CHAPTER 15:
CREATING A NATIONAL MONITORING NETWORK

Ongoing monitoring is essential to assess the health of ocean and coastal ecosystems and detect changes over time. More than any other measure, monitoring provides accountability for management actions. The nation needs a coordinated, comprehensive monitoring network that can provide the information necessary for managers to make informed decisions, adapt their actions as needed, and assure effective stewardship of ocean and coastal resources. In developing such a network, the National Oceanic and Atmospheric Administration, the U.S. Environmental Protection Agency, the U.S. Geological Survey, and other agencies as appropriate, should coordinate and expand their efforts to ensure adequate monitoring in coastal areas and the upland regions that affect them. Input from states, territories, tribes, counties, and communities—where much of the monitoring will be conducted—is also essential. In addition, because of the inherent overlap among inland, coastal, and open-ocean monitoring and observing, the national monitoring network should be closely linked with the Integrated Ocean Observing System and, ultimately, incorporated into a broad Earth observing system.

RECOGNIZING THE VALUE OF MONITORING

The nation's coasts suffer from thousands of beach closures a year, oxygen depletion, nutrient enrichment, toxic contamination, sedimentation, harmful algal blooms, habitat degradation, invasions by exotic species, and many other problems. Yet, a comprehensive network to monitor these changes and their causes, facilitate estimates of their economic impact, and measure the success of management efforts is lacking. Long-term status and trends monitoring is critical to assess and reduce the impacts of human activities on coastal waters. Increased monitoring is needed not only along the nation's coasts, but also inland from where pollutants make their way downstream, ultimately impacting coastal waters. A national monitoring network will be needed to provide information not only on water quality, but also on other measures of aquatic ecosystem health, such as sediment loadings, biological conditions, and water flow (Box 15.1).

A national monitoring network is also essential to support the move toward an ecosystem-based management approach that considers human activities, their benefits, and their potential impacts within the context of the broader biological and physical environment. While current monitoring helps track specific substances, it has been less effective in helping understand how various ecosystem components interact and change over the long term. The data and resulting information products collected from a national monitoring network, combined with broader assessment and observation efforts, will be the key to implementing truly effective and adaptive ecosystem-based management.

Monitoring information will be of direct benefit to many people including managers, fishermen, scientists, water providers, and others. Formulating management actions based on better monitoring will ultimately improve beach quality, allowing the public to enjoy trips to the beach with fewer disappointments due to beach closures. Monitoring information will be particularly helpful to coastal managers who need to

understand the scope of the problems before they can effectively respond. After responding, monitoring information will also help assess the effectiveness of the selected management approaches.

There are currently a number of disparate monitoring efforts and questions have been raised about the comparability and accuracy of information produced by these programs and about the practical value of the information to stakeholders. Baseline information at the scale, resolution, and frequency necessary to manage is generally lacking.

Federal and state agencies around the country will need to work closely together to achieve a fully effective national system. Designing and implementing an effective monitoring network will require input and close coordination among federal and state agencies, as well as academic and research institutions, nongovernmental organizations, and volunteer groups.

Box 15.1 Ocean and Coastal Monitoring Needs

Long-term environmental monitoring is essential to determine baselines, measure change, and assess overall ecosystem health. Throughout this report, enhanced monitoring is called for to improve the management and protection of marine resources, as well as to protect human health. The creation of a national monitoring network that encompasses not only coastal waters, but also upstream watersheds, will allow the nation to track critical factors such as those listed below.

In close coordination with coastal and ocean observing systems, the national monitoring network should help document:

- Concentrations of industrial, municipal, and agricultural contaminants.
- Conditions of natural, cultural, and economic resources in coastal areas.
- Quantity, quality, and timing of stormwater flows.
- Presence of pathogens and chemical toxins in organisms, including fish and seafood consumed by humans.
- Rates, locations, and composition of atmospheric deposition.
- Impacts of flooding, coastal hazards, and sea level rise.
- Status of coastal habitats to support conservation and restoration efforts.
- Impacts on ecosystem and human health from pollution.
- Introductions and spread of invasive species.
- Impacts of offshore activities.
- Performance of marine protected areas.
- Sources and quantities of marine debris.
- Extent, productivity, and functioning of coral communities.

