial and temporal resolution to determine specific mechanisms of interaction needed to build cause and effect models.

Data and information generated at each tier help in the interpretation of results from the other tiers. For example, Tier I (characterization) data provide geographic context for data collected at Tiers II and III (e.g., how widespread is the problem and how much of the nation's resources are affected by its occurrence?). Tier II (diagnosis of causes) and Tier III (diagnosis of interactions) aid in understanding the seriousness of a particular relationship or issue. Tier III also aids in interpreting results at Tiers I and II and links process research with long-term ecological and environmental measurements to strengthen cause and effect linkages and predictive models that relate stresses and environmental responses.

As more locations are studied for invasive species and as the protocols for monitoring become more standardized, more systematic knowledge will be gained of anecdotally known regional variations in invasion rates and species. Intensive study at specific locations where invasions have taken place, as well as at ecologically and climatically similar locations with invasion observed to a different extent or by different species, will help establish what factors put a particular area at risk from what species or types of species.

Characterization of the Problem (Tier I)

Measurements in Tier I are designed to characterize problems by tracking the natural dynamics of coastal ecosystems in order to identify large-scale existing and emerging issues. Therefore, these measurements focus on the first step of integrated assessments—

documenting status and trends in order to characterize the problem(s). Tier I measurements would generally be taken at fairly coarse spatial and temporal scales based on probabilistic approaches except for those that can be generated by remote platforms (e.g., satellites) where coverages may be complete. This approach is state-oriented and, through consistency of design and measurements, produces a national coverage. In accordance with the most recent work in this area (CENR, 2000), indicators to be measured in Tier I include (1) measures of community and ecosystem structure and function (productivity, abundances and distributions of plants and animals, diversity, and important attributes of nutrient and chemical cycling) and (2) environmental stressors (primary stressors of coastal ecosystems) and habitat variables (measures required to interpret natural variability in rapidly changing coastal environments).

Many measurements in Tier I can be derived through automated sensors (e.g., satellites, aircraft reconnaissance, and buoys). However, several measurements must still be conducted through field sampling and laboratory analysis. These measures, collected using an integrated probabilistic design including all coastal states, would provide a comprehensive, integrated assessment of the "health" of each state and, through integration, the nation's coastal resources. The number of sites likely to be included at this level would be 50 for each coastal state for each coastal environment (e.g., wetlands, estuaries, beaches, Great Lakes, offshore).

Diagnosis of Large-Scale Causes (Tier II)

To assess the causes of problems identified in Tier I, Tier II monitoring would be conducted only in areas identified as impacted by Tier 1 monitoring or through other available databases (e.g., the TMDL Tracking System). This "national" sampling tier would be stratified by environmental issue, with a monitoring program associated with each stratum. Examples of strata are

- Eutrophic condition
- Contamination by metals and organics
- Contamination by microbial organisms
- Invasive species
- Habitat degradation
- Fisheries declines
- Harmful algal blooms
- Hypoxia.

The primary purpose for the collection of monitoring data at the Tier II level would be to quantify the relationships among ecosystem response variables (e.g., productivity, benthic abundance, bird abundance) and environmental stressors (e.g., nutrients, low dissolved oxygen, habitat loss) in order to diagnose the cause(s) of the observed environmental problem. It is through this quantification that better stewardship and better correctional operations can be determined. The number of sampling sites for each issue stratum would be determined largely by the number of locations and regions displaying the particular issue, although an expectation of about 100 to 250 sites per issue stratum seems to be reasonable.

Tier II alone is not sufficient for understanding relationships well enough to develop predictive capabilities. The integration of Tiers II and III should provide that predictive power.

Diagnosis of Interactions and Forecasting (Tier III)

Monitoring at Tiers I and II provides information that can be used to develop policies and actions to correct the environmental problems found throughout the nation. However, many problems are the result of complex interactions of stressors, habitats, natural environments, and anthropogenic activities. To determine these interactions and forecast the likely environmental response of these interactions, this strategy proposes the development of Tier III sites. At these sites, measurements are spatially and temporally intensive and are completed at few locations over relatively short time periods (weeks to years). Much of the research necessary to develop indicators or indices with forecasting power will be accomplished at these sites in conjunction with the intensive monitoring. Approximately 25 to 50 of these sites would be identified.

