West Coast Regional

MARINE RESEARCH AND INFORMATION NEEDS

Sea Grant

Sea Grant
Washington
Oregon
California
University of Southern California

West Coast Regional Marine Research and Information Needs.
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The goal of this report is to establish priorities that foster collaboration among a full range of regional information providers and end users.

The California Current Large Marine Ecosystem (CCLME) has dynamic borders stretching from Baja California to Vancouver Island, British Columbia, and encompasses the shorelines, estuaries, and nearshore and offshore ocean environments of Washington, Oregon, and California. These coastal and ocean ecosystems are critical to regional vitality, provide diverse ocean and coastal habitats, and support a wealth of living marine resources. More than 35 million people live and work in the coastal counties of the three states and contribute to a regional ocean economy of about $32 billion annually. With increasing demand for natural resources, continuing population growth, and budgetary declines, West Coast communities face numerous challenges to the health and sustainability of their coastal and ocean resources and habitats, including polluted coastal waters, habitat loss, nonnative species invasions, eroding coastlines, and marine wildlife declines. Given the size, complexity, and interconnected nature of the ecosystem, more integrated regional approaches to conserving and managing our oceans and coasts are needed. Such an ecosystem-based approach must be based on greater knowledge of West Coast ocean and coastal ecosystems, including how they are affected by human activities. Comprehensive information is needed to answer environmental, economic, and social questions in a way that is place-based, considers the entirety of the ecosystem, and provides a strong scientific basis for decision makers. Effective policy and management depend upon information, research, and outreach coordinated at a scale mirroring that of the dominant CCLME.

National reports emphasize the importance of regional approaches as a cornerstone of sound ocean policies. They call for enhanced scientific efforts at the regional level to provide essential information for managing ocean and coastal ecosystems. In 2006 the National Oceanic and Atmospheric Administration (NOAA) provided funds through the National Sea Grant College Program to develop regional plans in coastal regions around the country. The Washington, Oregon, California, and University of Southern California Sea Grant programs partnered to develop a marine research and information plan for the West Coast region. Each Sea Grant program has worked with coastal communities in its state for decades to conduct scientific research, education, training, and extension projects designed to foster science-based decisions about the use and conservation of aquatic resources in the CCLME. With strong connections to the full range of individuals who study, manage, and rely upon coastal and ocean resources, the West Coast Sea Grant programs took on the task of initiating a regional planning effort that integrates the concerns, priorities, and expertise of all interests and sectors.

The primary goal of this Sea Grant West Coast planning process has been to identify continued and new research and outreach related to the CCLME that would contribute to the transition toward an ecosystem-based approach to ocean and coastal management. The goal is not to create a Sea Grant plan, but rather to establish priorities that foster collaboration among a full range of regional information providers and end users. To this end, the initial stage of the West Coast process used workshops, a Web survey, and an

Haystack Rock, Cannon Beach, Ore.

analysis of existing research plans by organizations in the region to accomplish three objectives:

- encourage broad-based stakeholder participation within each of the states;
- explore and develop focal research and information needs and requirements for investment; and
- enhance cooperative planning and priority setting by local, tribal, and state governments; research institutions; and nongovernmental organizations.

This report covers the first phase of the process and presents research and information needs identified by regional stakeholders. It can be used by federal, state, tribal, and local agencies for planning and prioritizing local and regional research and information efforts. Academic institutions, private research enterprises, and nongovernmental organizations will also find this report helpful for linking to regional stakeholder needs and identifying a regional context for existing or planned work. The second phase of the West Coast process will develop priorities to guide regional-level initiatives and investments in natural and social science research to provide the best-possible science for wise policy and resource-management decisions.

Regional Research Perspectives

Fifteen years ago, Congress established a regional marine research program, and planning was begun in nine U.S. coastal areas to set priorities for research to enhance water quality and ecosystem health. On the West Coast, the Pacific Northwest and California developed separate regional agendas using well-designed planning processes and with carefully considered priorities for marine and coastal research. Federal funding for the program never materialized, however, and regional needs have evolved since the initial agendas were developed. However, the planning processes strengthened regional relationships and highlighted the need for a long-term commitment to regional marine-research planning and implementation by federal and state agencies.

In 2003 and 2004 two national commissions released landmark reports recommending comprehensive ocean policies that rely on an ecosystem-based management approach to address environmental and economic concerns. The reports of the U.S. Commission on Ocean Policy and the Pew Oceans Commission called for improved coordination to address issues that cut across jurisdictional boundaries and affect multiple and overlapping watershed, coastal, and offshore uses. The commissions emphasized the need for regional partnerships to make full use of the expertise, resources, and capacity found in governments at all levels and in industry, universities, and other nongovernmental entities. The U.S. Commission on Ocean Policy Report specifically recommended the development of user-driven regional priorities for research, data, and science-based information products, and it identified four essential information needs: (1) research; (2) data collection, monitoring, and observations; (3) useful information products; and (4) outreach, education, training, and technical assistance for decision makers.

In January 2007 the federal interagency Joint Subcommittee on Ocean Science and Technology released *Charting the Course for*

Stakeholders discuss West Coast regional marine research needs in Depoe Bay, Ore., May 2007. Sea Grant held 16 workshops in Washington, Oregon, and California for stakeholders who study, manage, and rely on coastal and ocean resources.

Ocean Science in the United States for the Next Decade: An Ocean Research Priorities Plan and Implementation Strategy (ORPP). Developed with significant agency, academic, and constituent involvement, the plan identifies and updates federal agency strategies for addressing the national ocean research priorities. Necessarily broad in scope, the ORPP recommends further efforts to address specific regional research and information needs and suggests the use of regionally established priorities to help guide limited resources to high-priority problems, including those on the West Coast. Within the federal agency structure, NOAA is expanding its coordination efforts and emphasizes regional collaboration to improve productivity, build capacity, and increase the value of NOAA research activities and products. The West Coast Sea Grant programs worked closely with representatives from NOAA's Western Region team to develop this report.

In addition to providing an impetus for change at the federal level, the two ocean commission reports sparked substantial progress toward regional collaboration among state and provincial governments. In September 2006 the three West Coast governors signed the West Coast Governors' Agreement on Ocean Health (WCGA)[1], a groundbreaking agreement to protect and manage ocean and coastal resources along the entire coast. An action plan to implement the agreement was released in July 2008 and identifies the Sea Grant planning process as a major vehicle for identifying regional research priorities. The WCGA participants have expressed their commitment to seeking federal support to pursue the identified major marine research needs. In 2008 the governors of Alaska, California, Oregon, and Washington and the premier of British Columbia agreed to establish a Pacific Coast Collaborative to work on Pacific Coastal issues including clean energy, research and development, and emergency management. The impact of West Coast regional planning is magnified by state, tribal, and federal commitments to pursue joint funding for actions in which pooled resources or coordinated efforts will increase the return on investments to the region.

The Joint Ocean Commission Initiative (JOCI), which seeks coherent national ocean policy through encouraging and monitoring progress toward meaningful ocean policy reform, is also a result of the two commission reports. In January 2009 JOCI released *One Coast, One Future: Securing the Health of West Coast Ecosystems and Economies*. The report was developed in response to 19 local and state elected officials in Washington, Oregon, and California who requested guidance on the steps that should be taken to advance their "mutual interest in vibrant, sustainable coastal communities and ocean resources." The JOCI document recommended engaging stakeholders in setting goals and leveraging resources with cross-jurisdictional partnerships to address shared priorities. Additionally, the JOCI report highlights some regional information needs such as making the land-sea connection, use and availability of locally relevant information, integrated ecosystem-based information, and impacts of climate change. Each of the JOCI recommendations substantively overlap with the themes and topics in this report.