MONITORING AT THE FEDERAL LEVEL

A number of monitoring programs are currently conducted by federal agencies, state governments, research institutions and academia, nongovernmental organizations, and individual volunteers. Existing monitoring programs vary in many respects, including sampling design and intensity, parameters tested, analytical methodology, data management protocols, and funding. Even when the same properties are measured, different data management protocols may make the integration of that information difficult.[1] Consequently, while a number of monitoring programs exist, they are not designed to support a comprehensive and coordinated national monitoring network. To make matters worse, budget constraints have resulted in significant reductions in monitoring of coastal areas.

Responsibility for monitoring and assessing natural resources is divided among a number of agencies whose activities are focused on achieving specific programmatic objectives or agency missions.

Federal Programs

The primary federal agencies involved in monitoring include the National Oceanic and Atmospheric Administration (NOAA), the U.S. Geological Survey (USGS), and the U.S. Environmental Protection Agency (EPA). The U.S. Department of Agriculture (USDA) and the U.S. Army Corps of Engineers also conduct some limited monitoring.

The mission of NOAA's National Status and Trends Program is to determine the status of, and detect changes in, the environmental quality of the nation's estuarine and coastal waters. The program conducts long-term monitoring of contaminants and other environmental conditions at approximately 350 sites. In addition, since 1995, NOAA's National Estuarine Research Reserve System has operated the System-wide Monitoring Program dedicated to the collection of long-term environmental information in support of local coastal management. The primary goal of this monitoring program is to develop quantitative measurements of short-term variability and long-term changes in water quality, biotic diversity, and land cover characteristics of estuarine ecosystems. The program supports coastal zone management through collection of real-time and near real-time data, standardized national data management and quality assurance and quality control procedures, and long-term information collection for a suite of water quality and weather parameters. NOAA also assists coastal states in monitoring harmful algal blooms by partnering with regional management and scientific institutions through the Monitoring and Event Response for Harmful Algal Blooms (MERHAB) program. MERHAB-sponsored projects enhance existing water and shellfish monitoring programs by applying new technologies that allow for proactive detection of coastal harmful algal bloom events.

USGS operates the National Streamflow Information Program, a network of about 7,000 stream gages nationwide. About 6,000 of these stations are linked to an Earth satellite-based communications system. The majority of the stream-gaging stations are jointly funded in partnerships with more than 800 state, local, and tribal governments or other federal agencies.[2] The data are available in real time to conduct water resource projects and for NOAA's National Weather Service to forecast floods. Streamflow data are needed at many sites on a daily basis for forecasting flow extremes, assessing current water availability, and managing water quality and quantity. In addition, USGS conducts long-term water quality and quantity monitoring through the National Stream Quality Accounting Network at fixed locations on large rivers around the country. USGS also operates the National Water Quality Assessment, which uses a regional focus to study status and trends in water, sediment, and biota in forty-two major river basins and aquifer systems. This effort has made considerable progress toward assessing current water quality conditions and long-term trends.[3] In addition, USGS's Biomonitoring of Environmental Status and Trends Program conducts monitoring of effects of water quality on biota of large rivers. The Contaminant Biology Program develops biomarkers and other tools that can be used within monitoring programs for measuring exposure and effects. This program also conducts studies to determine the effects of emerging contaminants.

EPA's Environmental Monitoring and Assessment Program aims to develop the tools and science needed for a state-based statistical monitoring framework to determine trends in the condition of all the nation's aquatic ecosystems. This program uses a probabilistic sampling design that relies on data from many sites of similar habitat type as the best estimate for overall condition of that habitat. A variety of information is collected through this program, including water column parameters, sediment chemistry and toxicity, and measurements of benthic communities. EPA also conducts monitoring through its National Estuary Program. As National Estuary Program sites were created, they included an extensive characterization phase and an estuary-specific monitoring plan. Although most continue monitoring to evaluate the effectiveness of their implementation efforts, there is no program-wide monitoring strategy. Finally, EPA is authorized to

support microbiological testing and monitoring of coastal recreational waters through the Beaches Environmental Assessment and Coastal Health Act, which was designed to reduce the risk of disease to users of the nation's coastal recreational waters.