The data and information generated at each tier helps in interpretation at the remaining tiers. Tier I information places Tiers II and III information into perspective—how broad a problem is the issue and how much of the nation's resources are affected by its occurrence, correction, and understanding? Tiers II and III provide an understanding of the seriousness of a particular relationship or issue. At Tier I, all problems are, in essence, treated equally, but work at Tiers II and III may show that losses of some species distributions are more important than others. Tier III aids in interpreting results at Tiers I and II and links process research with long-term measurements of ecological and environmental measures to strengthen cause and effect linkages and predictive models relating stresses and ecosystem response.

Scientists retrieve a Tucker net, which has three nets to sample different depths and obtain discrete samples of tiny organisms that make up the base of the food web in the Cordell Bank Sanctuary (Photo: Jamie Hall).

These three monitoring tiers correspond to the characterization of the problem and diagnosis of causes and interactions of existing environmental problems within the integrated assessment model. Regardless of the requirements for specific spatial and/or temporal scales, these monitoring tiers provide information for the assessment of the effectiveness of actions and continued assurance of that effectiveness.

The Olympic Coast National Marine Sanctuary is recognized for its profound ecological value. The Sanctuary's parent agency, the National Oceanic and Atmospheric Administration (NOAA), commits significant technical resources, including its research ships (like the McArthur, shown here), to understand how ecological processes work (Photo: Olympic Coast NMS).

Research

The interaction of research in the development, execution, and revision of monitoring coastal ecosystems is a closely paired activity. Integrated assessments adapt current monitoring approaches by taking advantage of information that has been accumulated over time such as previous monitoring results, research that has been completed to enhance the measurement of indicators, new understanding of cause and effect relationships, and improved sampling approaches to reduce uncertainty.

Research activities must occur at all three tiers, but represent distinct research programs. Indicator research and development of survey methods and tools enhances our ability to characterize ecosystem condition (Tier I). Initial monitoring activities to characterize (Tier I) must, of necessity, be based on available, tested, proven, and understandable indicators. This does not imply that they are the best indicators of ecosystem condition, just the best available, and continuing research should produce better, more certain indicators. Cause and effect research drives our understanding of what the information collected during monitoring represents. This research, whether at the larger scale (Tier II) or intensive scale (Tier III), provides the necessary interpretive information to bridge the gap between status and trend information and management actions.

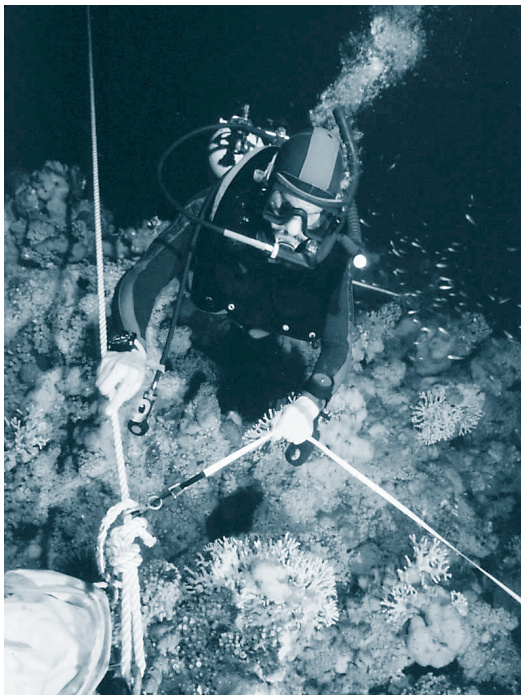
Prediction of environmental problems is the long-term goal of the monitoring and research interaction. Currently, our monitoring approaches and research programs must be reactive—monitoring results driving the research agenda and the research results modifying the monitoring approach. As cause and effect monitoring and research progresses, the results will provide the basis for predictive modeling, forecasting emerging environmental problems, and separating changes due to natural variability from those resulting from anthropogenic stress. Once forecasting abilities can be verified, the interactive roles of monitoring and research (particularly at Tiers II and III) will change, adapting to these new abilities to focus efforts in an unbiased manner rather than approaching the coastal environment as one large population.