While the growing focus on ecosystem-based approaches to management has renewed interest in cooperative regional approaches, a number of organizations have developed substantial regional research and information investments that will be important elements in a comprehensive plan. Included among the ongoing regional programs in all three states are

- the Integrated Ocean Observing System (IOOS), a coordinated network of people and technology working together to provide continuous data on coastal and ocean conditions around the nation. For the CCLME, the Northwest, Central, and Southern California Regional IOOS associations work to detect, assess, and predict the effects of weather, climate, and human activities on the coastal ocean;
- the Pacific States Marine Fisheries Commission, which supports significant data collection and management pro-

[1] *The West Coast Governors' Agreement on Ocean Health and Action Plan can be downloaded at www.westcoast-oceans.gov.*

View from Shi Shi Beach, Olympic National Park, Wash.

grams directed toward the conservation and management of fishery resources in California, Oregon, Washington, Idaho, and Alaska. The Pacific Fisheries Information Network (known as PacFIN), the nation's first regional fisheries data network, provides up-to-date information to agencies and industry on commercial fish catches. Similarly, the Recreational Fisheries Information Network (known as RecFIN) provides a searchable database of biological, social, and economic data on state and federal marine recreational fisheries on the Pacific Coast;

- The Nature Conservancy (TNC), which has conducted Pacific Coastal marine ecoregion assessments from Baja California to Vancouver Island and from the shore out to the edge of the continental slope. The assessments are designed for use by TNC, government, industry, academia, and other organizations to inform conservation action at all levels. They help organize and update biodiversity information, produce spatial databases and maps, and provide benchmarks for monitoring environmental trends. In many cases, the assessments are contiguous with those for terrestrial ecoregions;
- the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO), a consortium of scientists from four universities that conducts ecosystem-based science in the nearshore portion of the CCLME, combining sustained monitoring with active outreach to communities, managers, and policy makers; and
- the Pacific Fishery Management Council, which was established by the Magnuson-Stevens Fishery Conservation and Management Act and works to coordinate fisheries management and establish research agendas for fisheries throughout the region.

Additional funding and institutional investment will facilitate expanded collaboration and coordination of institutions and organizations working to address regional-scale research and information needs across disciplines.

West Coast Environment, Economy, Governance

Covering the entire Pacific Coast of the continental United States, the coastal and ocean environments of the CCLME are characterized by high interannual variability due to such climatic events as the El Niño Southern Oscillation. This variability, along with anthropogenic influences and the effects of climate change, has significant impacts on the health of estuarine, nearshore, continental shelf, and offshore environments.

The ecosystem is typically divided into two physically and ecologically distinct zones at Point Conception. The northern boundary, marked by Washington's Olympic Peninsula, is a dynamic and transitional zone where the CCLME interfaces with the Gulf of Alaska LME. The northern portion of the ecosystem is characterized by the colder waters of the southward-flowing California Current, high-energy rocky coastlines, and northern marine flora and fauna. The wintertime, northward-flowing Davidson Current seasonally steers the direction of the Columbia River plume in conjunction with winter winds. The plume of the Columbia River, one of the continent's largest, exerts influence over a broad area at the Washington-Oregon border. Shorelines vary extensively, from Puget Sound's protected deep-water fjords and inlets to the outer coast's mixture of islands, submerged reefs, rocky cliffs and headlands, cobble and boulder fields, expansive dunes and sandy beaches, estuaries, embayments, and lagoons.

Point Conception, Cal., where two physically and ecologically distinct zones of the CCLME converge.

The southern portion, known as the Southern California Bight, is influenced by the warmer waters of the Davidson Current as well as the California Current. The two water masses converge at Point Conception, and the Santa Barbara Channel is a transition zone where many marine species reach their northern or southern range limits. Southern circulation patterns are more complex than elsewhere off the U.S. West Coast, and marine life is more typical of temperate and subtropical waters.

The West Coast is one of the most productive regions in the world, with a bounty of ocean and coastal resources that yield benefits associated with fisheries, tourism, alternative energy, and habitat for threatened and endangered species. Residents and visitors also draw deep cultural, aesthetic, and spiritual benefits from the ocean and its surroundings. West Coast communities have many economic, social, and cultural elements in common: reliance on coastal ports, a need for diversified economies, and a strong connection to natural resources.

The West Coast is also a study in contrasts—geographically, ecologically, socially, and culturally. Stretching from the misty rain forests of the Olympic Peninsula to the arid beaches of Southern California, it encompasses the largest metropolitan area in the United States and contains some of its smallest fishing towns. While some local ecosystems are nearly pristine, the natural features of long stretches of coastline have been dramatically reshaped by human habitation and commerce. Differences in cultural and economic demographics are equally striking. Northern California, Oregon, and outer Washington coasts, for example, share low population densities, dependence on small ports, natural resource-based economies, and multigenerational fishing families as well as limited access to goods, services, and infrastructure. By contrast, the urban centers of coastal Puget Sound, San Francisco Bay, and Southern California are densely populated and have diversified urban economies—along with significant concerns

about polluted waters, habitat loss, and declines in native species.

Washington. The state of Washington ranks 13th among states in total population, with more than 70 percent living within coastal counties. Over half the state's population of seven million lives in the Puget Sound region, which is home to three major cities and the second-largest U.S. container port. More than 10,000 streams and rivers flow into the Sound along its 2,500 miles of shoreline. In contrast, population densities along the outer coast are much lower, and there are no large cities. About 60 percent of tidelands and 30 percent of shorelands are privately owned.

Given differences in habitat, population density, and resource issues, separate state governance approaches have developed for Puget Sound and the Washington coast. In 2005 the Washington governor established a working group to evaluate outer-coast resources and develop an action plan for improving their protection and management. The Washington State Ocean Caucus evolved from this process and is currently working to implement the action plan. In 2007 the Puget Sound Partnership was established as a state agency charged with protecting and restoring Puget Sound and its diversity of life. The Partnership has worked with local decision-makers, tribal and business leaders, scientists, environmentalists, and the public to identify priorities and develop an action agenda that was released in December 2008.

The 29 federally recognized Indian tribes or nations in Washington all play an important cultural role and most serve as co-managers for coastal and marine resources. Individual tribes and intertribal councils conduct research, regulate fisheries, and work government-to-government with state and federal agencies. The Northwest Indian Fisheries Commission acts as a central coordinating body for its 20 member tribes and provides support services enabling them to efficiently use the limited federal funding provided for their natural resource-management activities.

Oregon. The state of Oregon ranks 27th among states in total population. Less than 40 percent of Oregon residents live within coastal counties, resulting in coastal population densities that are substantially lower than in neighboring states. Ninety percent of Oregon's 362 miles of ocean coastline is open to the public, with one public beach-access site for about every half-mile of coastline. Oregon has 10 federally recognized Indian tribes, and the coast has no major metropolitan cities.

The Oregon Territorial Sea Plan was established in 1994 to guide management of Oregon's nearshore and coastal zone. In 2008 the statewide Ocean Policy Advisory Council, a legislatively mandated advisory body to the governor, initiated action to amend the Territorial Sea Plan to examine the potential for ocean zoning brought to light by recent developments related to establishing marine reserves and wave-energy facilities. The 2006 Oregon Department of Fish and Wildlife Nearshore Strategy, meanwhile, promotes actions to conserve ecological functions and nearshore marine resources for long-term ecological, economic, and social benefits.

Oregon's pioneering land-use law recognizes the importance of ocean and coastal resources. The statewide planning goal for ocean resources seeks to conserve marine resources and ecological function for long-term benefits; the goal has guided ocean policy and the coastal management program since 1977. Additional statewide planning goals for estuarine resources, coastal shorelands,

The West Coast states have a variety of coastal landscapes, cultures, and ocean uses, including urban centers with thriving commercial ports and heavily used coastlines, small fishing communities with working waterfronts, and natural areas for conservation and recreation.

and beaches and dunes also apply to coastal management.

California. California is the most populous state in the nation, with 75 percent of its residents living in coastal counties. Many of the major metropolitan coastal cities, including San Diego, Los Angeles, San Jose, and San Francisco, are very culturally diverse. There are 11 federally recognized tribes and several unrecognized tribes within the state.