Several agencies monitor atmospheric deposition, the process by which chemicals in the air are deposited onto the Earth's surface in wet and dry forms, contributing significantly to coastal water pollution. The National Atmospheric Deposition Program, a cooperative effort of many different groups, measures deposition of a number of pollutants at more than 200 sites. The Mercury Deposition Network, one component of this program, measures mercury levels in wet deposition. EPA's Clean Air Status and Trends Network also measures dry deposition at about eighty sites. In addition, the Interagency Monitoring of Protected Visual Environments (IMPROVE) is a cooperative measurement effort to aid the creation of federal and state implementation plans for visibility in 156 national parks and wilderness areas.

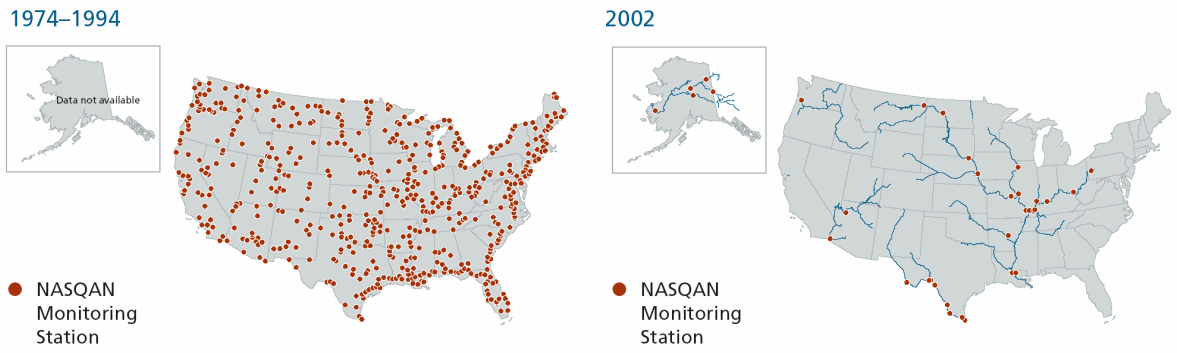
Shortcomings in Federal Programs

Notwithstanding the many programs described above, their combined efforts do not add up to a comprehensive, coordinated national monitoring network. One severe limitation of current efforts is the lack of monitoring in coastal waters.

National monitoring has been greatly reduced, particularly in coastal areas, due to funding cuts at USGS and many partner agencies. The USGS National Streamflow Information Program has eliminated a number of stream gages, including long-term gages that are critical for studying climate change. To fully realize its potential, the stream-gaging network will need to be modernized and gaps in coverage filled. Funding cuts have also affected USGS's water quality monitoring programs, resulting in reductions in the number of sampling sites and sampling frequency. USGS's National Water Quality Assessment's coverage has been reduced in recent years, leaving out much of the coastal region. A 2001 National Research Council report concluded that while this program has downsized in a logical manner, it cannot continue this trend and still be considered a national program for assessing water quality.[4]

Budget constraints have also affected the National Stream Quality Accounting Network. At its peak in 1978, this program included 520 fixed-station sampling sites on moderate and large rivers, which provided monthly estimates of flow rates, suspended sediment, nutrients, trace metals, indicator bacteria, and phytoplankton. About 140 of the sites were located in areas helpful to estimating the input of water and materials to estuaries.[5] Currently, this program focuses only on monitoring the water quality of the nation's largest rivers—the Mississippi, Columbia, Colorado, Rio Grande, and Yukon—with a total of only thirty-two stations. Most coastal regions are left out of the monitoring network altogether (Figure 15.1).

Figure 15.1 Watershed Monitoring Has Been Reduced Near the Coasts



15.1 A. The National Stream Quality Accounting Network program was created in 1974 to develop baseline water chemistry data for the nation. Although the network started with over 500 sampling stations, by 1994 the program had been reduced to approximately 275 stations throughout the United States. (Not shown are the 13 stations in Alaska, 8 in Hawaii, 6 in Puerto Rico, and 1 in Guam.)

15.1 B. Today, the program consists of only 32 stations focused on the nation's five major river basins, leaving almost the entire coastal region unmonitored.

Source: U.S. Geological Survey. <http://water.usgs.gov/nasqan/progdocs/index.html> (Accessed January 2004).

NOAA's National Status and Trends Program is limited by the number of sites sampled per state and the lack of full representation of estuarine habitats in those states. The program samples mollusks for contaminants only every other year, and even less frequently for sediments.