After characterizing the coastal environment, predicting the probability of change from human activity, and diagnosing the likely causes of these changes, environmental managers and stakeholders must make decisions on future policies, programs, and actions. Decisions include continuation of current activity (no action), control of future inputs, remediation of environmental contamination, or restoration of the coastal

ecosystem to a desired state. Some of the uncertainties associated with these decisions are based on a lack of understanding of coastal system response. Research is needed to support the management decision element of the integrated assessment model, including:

- Development of standardized protocols for environmental remediation and restoration, which ensure consistent outcomes.
- Evaluation of costs and effectiveness of management actions.
- Development of decision analysis methods to help managers establish relevant goals and to facilitate consistent cost-effective decisions.

Therefore, research plays a vital role in interpreting outputs from, and methods used in, monitoring programs and represents a key to the integrated assessment model. Research supports all phases of the assessment process. Characteristic research activities that support the integrated assessment process are described in the remainder of this section.



A Cordell Bank Expeditions research diver over a bed of filter-feeding invertebrates. The food-rich currents over Cordell Bank offer habitat for filter-feeding animals (Photo: Cordell Bank Expeditions).

Research To Support Characterization of the Problem (Tier I)

In addition to improving our ability to document status and trends, research at this level can also establish a means to provide early warnings. Ecological characterization is a description of particular attributes at points in space and time and comparison of those attributes with expectations or criteria. It is clearly impossible to do this for all environmental parameters and their changes, so indicators of these parameters are often sought. Indicators are properties that summarize elements of environmental change and provide the greatest information return for the least investment. The key question in indicator research is defining which parameters serve as appropriate surrogates for system condition and response. This is a challenge because ecosystem processes are poorly understood, the distribution and intensity of stressors and their threats to ecological resources are uncertain, and it is not known which stressors place ecosystems at the most serious risk or the extent to which critical ecological processes are being impaired. Another important issue is reliability/predictability. It is important to select biological indicators, for example, that are able to predict stress where stress should be occurring (due to presence of pollutants) in a high percentage of cases.

To help characterize systems, research is needed to address four basic questions:

- **What should be measured?** Answering this question requires an understanding of the important components of structure and function of the system (i.e., a conceptual model), an evaluation of the appropriate

levels of biological organization relevant to the monitoring purpose, and the classes of stressors that are potentially important for that resource and scale.

- **How should the indicator be measured?** The answer to this question requires that a standard protocol be defined.
- **How responsive is the indicator?** It is important to determine the degree to which a particular indicator actually responds to various stressor gradients at multiple scales or if a stressor indicator responds to modification of input.
- **How variable is the indicator?** Ecological condition reflects the combined effects of natural variability and anthropogenic stress. Research is needed to determine methods by which natural or introduced fluctuations can be distinguished to allow detection of actual status and trends in ecological conditions.

Research To Support Diagnosis of Large-Scale Causes (Tier II)

This step determines the causes and consequences of detected changes. Cause and consequence are usually determined by integrating relevant process-oriented research with tools to diagnose and predict system dynamics. This step determines the causes and consequences of detected changes. Cause and consequence are usually determined by integrating relevant process-oriented research with tools to diagnose and predict system dynamics. Once conditions and trends for an ecological system have been described, it is important to identify which parts of the system are changing, why they are changing, and whether particular environmental policies will be effective in dealing with those changes. To answer these questions, it is necessary to understand and be able to predict how a system will respond to individual or multiple stresses (i.e., develop a "load-response" relationship that describes how properties of concern relate to changes in natural and human inputs). To couple monitoring results with causes of system change and to predict system responses, research must address three basic questions:

- **How are measures extrapolated across scales of organization?** Historically, much of the stressor-effects data used in ecological assessment have been obtained from laboratory tests focused on responses at lower levels of biological organization. An implicit assumption in applying such results at the ecosystem level is that processes and mechanisms occurring at lower levels of organization are sufficient to describe the behavior of systems at higher levels of organization. This may have limited utility to identify properties that emerge only at higher levels. Greater understanding is needed about how impacts measured at lower levels of ecological organization reflect impacts at higher levels. Further research is also needed to evaluate how impacts measured in one estuary can be extrapolated to other estuaries.
- **How do human activities propagate through the ecosystem?** For many human activities, pathways of transmission and adaptation in ecosystems are poorly understood, hindering development of accurate assessment of ecological effects due to human activities. Additional research is