In 1990 the California Ocean Resources Management Act was passed to coordinate policies of different state agencies that have jurisdiction over ocean and coastal resources. In addition, the Act required that state agencies coordinate with local and federal governments. Nine years later, California enacted the Marine Life Management Act (MLMA) and the Marine Life Protection Act (MLPA). The MLMA calls for sustainable management of marine ecosystems and is primarily devoted to fisheries management, recognizing that maintaining the health of marine ecosystems is essential to sustainable and productive fisheries. The MLMA recognizes the importance of nonconsumptive aesthetic, educational, and recreational values, along with the inherent value of maintaining the health of marine ecosystems. The MLPA requires that the state assess its existing system of marine managed areas and design and manage a coordinated network of marine protected areas to protect marine life and habitats, marine ecosystems, and marine natural heritage, as well as improve the recreational, educational, and study opportunities they provide.

In 2004, passage of the California Ocean Policy Act established the California Ocean Protection Council (OPC). The OPC developed its strategic plan in 2004, and that document, along with the 1999 legislation, now guides ocean protection in the state.

Regional Report Development

The regional planning process was a collaboration among Sea Grant and state, tribal, and federal representatives. This report is based on extensive communication with stakeholders throughout Washington, Oregon, and California. Sea Grant has involved a broad range of ocean and coastal interests, including coastal residents; scholars and researchers; educators; industry; community organizations; marine conservation groups; tribal, state, and local governments; state, federal, and tribal resource managers; and many citizens and groups that depend on ocean resources for their livelihoods and recreational opportunities.

Sixteen workshops, attended by more than 600 participants, were held across the three states between May 2007 and January 2008. Stakeholders also commented on regional research and information needs through an online survey from July 2007 through January 2008. In total, nearly 1,000 project

Cross-cutting Themes

- Climate Change
- Ocean Education and Environmental Literacy
- Access to Information and Data

Research and Information Topics

- Vitality of Coastal Communities and Maritime Operations
- Ocean and Coastal Governance and Management of Multiple Uses
- Fisheries and Aquaculture
- Marine Ecosystem Structure and Function
- Ocean Health and Stressors
- Physical Ocean Processes, Related Climate Change, and Physical Coastal Hazards
- Water Quality and Pollution
- Resilience and Adaptability to Hazards and Climate Change

participants contributed more than 5,200 comments, which were categorized and distilled into the research themes and topics presented in this report. A more complete description of the stakeholder engagement process is provided in Appendix A.

This report was released in draft form for public review in December 2008. Sea Grant received 30 letters from stakeholders that recommended specific additions and changes to the draft. Each recommendation was carefully considered, and most resulted in changes to the draft that improved the overall quality and clarity of this report.

Numerous state, federal, and tribal agencies; local governments; academic institutions; private research enterprises; and nongovernmental organizations have invested significant effort in regional research, information, and outreach. These organizations have established considerable capacity to implement the needs presented in this report and to transition the region to an ecosystem-based approach to management. The content of this report is centered on the research and information needs. Some examples of organizations are included in this report, but the examples do not represent a comprehensive list of contributing organizations.

Who Participated?

- Coastal residents
- Scholars and researchers
- Educators
- Industry
- Community organizations
- Marine conservation groups
- Tribal, state, and local governments
- State, federal, and tribal resource managers
- Individual citizens and community groups that depend on ocean resources for their livelihoods and recreational opportunities

This report organizes research and information needs into three cross-cutting themes and eight broad research and information topics. The three cross-cutting themes surfaced during stakeholder discussions across all topics. Participants repeatedly asserted that substantive progress on topical issues would be hindered without considering climate change, ocean education, and access to data and information. The eight topics emerged as core concepts from the analysis of stakeholder comments. The individual research and information needs, while varied in scope, capture the suggestions highlighted by participants. The cross-cutting themes, topical sections, and the research and information needs presented in this report are interconnected; each should be approached in the context of the others, as success in one topic will strengthen progress in the others. The research and information needs are cross-referenced to the WCGA Action Plan, and specific actions have been linked to each thematic and topical section as shown below.

WCGA Action Plan Link:

Action 6.1—Develop a regional research agenda in partnership with the four Sea Grant programs and seek federal support to fill marine research needs identified

This report synthesizes the marine research and information needs and perspectives of diverse stakeholders across the West Coast, highlights shared issues, and demonstrates the regional significance of those needs and perspectives. This document is intended to help the full range of information producers, providers, and end users prioritize, solicit, conduct, and apply the natural and social science research required for ecosystem-based management and wise use of our natural and human resources. Complete listings of individual stakeholder comments are also available online at http://seagrant.oregonstate.edu/research/RegionalPlanning and may be of additional use to stakeholders interested in participant perspectives on a range of scales, from the entire West Coast to individual communities.

Climate Change

Global-scale indicators and impacts of our changing climate[2] are now well established and accepted. They include increases in average global temperatures, extreme temperature events and sea surface temperatures, a rise in sea level, and decreases in snowpack and sea ice extent. On the West Coast, important climate-related factors include changes in sea level, air and sea surface temperatures, ocean circulation patterns, water properties, winter precipitation, and storm intensity. These factors have the potential to increase the risks associated with various ocean and coastal stressors such as erosion, flooding, compromised water quality, invasions of exotic species, and large storm events.

Significant resources are dedicated to understanding the dynamics and effects of climate change on various scales. Federally, the U.S. Climate Change Program spends roughly $2 billion each year to conduct research to better understand, assess, predict, and respond to global climate change. Regionally, the Northeast Pacific Global Ocean Ecosystem Dynamics Program, known as GLOBEC, is a multidisciplinary research program that seeks to understand the effects of climate change on the distribution, abundance, and production of marine animals. Among all three West Coast states, numerous academic institutions, government agencies, cooperative and interdisciplinary entities, and other organizations are attempting to understand and address climate change on regional, state, and local scales.

Although scientists are aware of climate change and its actual and potential effects on ecosystems and coastal communities, many do not incorporate this information into research that does not specifically address climate change issues. Similarly, coastal managers are familiar to varying degrees with climate change, but they rarely frame their planning and operations in the context of climate forecasts. As a crosscutting theme, climate change has the potential to impact research approaches and results, as well as the use of information, in all other research topics identified in this report.

[2]In this report, the term "climate change" refers to both long-term changes in climate and temperature and shorter-term variability in climate.

Stakeholder Comments

"A research need is to understand effects of multiple stressors on marine organisms with climate change being one of the stressors."
—Bellingham, Wash., Oct. 24, 2007

"How should restoration practitioners and wetland managers plan coastal wetland restoration projects with climate change and sea level rise in mind?"
—Charleston, Ore., workshop, Aug. 6, 2007

"What is the role of fresh water input on coastal ecosystem/population dynamics? How does this vary over time/respond to climate change? This issue is clearly of importance to anadromous fishes, but… can also influence larval ecology for marine fish and invertebrates."
—Eureka, Calif., Oct. 24, 2007

Questions related to climate change were raised during virtually every topical discussion, indicating that climate change was a cross-cutting theme that influenced stakeholder research and information needs across all other subjects. Nearly 150 comments expressed concerns and specifically called for research and information on the impacts of climate change. For example, participants indicated that climate change must be a factor considered in research on coastal storms, ocean acidification, hypoxia (low oxygen events), and water quality. Stakeholders also indicated a need to better understand the effects of climate change on local oceans and ecosystems, and for climate change scenarios to be developed on local scales for relevant application at the community level.

Research and Information Needs

1. Frame ocean and coastal research and information in the context of climate change.

Climate change research and information needs cut across the topical areas presented in this report. While there is a need to directly investigate the patterns and effects of climate change (detailed in Topic 7: Physical Ocean Processes, Related Climate Change, and Physical Coastal Hazards; and Topic 8: Resilience and Adaptability to Hazards and Climate Change), there is a complementary

Climate Change

continued

need to consider many research questions reflected in this document in the context of our growing understanding of climate change and anticipated associated impacts. In many cases, this context is identified specifically in the research needs of each topic section in the report. For example, research and information needs associated with the effects of climate change on connectivity among ecosystem components, oceanographic conditions, and vulnerability of marine habitats are highlighted in Topic 5: Marine Ecosystem Structure and Function. Similarly, the role of climate change is made explicit in the research needs for control of aquatic invasive species in Topic 6: Ocean Health and Stressors. The potential for climate change to affect processes and resources that form the basis for all natural and human coastal dynamics suggests that it should be considered for all aspects of understanding and managing our ocean and coasts.