Of the more than 200 sites in the National Atmospheric Deposition Program, very few are located in coastal areas. Less than 20 percent of sites in the Atmospheric Integrated Research and Monitoring Network, a subnetwork of the National Atmospheric Deposition Program, are located in coastal areas.

Much of the monitoring in the United States is conducted by states, territories, nongovernmental organizations, and volunteers. There is considerable variation in the ways states select monitoring sites, the kinds of tests they perform, the methods they use to determine causes and sources of pollution, and the analytical approaches they choose to evaluate water quality. As a result, reports on the quality of a particular water body often differ on either side of a state line. These disparities diminish the usefulness of state monitoring programs for regional or national assessments. To be fully effective, monitoring data collected by state, territorial, tribal, and local governments, nongovernmental organizations, and volunteers will need to be coordinated with the national monitoring network.

PROMOTING INTERAGENCY COORDINATION

Several interagency initiatives have been proposed for achieving a more coordinated monitoring strategy. The Intergovernmental Task Force on Monitoring Water Quality was established in 1992 to review national monitoring activities and to develop an integrated national monitoring strategy. Chaired by EPA, with USGS as vice chair, the Task Force recommended, among other proposals, the development of closer working relationships among organizations that monitor and use water information and the development of comparable technical methods.[6]

The National Water Quality Monitoring Council was formed in 1997 as the successor to the Task Force, with the mandate to implement its strategy. Jointly chaired by EPA and USGS, the Council is composed of thirty-five representatives from federal, state, tribal, local, and municipal governments, watershed groups, academia,

and the private sector. The Council serves as the major national forum for the coordination of consistent and scientifically defensible federal and state water quality monitoring methods and strategies. Its focus has been on fresh water monitoring, but many of the methods it has developed could also be applied to marine environments.

The National Science and Technology Council's Committee on Environment and Natural Resources has also promoted an initiative to integrate and coordinate environmental monitoring efforts. From this initiative came the 1997 report, *Integrating the Nation's Environmental Monitoring and Research Networks and Programs: A Proposed Framework*. The framework is designed to produce the necessary scientific data and information to produce integrated environmental assessments.

The Coastal Research and Monitoring Strategy Workgroup was formed in 1999 with representatives from federal, state, tribal, and nongovernmental organizations. NOAA, EPA, USGS, and USDA led the development of the Workgroup's Coastal Research and Monitoring Strategy, published in 2000, which called for addressing problems of coastal water quality and coastal resources by replacing single-issue, single-agency, single-discipline problem solving with a coordinated, multi-agency, interdisciplinary approach.

While these interagency initiatives are moving in the right direction, they have not resulted in the comprehensive and coordinated national monitoring network resource managers need, particularly in coastal areas. Significant obstacles include a lack of: focus on the coast; participation by agencies with relevant responsibilities; follow-through; and commitment at the highest levels of government.

ENSURING COMPREHENSIVE, COORDINATED COVERAGE

The nation's coastal margin is the most densely populated and developed region of the nation, and its waters have been significantly degraded by pollution. Yet in recent years, due largely to lack of funding, monitoring has been extremely sparse along the coasts. Much remains unknown about the status of coastal environments, and increased monitoring will be required to make informed management decisions about this economically and ecologically valuable region. A long-term, comprehensive monitoring network can establish a baseline to facilitate the analysis of ecosystem change. It would also create an information base to allow managers to understand whether their strategies were effective in meeting their goals. While expanded monitoring will be needed, it will also be important to disseminate and use the substantial data that have already been collected.

The connections between coastal and upstream waters dictate that any monitoring network must be national in scope, with flexibility to allow for regional differences. For example, geographically isolated islands must be accommodated to allow for differences in scale, climate, temperature regimes, and limited fresh-water resources, compared to many mainland areas.

Despite decades of monitoring by many agencies, the nation still lacks a coordinated national network. It will be necessary to coordinate and strengthen federal monitoring efforts and then use a partnership effort among state, local, territorial, tribal, and federal agencies, as well as academic and research institutions, marine labs, nongovernmental organizations, and volunteer groups where appropriate. States will need to be active partners in this effort through a coordinated monitoring strategy that builds on and takes advantage of work already underway by states and federal agencies.