Seagrass is one of the most productive and important ecosystems in the Keys, and it is being destroyed at an alarming rate. Much of this damage is due to recreational boaters operating in shallow water. Propeller scars can take up to 10 years to recover (Photo: Harold Hudson).

needed to understand how human-induced changes in the landscape alter hydrologic and biogeochemical cycles in the coastal areas, and how adaptations or buffers in the system mitigate those changes.

- **What changes in system structure and function are due to changes in inputs?** Addressing this question requires a sound basis to link an ecological response and a change in input. In large, complex systems, these links are usually developed based on observation of co-occurrence of input and response and analysis of the strength and consistency of that co-occurrence. Due to lack of appropriate data at large scales, our current understanding is insufficient to ensure correct identification of the cause of change in many systems or to predict the result of human activities on an ecosystem.

Research To Support Diagnosis of Interactions and Forecasting (Tier III)

This step determines the causes, consequences, and interactions of detected changes at small or local spatial scales, particularly with regard to natural environmental changes. Cause and consequence, at this scale, are usually determined by integrating relevant process-oriented research at specific locations with tools to diagnose and predict system dynamics. The research questions at Tier III are identical to those at Tier II with the exception that at Tier III the scale is local, the importance of interactions may be greater, and the role of natural variability may be greater. Because of this similarity, the specific research questions for Tier III will not be repeated here.

Research To Support Development of Policy and Environmental Remediation Programs

Although this research does not specifically correspond to one of the monitoring tiers, it is essential to the integrated assessment process. This level of research helps to determine if coastal environmental policies are having the desired effect, or if the same goals could be achieved in another manner. While monitoring can determine if management actions are achieving their desired goal, research is needed to reduce the uncertainties in ecological cause and effect relationships—the basis of predictions. Also, because management actions often involve behavior modification, it is important that economic and social considerations, inherent in the decision-making process, are assessed. Specific questions that must be addressed include the following:

- **How are multiple management options evaluated to select the best option?** This requires development of methods to model coastal ecosystem responses to changes so that future scenarios under different management alternatives can be simulated.

- **How are ecological services and capital reserves valued in the decision process?** This requires the ability to integrate and predict economic consequences of ecological change in coastal areas. Methods to assess and predict nonmonetary benefits and impacts to society, such as aesthetic or cultural requirements, are also needed.
- **How is human response to management actions measured?** Achieving desired results from many management decisions rests on the willingness and efficacy of humans to change behavior. Indicators are needed to measure this change in behavior.

While the objectives and the conceptual framework for the *Coastal Research and Monitoring Strategy* have been finalized, important aspects of the Strategy can be defined only as the Strategy evolves into a workable program. The *Coastal Research and Monitoring Strategy* identifies the programmatic actions identified by the Workgroup as next steps; further development of action plans for each of the following recommendations and implementation of those recommendations is beyond the charter of the Workgroup.

We are all drawn to the ocean's edge to wonder at life's most basic questions and marvel at the ocean's astonishing diversity (Photo: Olympic Coast NMS).

Summary

This report compiles available information to describe the overall ecological condition of the estuarine waters of the United States. The characterization is based on the use of information to create an impression of existing condition. At times, that impression is based on large amounts of information (e.g., Chesapeake Bay); at other times, it is based on a paucity of information (e.g., Alaska).

One outcome of this report has been to demonstrate that we do not have adequate information to make clear and encompassing statements regarding ecological condition for the nation's coastal resources regardless of spatial scale (national, regional, state, estuary). However, it should also be clear that federal and state programs exist to collect much of this information in some areas but are nonexistent in others. In order to realize its full potential, coastal monitoring must be addressed through new and innovative partnerships among federal agencies, state agencies, and local municipalities. No single agency can accomplish this task. Only through a coordinated and integrated effort can coastal monitoring be successful at all the levels at which it is necessary to preserve, protect, manage, and enhance the coastal resources of the United States.