2. Improve and integrate regional and local models and forecasts.

As we improve our understanding of California Current dynamics in the face of climate change, there is an increasing need to transfer that knowledge to applicable scales. Reducing the spatial scale of modeling and forecasting results would provide more-specific determination of likely changes to local ecosystems and human communities, allowing for informed mitigation or adaptation strategies. Meanwhile, the capacity to integrate our understanding of climate change with other research and information needs would be greatly enhanced by improving and increasing opportunities for interdisciplinary training and research, bridging the gap between climate research and other disciplines such as ecology, fisheries, socioeconomics, and human health. As researchers and managers adaptively incorporate climate-change scenarios into their specific disciplines and decisions, our understanding and management of marine systems and resources will remain relevant even as the California Current and its dependent communities change.

WCGA Action Plan Link:

Overarching Action 2—Facing the effects of climate change

NOAA National Weather Service buoys, like this one, measure ocean and atmosphere conditions and transmit the data via satellite to scientists, who use the data to monitor and predict climatic trends and weather events.

Ocean Education and Environmental Literacy

Each of the three West Coast states supports a broad range of ocean and coastal educational programming for all ages in classrooms and other settings such as state parks, museums, aquaria, interpretive centers, and coastal research laboratories. Four Centers for Ocean Sciences Education Excellence operate in partnership with the National Science Foundation and several universities in Washington, Oregon, and California. Networked programs such as the National Estuarine Research Reserve System, the National Marine Sanctuary System, and the coastal National Wildlife Refuges have active programs for education, public outreach, and professional training. Sea Grant programs based at the University of Washington, Oregon State University, University of Southern California, and multiple campuses in the University of California system host education programs ranging from professional development for educators and K–12 curriculum development to supporting graduate students in marine science, policy, and outreach.

A Sea Grant educator teaches students about shark anatomy. Sea Grant is one of many organizations that offer programs to enhance K–12 science education and create opportunities for hands-on learning.

Understanding which elements of education and learning are most effective in providing stewardship skills and fostering behavior changes is fundamental to ensuring that education programs build ocean literacy. NOAA defines ocean literacy as "an understanding of the ocean's influence on you and your influence on the ocean." True literacy requires more than knowledge of facts, but is achieved when information is provided in the context of individual interests and experience, helping learners develop critical-thinking skills and the ability to use their knowledge to make wise decisions. An ocean-literate individual has an understanding of the essential principles and fundamental concepts of estuarine, shoreline, nearshore, and offshore ecosystem functions, and can communicate about the coast and ocean in meaningful ways. Proven formal, informal, and free-choice learning approaches should be used as a way to enrich existing educational programs and as a tool for developing new ones. Additionally, educators should be supported to develop and use creative methods to reach underserved communities.

Engagement of citizen volunteers in scientific monitoring of ocean and coastal health is one approach that has led to meaningful stewardship. Organizations such as the Surfrider Foundation, local Waterkeepers, Reef Check, the Coastal Observation and Seabird Survey Team, and Marine Resources Committees of the Northwest Straits Commission have demonstrated the value of this approach. Citizen-science also serves to meet the critical need for widespread monitoring of threats to ocean health. For example, the SoundToxins program, and the Olympic Region Harmful Algal Bloom program in Washington State are partnerships among federal, tribal, state, and local management agencies; marine resource-based businesses; public interest groups; and academic institutions designed to monitor harmful algal bloom events to minimize human health risks and economic losses. The Environmental Protection Agency supports a nationwide volunteer monitoring program that is a coordinated effort to train volunteers

to build awareness of water-quality problems and increase the amount of water-quality information available to decision makers at all levels of government.

Researchers and educators are actively working to identify new approaches to learning and monitor the effectiveness of education and outreach efforts. Also critical is an understanding of how individuals can direct their own learning, make use of available education products and online tools, and apply new knowledge about the ocean and coastal environments to make good decisions that benefit the environment and improve quality of life.

Stakeholder Comments

"How can we increase the general public's awareness that what happens on land impacts the ocean?"
—Port Angeles, Wash., Web survey response

"Fund non-profits that directly engaged trained volunteers in scientifically robust data collection."
—Oakland, Calif., Web survey response

"Examine the relationship between ocean education and literacy…"
—Corvallis, Ore., workshop, Jan. 15, 2008

West Coast stakeholders submitted more than 600 comments that urged improvements in, and expansion of, ocean education programs to inspire informed stewardship and prepare citizens to deal effectively with the challenges of the 21st century. Specifically, the stakeholders called for

- development of ocean and coastal science standards for incorporation into K–12 curricula;
- expansion of informal, free-choice, and outside-the-classroom programs for children and adults;
- enhancement of hands-on and virtual educational tools; and
- increased opportunities for professional training to strengthen the current and future workforce, including community leaders and coastal and ocean managers.

In addition, more than 100 stakeholder comments identified a need for innovative research into the process of learning itself, including assessment of (1) the effectiveness of education in altering human behaviors and inspiring ocean stewardship, and (2) how free-choice and informal learning enhances understanding of the marine environment.

Education Needs

1. Raise awareness.

One step in improving ocean literacy is supporting expansion and improvement of student and public education programs that promote heightened awareness of ecological and societal aspects of our coast and ocean. There are many successful programs in need of sustained support. Examples include: Marine Activities Resources and Education (known as MARE) and Global Learning and Observations to Benefit the Environment (known as GLOBE), which focus on inquiry-based, age-appropriate science for students and teachers; museum and aquaria-based free-choice learning programs that reach all ages of coastal visitors and residents; and programs that engage volunteers to collect valid and useful scientific information while enhancing their own awareness about issues such as wetland function, impacts and prevention of aquatic invasive species, and health risks associated with poor water quality.

A NOAA Science Camp participant examines a fish ear bone (otolith) to learn the age of the fish. NOAA Science Camp is one opportunity for students to work with scientists to learn about the marine environment and about what a career in marine science might entail.

Ocean Education and Environmental Literacy continued

Ocean Education and Environmental Literacy continued

A mother and her son examine tide-pool animals at a coastal aquarium that offers free-choice learning to people of all ages. The facility also serves as a laboratory to evaluate different educational models.

The West Coast is in need of support for awareness programs that focus on

- ecosystem services we depend on for basic survival, as well as the cultural and societal services provided by marine ecosystems such as ocean-related industries, authentic working waterfronts, and aesthetic and spiritual benefits;
- marine ecological function concepts such as the land-sea connection, migrations, trophic dynamics, ocean circulation, and the basic habitat and survival needs of marine organisms;
- human health risks such as the effects of exposure to poor water quality and contaminated seafood, and benefits such as the availability of recreational opportunities and nutritionally rich seafood; and
- human impacts (e.g., pollution and coastal development) and the human role in environmental protection, through outreach with easy-to-use tools and methods that enable individuals, institutions, governments, and businesses to be effective stewards.

Effectiveness and accuracy of messages related to the above focus areas could be improved by coordinated communication and message consistency among those organizations and institutions involved in building awareness. The media is a key partner that should be communicated with early and often to ensure that information delivered to the public is accurate and balanced and serves to expand awareness of coastal and ocean issues.

2. Integrate regional coasts and oceans into K–12 curricula.

K–12 educational institutions have a critical role in developing ocean literacy in our young people and fostering a society that understands and values coastal communities, coastal and ocean ecosystems, and the services they provide. Two approaches are needed: first, support for professional development of educators to learn techniques that infuse coastal and ocean themes into current curricula across natural sciences, social sciences, mathematics, the arts, and even physical education; and second, the augmentation of standards to include regionally and locally relevant ocean and coastal science—both natural and social science—in curricula. The latter approach will require funding for teacher training and development of enhanced text to include up-to-date, well-rounded coastal and ocean topics that range from coastal natural history, ecology, geology, and oceanography to social, cultural, and economic aspects of coastal communities. There is also a need for expanded opportunities to join K–12 education with informal learning programs that add value to traditional ocean curricula by providing hands-on, out-of-classroom experiences.