Because of the inherent overlap between inland, coastal, and open-ocean monitoring and observing, the national monitoring network should be closely linked with the Integrated Ocean Observing System (IOOS; discussed in detail in Chapter 26) and ultimately with a broad Earth observing system. The national monitoring network will provide the capability to observe, analyze, and forecast natural and human-induced changes that affect watershed, estuarine, and coastal ecosystems. The IOOS will provide the nation with similar information for the coasts and open-ocean environments. Because these systems will overlap in

coastal areas, they should be closely coordinated to ensure compatibility of information. At some point, the national monitoring network and the IOOS should both become components of a true Earth observing system that links land, air, and water around the globe.

Because the land, air, and sea are all interconnected, increased monitoring of atmospheric deposition will be critical to any monitoring network. Monitoring atmospheric deposition in coastal areas is particularly important because these areas receive significant input of toxics and nutrients.

Recommendation 15–1. The National Oceanic and Atmospheric Administration, U.S. Geological Survey, and U.S. Environmental Protection Agency, working with states and other appropriate entities, should develop a national monitoring network that coordinates and expands existing efforts, including monitoring of atmospheric deposition. The network should be built on a federally funded backbone of critical stations and measurements to assess long-term trends and conditions, with additional stations or measurements as needed to address regional characteristics or problems.

Recommendation 15–2. The National Oceanic and Atmospheric Administration should ensure that the national monitoring network includes adequate coverage in both coastal areas and the upland areas that affect them, and that the network is linked to the Integrated Ocean Observing System, to be incorporated eventually into a comprehensive Earth observing system.

CREATING AN EFFECTIVE MONITORING NETWORK

In addition to coordinating and expanding current efforts, an effective national monitoring network should have specific goals and objectives that reflect user needs and are helpful in assessing the effectiveness of management approaches. The overall system design should determine what and where to monitor, including the definition of a set of core variables. Technical expertise is needed to standardize procedures and establish quality control, data management, and reporting protocols. It is important for the national monitoring network to be periodically assessed and modified as necessary. Most important, the data collected through the national monitoring network should be useful to managers and stakeholders in evaluating management measures, determining best management practices, and making continual improvements in reaching ecosystem goals.

System Goals and Objectives

The national monitoring network should set clear, specific goals and objectives that reflect national, state, regional, territorial, tribal, and local needs. The goals and objectives should be geared toward the assessment of management approaches, including best management practices, and be based on pressing management issues. Successful monitoring should target issues that policy makers, scientists, managers, and the public consider important, providing a basis for possible management actions. Thus, in designing a coordinated national monitoring network, input will be needed from all of these sectors. However, attempts to be everything to everybody will result in an unfocused and ultimately unsuccessful program. Monitoring results should support adaptive management, allowing decision makers to support approaches that demonstrate measurable success in attaining ecosystem goals and revise practices that are falling short of achieving those goals.

System Design

Sampling protocols are central to the design of an effective national monitoring network. Because regular sampling of all areas for all contaminants would be unacceptably costly, only a subset of locations can be monitored. The network's designers need to determine what, where, and how often to sample, examining existing monitoring systems at the federal, state, territorial, tribal, local, and private levels to determine gaps.

Designers must agree on a set of core variables to be measured at every station, with flexibility for stakeholders to measure additional variables to meet regional and local needs. Along with core variables, determining consistent national indicators will allow decision makers to assess ecosystem health and conduct long-term evaluations. Some efforts have been made to establish a set of national indicators. For example, in 2002 the H. John Heinz III Center for Science, Economics, and the Environment issued *The State of the Nation's Ecosystem's*, which described national indicators that provide a very broad perspective on national trends and conditions.

To be effective, it is critical for a national monitoring network to incorporate various types of measurements, including a broad-scale census of fundamental properties, issue- and resource-specific surveys, and intensive monitoring at higher resolution to support the scientific study of ecosystem processes. The network should include both effects-based monitoring, which measures the current condition of the environment, and stressor-oriented monitoring, which measures parameters that are known or suspected to be associated with a decline in environmental health. In addition, it is desirable for the network to combine probabilistic sampling, which allows for statistically valid assessments of environmental conditions in monitored and unmonitored areas, with fixed-station sampling, in which specific areas are repeatedly sampled over an extended period of time. Probabilistic sampling is beneficial because it allows reliable general conclusions to be made about a site or a region. Fixed-station sampling also has its advantages because sampling one area repeatedly allows for long-term trend analyses. Because both of these sampling methods are beneficial in different ways, an ideal monitoring network would combine the two approaches.