Ocean Education and Environmental Literacy continued

3. Enhance and increase professional training.

Management of coastal and ocean communities, ecosystems, and industries over the long term relies on a well-trained future workforce. Development of a future workforce starts during K–12 education and can be enhanced by hands-on experiences that expose students to ocean science in and out of the classroom and spark interest in ocean careers. These programs should be coupled with mentoring programs that place college students with K–12 students, to focus on meaningful projects from which both the mentors and their mentees gain understanding of ocean and coastal science and management issues.

Enhancement and professional growth of the existing ocean and coastal workforce is an immediate and continual need that should be addressed in at least two ways. First, ocean and coastal professionals need technical training to deal with current and emerging issues (e.g., ecosystem-based approaches to management and effects of climate change) through a variety of degree programs offered by community colleges and universities, and through existing, informal, non-degree programs. Second, there is a need for cross-training that provides scientists with improved communication and outreach skills so they can serve as a resource to decision makers and resource managers by supplying up-to-date, easy-to-understand-and-apply scientific information, to improve the use of science in decision making. University extension programs and community colleges can play a significant role in ensuring that the current workforce is capable of handling today's challenges and the future workforce has the capacity to meet tomorrow's challenges.

Research and Information Needs

1. Examine sources of coastal and ocean information and understand how learners choose and process new information into knowledge.

Information about the coasts and ocean is all around us. Classrooms, the Internet, mass media campaigns (such as the Thank You Ocean campaign and the Shifting Baselines media project), interpretive centers, parks, after-school and extracurricular programs, and volunteer programs are just a few of the pathways to access information. Beyond those structured programs, anyone who influences our use of knowledge to make decisions is an educator. Teachers, parents and guardians, neighbors, the news media, university extension staff, and nongovernmental organization volunteers all play a part in education. An understanding of the criteria people use to choose from among the many sources of information available to them, how they determine whether information is valid, and whether they are able to translate that information into actions is an important element in developing improved education programs. Formal and informal educators need easy-to-access resources that provide empirically established approaches for delivering information that is personally meaningful and builds the skills necessary for making decisions.

2. Identify the key elements of education programs that effectively encourage stewardship.

Education evaluation methods are often used to demonstrate a program's effectiveness in providing information and to assess the learner's ability to remember new information over the short term. However, more-comprehensive evaluation methods are needed to demonstrate long-term learning and the ability of learners to use knowledge in constructive ways, both to improve the quality of their lives and to protect ocean and coastal resources. New evaluation methods, applied to varied educational approaches over multiple timescales, could identify key elements of education programming that provide learners with a lasting ability to translate knowledge into stewardship actions. Evaluation methods and results that inform development of effective techniques for use in informal, free-choice, and formal learning settings must be shared with educators.

WCGA Action Plan Link:

Action 5.1—Enhance ocean literacy

Action 5.2—Support ocean awareness efforts

Access to Information and Data

Research and monitoring efforts are a rich source of information, but the planning, design, and execution of research often do not include measures to ensure that: (1) data collection and storage are compatible with current standards; (2) the means for integrating data with other data types, with historical data, or with data from other locations are effective; and (3) the results are made widely available in the form of user products and applications or tools that place data and results in a context and provide useful information for decision making. In particular, there is an abundance of data available from monitoring programs that can be applied to a broad range of questions and decisions, often unrelated to the primary motivation for the monitoring effort; however, funding is rarely available for processing, analysis, and development of tools to facilitate the use of data in management.

Data from this instrument used by researchers to measure water column properties (conductivity, temperature, and depth) have a variety of applications from fisheries management to climate change research.

State-level coastal zone management organizations; nongovernmental organizations such as The Nature Conservancy; collaborative research groups such as the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) and the California Current Ecosystem long-term ecological research program; the Pacific Fishery Management Council; state, tribal, and federal management and regulatory agencies; and regional associations of ocean-observing networks are just a few examples of entities that are generating and managing substantial datasets. Researchers from those organizations face the significant challenges of integrating data into useful applications for managers and transitioning data into information suitable for communication and outreach programs that are effective in conveying the social and ecological meaning of their work to a broad and diverse audience.

Several organizations are already taking the initiative to ensure data accessibility, integration, and synthesis, and to develop products and tools specifically based on West Coast regional research and monitoring programs. Below are some examples that could serve as models for future efforts.

- The National Center for Ecological Analysis and Synthesis, based at the University of California at Santa Barbara, brings scientists together to use existing information in addressing important social and ecological questions.
- The National Marine Protected Areas West Coast Pilot Program is working to integrate science-based data and traditional ecological knowledge. The program emphasizes the importance of information sharing to achieve common place-based management goals related to marine protected areas in Washington, Oregon, and California.
- The following organizations support and emphasize West Coast regional and subregional coordination of research through making data and information publicly available, integrating and synthesizing results, and developing useable tools to support decision making: PISCO; the Pacific Coast Ocean Observing System (known as PaCOOS); and the Northwest, Central, and Southern California Regional Associations of the Integrated Ocean Observing Systems, or IOOS; as well as the Puget Sound Partnership, the Northwest Straits Initiative, the Southern California Coastal Water Research Project, the California Cooperative Oceanic Fisheries Investigations (known as CalCOFI), and the California Sanctuary Integrated Monitoring Network (known as SIMoN).

Access to Information and Data continued

In addition, several larger-scale organizations are working to address the technical challenges associated with data integration and compatibility. These include the Global Biodiversity Information Facility, the Ocean Biogeographic Information System, the Census of Marine Life, and the National Ecological Observatory Network.

Stakeholder Comments

"A lot of information is being gathered by various coastal agencies. This should be available to all for assessment of ocean conditions and research needs. Much of this is tax-dollar generated. It is often difficult to get data unless a long application/requesting process is gone through."
—Ocean Shores, Wash., workshop, Oct. 12, 2007

"Bring data together. There may be information that already exists but we need improved accessibility."
—Charleston, Ore., workshop, Aug. 6, 2007

"Ensuring some uniformity in types of data collected (e.g. monitoring) so that it can all be integrated into analyses/models of the entire coast."
—Costa Mesa, Calif., workshop, Sep. 18, 2007

Access to data and information—existing and new—was a recurring stakeholder theme during the Sea Grant regional workshops. Stakeholders provided 146 comments specifically about data and information issues, including suggestions to

- expand public and professional access to new and existing data;
- integrate and synthesize data sets across time, space, and fields of scientific inquiry; and
- develop usable data tools and products to support science-based decision making.

Hundreds of other comments suggesting specific research needs detailed in the topical sections of this report included such phrases as "make widely available to the public and managers" and "make sure that data from this program are synthesized."

WCGA Action Plan Link:

Action 6.2—Support long-term maintenance of ocean-observing systems and monitoring assets

Research and Information Needs

1. Identify which standards and guidelines for data collection, storage, and analysis can be used to increase compatibility of datasets across disciplines and locations.

Maximizing the benefits of coastal and ocean data begins with establishing common protocols and methodologies for data collection and utilizing established standards for data storage, including use of accepted quality-control measures and metadata. Collaborative efforts among organizations and institutions conducting research and monitoring to determine and test appropriate standard data collection and analysis methods should be supported. Current accepted data storage standards should receive continued support; these include the National Biological Information Infrastructure and associated standards established by the Ocean Biogeographic Information System and the Federal Geographic Data Committee. Similar standards are required to ensure social and economic data are collected using coherent and comparable methods.

2. Ensure that technical information is more accessible, particularly to those who can incorporate new knowledge into decisions about ocean resource use and coastal management.

A great deal of information about the West Coast ocean and coastal environment already exists; however, much of it is inaccessible and cannot be put to use to inform decisions of policy makers, coastal and ocean resource managers, and the public. Research and monitoring programs often lack incentives and financial or staff resources to make results widely available, even to intended users or for obvious applications. Meanwhile, many data can be applied even more broadly than originally intended, if the information is accessible. Efforts should be directed toward programs that seek to make informa-

Access to Information and Data continued

tion more accessible, as well as programs that seek to gather, synthesize, and disseminate existing social, economic, and ecological information, to enable managers, decision makers, and scientists to build on what is already known, improve understanding of changes to ocean and coastal environments and communities over time, and better integrate science into decision making. Use of established electronic and physical information-access points will allow more-expedient delivery of information to users.

A remote-controlled submersible vehicle used to study and monitor marine environments that would otherwise be difficult to access. When data are analyzed, synthesized, and made available, the resulting information is valuable to management.

3. Promote development of tools that help make sense of marine science data and apply technical information to pressing coastal problems.

Funding agencies should require and fund researchers to extend their activities beyond the generation of data, analysis, and publication in peer-reviewed literature. Similarly, monitoring programs should be encouraged to make routinely collected data available for wider and opportunistic application to ocean and coastal issues. Scientists, communicators, and outreach specialists must be encouraged to work together to develop innovative user products and application tools that can be used by the public, managers, decision makers, and other researchers. Significant growth in this area will require additional funding and professional incentives.

Development of information products and tools is far more complex than posting data on the Web in a timely fashion. As one stakeholder noted, "It doesn't do any good giving a manager a terabyte of model output." Products and tools with user-friendly interfaces such as interactive maps and searchable, Web-served databases should be available in understandable, jargon-free language to facilitate science-based ocean and coastal decision making. To make these tools more useful for management-critical needs, they should be developed with, and regularly evaluated by, those who will use them.

4. Support better integration and synthesis of varied research outcomes to address overarching concerns.

Integration and synthesis of information across time, space, and disciplines of scientific inquiry are needed to understand large-scale changes to coastal communities and ecosystems over time. Understanding these large-scale changes can be enhanced by integrating historical information based on a variety of insights—for instance, combining traditional ecological wisdom with contemporary biological monitoring results. In addition, combined social and ecological datasets over long time periods can help establish a better understanding of current and historical coastal and ocean conditions to inform decisions. This type of work requires that agencies and institutions apply accepted standards to new data collection and work to update older databases to make them as compatible as possible with current standards and norms of collection, storage, and analysis.

The above steps, taken together, could increase the ability to apply research and monitoring results to critical social and ecological issues, prevent duplication of effort, strategically fill critical data gaps, build on the body of existing information, and connect research and monitoring to ongoing efforts in other disciplines and locations.

Vitality of Coastal Communities and Maritime Operations

Washington, Oregon, and California coastal zone counties support a nearly $2.3 trillion annual economy. In 2007 the coastal economy made up about 80 percent of the total three-state economy. The region's ocean industries employed more than 436,000 people, with a gross domestic product of $31.5 billion (2004) and commercial fishery landings valued at more than $413 million (2007).[3] The rich coastal and ocean resources of the region have provided the foundation for culturally, socially, and economically diverse coastal communities. In order to maintain the social and economic vitality of coastal communities, which face increasing populations and changing economic and environmental conditions, investments need to be made to ensure that coastal community development is sustainable and accounts for the value of both market goods and nonmarket ecosystem services, and that our communities have the necessary infrastructure to maintain and enhance benefits from ocean and coastal industries.

The urban coastal economies of Southern California, the San Francisco Bay Area, and Seattle-Tacoma are well known for huge container ports that are the locus of trade with the Far East and employ thousands of skilled workers. These coastlines also see large populations and a variety of ocean and coastal uses including fishing, recreation, residential, power generation, and a host of other activities and coastal-dependent businesses. These regions are often dominated by issues pertaining to population growth, demand for coastal real estate, and environmental impacts of heavy use. These urban ports and coasts are beginning to examine innovative development and redevelopment scenarios.

Substantial similarities also unite the small coastal communities of Northern California, Oregon, and the outer Washington coast. For example, all of these communities rely to some extent on commerce from small ports, timber, commercial fisheries, and coastal recreation. A regional approach to addressing questions of community development, social and economic assessment and monitoring, maritime infrastructure, and dredging is needed to stretch limited dollars for social and economic research. A regional approach can be especially helpful when federal, tribal, or state-based decisions have region-wide economic implications. Where communities or regions face similar social and economic challenges, those communities can work together by pooling resources or sharing solutions.

In recent decades, coastal communities have seen substantial changes in the size and composition of their populations. As coastal populations increase, environmental pressure from coastal development and other human activities also increases. Economies of many smaller coastal communities are in transition; for example, those that have historically depended upon the timber or fishing industries are looking to diversify by capitalizing on other strengths such as natural beauty,

[3] *Data from National Ocean Economics Program, http://noep.mbari.org/*

Large container ships and associated ports are the primary vehicle of international trade, supporting thousands of jobs for urban coastal areas in the region.

Vitality of Coastal Communities and Maritime Operations

continued

clean air, temperate weather, authentic working waterfronts, and local culture—all of which attract people to the coast and support tourism. A healthy economy depends upon a population willing and able to support new industries that can provide basic services such as transportation, health care, and education. Construction and sales of real estate (retirement and vacation homes, in particular) and increased transfer payments (such as retirement income and outside investments) have helped bolster coastal economies; however, volatility in the housing market dramatically reduces the contributions of construction and real estate in some coastal areas. Large ports and active smaller ports are also a key component of some coastal economies, and there is strong support in smaller communities to maintain and revitalize their ports.

Locally owned and operated vessels are central to active fishing communities and working ports that support local economies.

Federal, tribal, and state agencies have conducted significant work to assess the economic and social status of coastal communities. For example, NOAA recently completed basic social and economic profiles for 125 communities that rely in part on commercial fisheries landings and are home to participants in the fisheries. The National Ocean Economic Program (NOEP) also provides current social and economic data for coastal states that is helpful for tracking changes over time. In addition, the Oregon Coastal Zone Management Association conducts ongoing studies and releases periodic reports on coastal community demographics and economic conditions.

Many marine resource managers and natural scientists have responded to the economic issues facing coastal communities by working closely with social and economic scientists to incorporate human dimensions into an ecosystem-based approach to management. This approach views humans as part of the ecosystem and values the interdependence of healthy ecosystems and healthy coastal communities. Despite this new approach, and the fact that many of the social and economic research and information needs identified by stakeholders have been clearly identified for decades, research and information that can improve the vitality of coastal communities remains underfunded.

Stakeholder Comments

"How does the working waterfront contribute to the strength and vitality of the community? Beyond economic analysis, are there other ways to assess this value?"
—Bellingham, Wash., workshop, Oct. 24, 2007

"The issue of how to dispose of dredge spoils looms large for our working harbors. That would be an important question to research and solve."
—Santa Barbara, Calif., written comment, Nov. 13, 2008

"More research is needed to identify economic constraints to sustainable development in coastal communities, especially for infrastructure needs."
—Olympia, Wash., workshop, Dec. 13, 2007

The vision of community vitality, health, and well-being varies from one community to the next, depending on size, cultural diversity, social and economic conditions, and history. Yet urban and rural stakeholders alike expressed concern about long-term coastal community viability by submitting more than 200 comments that addressed the everyday concerns of coastal families, business owners, and participants in commercial fisheries. Many stakeholders expressed a desire for community-level economic development that protects natural resources and coastal community cultures. They asked how coastal and ocean resources can be valued and how they contribute to social well-being and economic stability of coastal communities. An additional 149

comments related to maritime operations including port and harbor infrastructure, port maintenance, safety and navigation, port-related transportation, impacts of dredging, and green port activities to reduce impacts on air and water quality.

WCGA Action Plan Link:

Action 1.6—Support emission standards for oceangoing vessels

Action 3.2—Support integrated ecosystem assessments, including biological, physical, social, and economic factors

Action 7.1—Support local planning efforts for sustainable communities

Action 7.2—Promote environmentally responsible port and harbor operations

Action 7.3—Assess the health and economic vitality of coastal communities

Action 7.4—Develop regional sediment management plans

Research and Information Needs

1. Develop robust cost-benefit analyses to support a balance between economic growth and sustainable natural resource use.