Technical Coordination

The monitoring system needs to include standardized procedures and techniques. In some cases new measurement technologies will be needed, for example with respect to for monitoring beach water quality or assessing the sources of pathogens affecting beaches. Quality assurance and quality control guidelines should be established so that management approaches can be assessed on comparable terms. Data management protocols should be established and uniform data storage formats specified so information can be broadly disseminated and easily accessed and understood by agency personnel, the scientific and management communities, and the general public.

Periodic Review and Modification

The monitoring network's design will need to be evaluated periodically to make sure it is measuring variables that are useful for assessing the health of an ecosystem, to add new variables when necessary, and to make any other changes that would improve its operation. While establishing and standardizing a core set of measurements is important, it is also critical to review this core set periodically to ensure that new substances are added as needed. As new chemicals are detected in the environment and wildlife, their toxicological significance should be assessed and they should be considered as possible additions to the suite of routinely monitored compounds (Box 15.2).

Design Based on User Input

The national monitoring network will require not only federal coordination, but also significant input from state, territorial, tribal, and local governments, as well as academic and research institutions, nongovernmental organizations, and volunteer monitoring groups. The monitoring network should be designed with regional needs in mind, in a way that answers the questions of greatest interest to the end users. To maximize the value of monitoring information, users should be fully included from the start in designing the network. The regional ocean information programs, discussed in Chapter 5, are appropriate entities to provide the monitoring network with input concerning regional information needs.

Box 15.2 Keeping Up With New Contaminants

In recent years, a number of studies have demonstrated the presence of contaminants that had not previously been measured in the environment. These include many commonly-used compounds such as insecticides, pharmaceuticals, antibiotics, hormones, fire retardants, detergents, and other industrial chemicals that are produced in high volumes and can be introduced to the environment during their production, use, or disposal. They have likely been present in the environment since they entered commerce, but the technologies for their detection have only recently become widely available.

Analytical techniques rarely permit the detection of every chemical within an environmental sample. Therefore, monitoring efforts typically look for compounds from a pre-selected list. In the 1970s, EPA established a list of 129 priority pollutants (there are currently 126) that were chosen out of thousands of candidates based on their presumed prevalence in surface waters and their ability to be analyzed. This list still remains the standard for environmental assessments, although it ignores many highly relevant chemicals.

Some of the recently-detected compounds are long-lived and can accumulate to high concentrations in the environment, wildlife, and humans. They have also become widely dispersed, spreading even to distant Arctic areas. Most of these compounds have only recently been considered as environmental contaminants, so information on their toxicology is still lacking. As analytical technologies improve and new contaminants continue to be found, it will be important to understand the presence and toxicologic significance of these compounds in the environment and to update the list of priority pollutants to include such compounds.

Recommendation 15–3. The National Oceanic and Atmospheric Administration, U.S. Geological Survey, and U.S. Environmental Protection Agency, working with states and other appropriate entities, should ensure that the national monitoring network has clear goals, specifies core variables and an appropriate sampling framework, and is periodically reviewed and updated. These agencies should also work with the regional ocean information programs to determine regional and local information needs.

Specifically, the national monitoring network should include the following elements:

- *clearly defined goals that fulfill user needs and provide measures of management success.*
- *a core set of variables to be measured at all sites, with regional flexibility to measure additional variables where needed.*
- *an overall system design that determines where, how, and when to monitor and includes a mix of time and space scales, probabilistic and fixed stations, and stressor- and effects-oriented measurements.*
- *technical coordination that establishes standard procedures and techniques.*
- *periodic review of the monitoring network, with modifications as necessary to ensure that useful goals are being met in a cost-effective way.*

MAKING DATA ACCESSIBLE AND USEFUL

A coordinated national monitoring network will produce an enormous amount of data. However, for these data to be helpful, they must be processed and converted into timely information products that are useful and accessible to a broad community of decision makers, the public, and other potential end users. These information products should take full advantage of previously collected monitoring data, as well as data from a variety of other sources.

Monitoring data, whether newly collected or mined from old sources, should become part of a broad national environmental data management system. Such a system can combine data from many sources, including the IOOS (Chapter 26), to create information products. The process of receiving, managing, and translating data

is described in greater detail in Chapter 28; it will be key to merging monitoring and IOOS data to create seamless products across the land/ocean interface.

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