One of the biggest challenges for coastal communities is balancing economic growth with sustainable use of natural resources. In addition to the need for expanded monitoring and study of market values of natural resources, there is a compelling need to identify and assign nonmarket values to ecological, cultural, and aesthetic services provided by coastal and ocean ecosystems. The results of these expanded valuation studies should be incorporated into a robust cost-benefit analysis to serve as a foundation for determining which new industries can most effectively diversify and stabilize coastal economies. These studies can assist communities in constructing realistic and achievable development strategies and implementing those strategies through appropriate management actions designed to reach each community's unique goals.

2. Develop key social and economic indicators to inform strategies for sustainable community development.

Coastal communities are likely to have distinct community development goals that focus on their strategic assets and unique social and economic conditions. To realistically identify and frame these goals, communities need standardized information on key indicators of social and economic vitality. These indicators should be developed through a stakeholder-informed regional effort, and indicator data should be shared with the public through a common information system available in all three states. There is also a need to develop local capacity to use this information to assess current community status and determine the full set of external barriers (e.g., lack of access to a skilled workforce, insufficient transportation, etc.) to achieving sustainable and vibrant economies and societies. Communities also need to know which public policies will help them foster solutions and overcome barriers.

3. Assess maritime infrastructure and operations for optimal support of coastal community vitality and minimal environmental and economic impacts.

Feasibility studies are needed to determine the potential of West Coast regional short-sea shipping as a practical, economically sustainable and more-efficient alternative to landside transportation for moving goods and people between ports in Washington, Oregon, and California. Efficient, feasible options and improvements need to be identified to move cargo between ports as well as from ports overland to final destinations with minimal environmental impacts, and maintain small ports with recreational access. These changes will require an evaluation of whether the appropriate maritime infrastructure exists to support short-sea shipping and recreational access where it is most needed, potential methods to enhance safety and functionality of small and large ports, and the current and potential capabilities for energy-efficient transportation. Research is also needed to determine novel, beneficial uses of dredge material, including remediation techniques, possible upland disposal, beach renourishment, and other uses.

Ocean and Coastal Governance and Management of Multiple Uses

U.S. ocean and coastal policy and management are undergoing a major paradigm shift—away from a traditional, single-sector focus to a more integrated-systems approach. Many policy makers have recognized that single-focus governance limits the effectiveness of marine management. Moreover, such approaches have played a critical role in the degradation of our oceans. At the federal level, responsibility for ocean and coastal decisions is fragmented among at least 20 agencies charged with implementing more than 140 ocean-related laws. This splintered approach is not limited to the federal level.

Visitors and residents of Puget Sound enjoy orca whale watching as one of many recreational uses of coastal and ocean resources.

Within the state of Washington, for example, marine matters are dealt with by some 15 state agencies and offices, 20 tribes, 15 coastal counties, three commissions, and numerous other organizations such as salmon-recovery lead entities and the Puget Sound Partnership. Current ocean governance on the West Coast is inefficient at best, may result in conflicts among sectors, contributes to management gaps and overlaps, and has given rise to calls for ocean zoning and more holistic approaches to managing ecosystems.

This shift affects all levels of government, from federal agencies to small coastal communities, and marine activities at all scales from regional to local. In 2004 the U.S. Commission on Ocean Policy established a set of fundamental principles to guide ocean governance, including ecosystem-based, multiple use, and adaptive management. In all three West Coast states, legislation and policy directives developed during the past decade have increasingly recognized the importance of integrated approaches to ocean management and governance. For example, these principles are reflected in the WCGA Action Plan and in many state- and community-level plans such as the Puget Sound Partnership Action Agenda, management plans for the West Coast national marine sanctuaries, and the Port Orford stewardship plan. Similarly, in 2005 the Communication Partnership for Science and the Sea (COMPASS) coordinated more than 200 scientists and policy experts, who developed a consensus statement on marine ecosystem-based management calling for management that integrates ecological, social, economic, and institutional perspectives.

The move toward ecosystem-based governance underscores the need for a strong and comprehensive scientific basis for ocean-related decisions. Information on the intensity and distribution of human activities and their effects on the marine environment, including social and economic factors, can be synthesized to provide tools for resource conservation, management, and informed planning, education, and research. In the Pacific region, NOAA is taking the lead on integrated ecosystem assessments with a five-step approach: scoping, indicator development, risk analysis, overall ecosystem assessment, and evaluation. Inherent in this model is identification of gaps in data and understanding, allowing for adaptive guidance of future research efforts. In addition, the Packard Foundation and other private funders are supporting a California Current initiative that seeks to advance science for ecosystem-based management on the West Coast. Among the limitations to such approaches are the lack of comprehensive social and economic data, incomplete understanding of marine resources and ocean dynamics, and gaps in baseline data in such areas as habitat mapping.

In addition to these general information constraints, new and emerging ocean uses create unique information needs that must be

Ocean and Coastal Governance and Management of Multiple Uses

continued

An experimental wave-energy buoy is deployed off the Oregon coast. Alternative energy is one of many commercial uses that require a governance structure to address competition and conflict among user groups.

addressed and incorporated into place-based ecosystem assessments. For example, a 2007 workshop on the ecological effects of wave-energy development in the Pacific Northwest made several key findings, concluding that (1) the lack of information around potential effects needs to be recognized, (2) monitoring is critical to understanding effects, (3) risk and uncertainty are important to characterize, and (4) cumulative effects must be understood. Similar findings would be applicable to other recent and emerging issues such as marine protected areas, habitat restoration, and noise pollution.

Finally, public participation is a fundamental principle of ocean governance, involving stakeholders and providing for both local interests and those of the broader public. One of the greatest challenges facing marine managers is the lack of public awareness of diminishing ocean and coastal health. While people place high value on our ocean and coastal environments, they do not necessarily recognize how they are threatened. For this reason, citizen outreach and education must be at the core of management and governance systems.

Almost 400 stakeholder comments identified research and information needs that fall into two general categories. The first is assessment of the impact of human activities along the West Coast on natural marine and coastal ecosystems, as well as the economic and social impacts on coastal residents and communities. Additional stakeholder comments questioned the impacts of three specific multiple-use issues: alternative energy sources such as waves and tides, marine protected areas, and habitat protection and restoration. The second general category is evaluation of the effectiveness of current management and decision-making

Stakeholder Comments

"…there is an enormous need to understand how diverse human activities act cumulatively or synergistically to affect the marine environment. In order to implement ecosystem-based management, managers must be able to make informed decisions about how different decisions will impact the environment…"
—Oakland, Calif., workshop, Nov. 28, 2007

"Marine reserves and wave energy parks, if set up in the wrong areas, could be a real impediment to companies, shippers, and all sea farers…"
—Astoria, Ore., workshop, Aug. 9, 2007

"Evaluate the effectiveness of traditional government organizations to address 21st century ocean issues. How are single subject agencies to address multi-subject/cross-jurisdictional/border/global problems?"
—Costa Mesa, Calif., workshop, Sept. 18, 2007

"Research is needed on how best to form a trans-boundary alliance in order to deal with common issues such as pollution, toxins, run-off, endangered population recovery."
—Bellingham, Wash., workshop, Oct. 24, 2007

Ocean and Coastal Governance and Management of Multiple Uses

continued

approaches and governance structures to inform the development and implementation of improved, ecosystem-based, adaptive approaches, such as comprehensive ocean zoning, that identify and resolve potential conflicts among competing uses. Pacific Northwest respondents placed a somewhat higher priority on governance issues than their California counterparts, with the exception of marine protected areas.

WCGA Action Plan Link:

Action 2.1—Document, describe, and map ecological communities and characterize human uses

Action 3.1—Encourage effective ecosystem-based management

Action 3.2—Support integrated ecosystem assessments, including biological, physical, social, and economic factors

Action 4.1—Oppose new offshore oil and gas operations

Action 4.2—Evaluate the potential and impacts of offshore alternative ocean energy development

Research and Information Needs

1. Determine impacts and conduct Integrated Ecosystem Assessments.

Fundamental to ecosystem-based management are assessments of impacts that integrate cumulative ecological, social, and economic effects. Impact assessments must be place-based and examine the ways in which systems are interconnected. Such approaches are necessary to monitor the effects of long-term actions such as marine protected areas, habitat restoration, and other mitigation activities. Development of indicators, long-term monitoring, and basic environmental information based on habitat mapping, human use mapping, geographic information systems, and an integrated ocean and coastal observing system are required to provide a baseline for impact assessments and to allow us to better understand the status of ecosystems. Substantial new investment will be required for collection and analysis of data on the human dimensions of ocean and coastal management. For example, in-depth and long-term monitoring and assessment of demographic and economic trends in coastal communities are necessary to track the human consequences of changing coastal ecosystems and resource-management practices. In addition to providing insights into current ecosystem function, impact assessments allow examination of potential effects of emerging issues such as noise pollution, wave energy development, and climate change. They also provide a basis for adaptive management.

2. Evaluate and improve institutional capabilities and policies.

While there appears to be strong agreement on the need for ecosystem-based approaches, there is far less certainty about the capacity of current institutional structures to implement such approaches. Little systematic investment has been made in the policy and social science research required to scientifically evaluate the effectiveness of current management and decision-making models, to assess the costs and merits of alternative approaches, and to develop recommendations for building effective new governance capacity and processes. An inventory of federal laws and institutions was conducted as part of the U.S. Ocean Commission process, and the Commission urged major revisions to the federal governance structure. However, similar analysis is needed at regional, tribal, state, and even local levels and to examine the interrelationships of overlapping layers of decision makers. In addition, federal-level resistance to sweeping institutional change, along with demonstrated progress with smaller-scale ecosystem projects, suggest that a systematic, bottom-up approach may have more immediate success in demonstrating effective new approaches to management. Educational institutions also must recognize the need to train a new generation of scientists and policy makers who are adept at understanding and responding to an emerging governance paradigm that addresses the many ongoing interactions among ocean and coastal processes, marine and human communities, and maritime and coastal activities.

Fisheries and Aquaculture

The waters of the California Current are highly productive due to upwelling, which brings nutrient-rich cold water to the surface, producing a robust food chain that supports a highly diverse marine ecosystem. Many populations of commercial, recreational, and subsistence fish and shellfish species thrive in this ecosystem, along with populations of marine mammals and seabirds.

Commercial, recreational, and subsistence fishing have a long tradition along the Pacific Coast and are composed of a diverse array of species and gear types. Significant fisheries common to Washington, Oregon, and California include Chinook salmon, Dungeness crab, groundfish, sablefish, Pacific whiting (hake), Pacific oyster, and sea urchins. Also common to all three states are the coastal pelagic species, which include northern anchovy, market squid, Albacore tuna, Pacific herring, Pacific sardine, and mackerel. Some of these species, such as the groundfish complex, salmon, and market squid, are managed by the Pacific Fishery Management Council under the Magnuson-Stevens Fishery Conservation and Management Act, while others are managed or co-managed by individual states and tribes. Some fisheries are unique to individual states, such as geoduck clams in Washington and lobsters in Southern California. One of the largest and most complex fisheries is that for the groundfish complex, which includes more than 90 different species that live, for the most part, on or near the ocean floor. This complex is managed under the Pacific Coast Groundfish Fishery Management Plan and includes rockfish, flatfish, roundfish, and sharks.

Many different gear types are used to target a wide variety of fished species. While the bottom and pelagic trawl fishery harvests the most groundfish, these species can also be caught with troll, longline, hook-and-line, pots, gillnets, and other gear, which are also used in other fisheries. In addition, there are dive fisheries for invertebrates such as sea urchins and geoduck clams.

Fisheries management is exceedingly complex as a result of the variables that can impact fish populations, including oceanographic conditions (for example, currents, temperature, salinity, pH, and oxygen concentrations) and impacts from human activities such as coastal development and industrial land uses. At its core, fisheries management requires a comprehensive knowledge of fish populations, including biological attributes, distribution, and abundance, that is rarely available. Larval dispersal and recruitment are highly dependent on both large- and small-scale variability in the estuarine, nearshore, and oceanic environment. In the short term, this includes factors such as the strength and intensity of storms, and wind velocity that drives upwelling and downwelling. Larger climatic changes such as the El Niño Southern Oscillation, interdecadal regime shifts, ocean temperature and pH, and large-scale ocean circulation have a significant impact on nutrient availability and, ultimately, the abundance of zooplankton available to nourish larval and juvenile fish.

Fisheries are managed through a number of measures, including harvest guidelines, quotas, trip and landing limits, area restrictions, depth restrictions, size limits, seasonal

A commercial trawler leaves its home port. Many fishing vessels based out of West Coast fishing ports are owner operated.

Fisheries and Aquaculture

continued

closures, and gear restrictions. While some stocks show signs of rebuilding, many fisheries are in decline despite a multitude of management tools. In 2008 the commercial, recreational, and tribal Chinook salmon season was closed for the first time in California and Oregon and restricted in Washington. All sectors of the groundfish fishery are constrained by the need to rebuild species that have been declared overfished, which creates a dilemma when many of the mixed-fishery stocks are healthy. The cost of collecting sufficient data to improve management is often a barrier. Nonetheless, state, tribal, and federal fisheries managers are striving to improve management, and recent population increases observed for some overfished species of rockfish are encouraging signs.

A Pacific oyster is harvested from a raised aquaculture bed.

Aquaculture provides another source of fresh seafood in Washington, Oregon, and California. Shellfish culture consists primarily of Pacific oysters and is centered in Willapa Bay and Puget Sound, where approximately 35 percent of the nation's oysters are grown. Manila clams; Kumamoto, Belon, Olympia, and eastern oysters; and blue (or bay) and Mediterranean mussels are also cultured commercially. There is an emerging industry culturing intertidal geoduck clams in Washington, but many questions remain about the potential impacts to wild subtidal populations and the intertidal ecosystems where culturing is taking place. Net pen culture of salmonids is permitted in Puget Sound by the Washington Department of Fish and Wildlife under a National Pollution Discharge Elimination System permit, but there is currently no such activity in California or Oregon. California passed a marine aquaculture bill (SB 201) in 2006 that would regulate such an industry. Protecting the health and genetic integrity of wild stocks from parasites, disease, and accidental introduction of invasive species is a notable challenge of aquaculture development. Feeding practices also cause concern related to nutrient enrichment of waters surrounding aquaculture facilities or feed fisheries that target wild species of forage fish, which play an important role in our ocean ecosystem.

Today nearly 80 percent of seafood consumed in the United States is imported, and even fully rebuilt U.S. commercial fisheries will fall far short of meeting demand. This was recognized in 1999 by the U.S. Department of Commerce (DOC), which developed an aquaculture policy to increase domestic aquaculture production by 2025 and reduce the $8 billion annual trade deficit created by seafood imports. Two of the goals of that DOC policy are to

- increase the value of domestic aquaculture production (freshwater and marine) from the present $1 billion annually to $5 billion, and
- increase the number of jobs in aquaculture from the present estimate of 180,000 to 600,000.

This rate of growth was predicated on annual production increases of 10 percent. Meeting this policy goal presents a significant challenge, given that, in the seven years from 1998 to 2005, aquaculture production and value increased from 2 to 3 percent annually.

Fisheries and Aquaculture

continued

Stakeholder Comments

"Better stock assessments, [we need to] know the difference between species and even genetic stocks to maintain harvest and ecological integrity."
—Depoe Bay, Ore., workshop, May 5, 2007

"What ecosystem factors affect fishing stocks and how can this information guide resource management and economic planning?"
—Olympia, Wash., workshop, Dec. 13, 2007

"We need to understand ways to make production of seafood via aquaculture environmentally sustainable."
—Union, Wash., workshop, Oct. 26, 2007

West Coast economies are tremendously diverse. Many small coastal communities with strong traditional ties to timber and fisheries face an uncertain future as these resources decline or access becomes limited. In contrast, larger metropolitan areas such as Seattle and Los Angeles struggle to keep pace with growth and the demands it places on fisheries and water quality. Nonetheless, regional stakeholders share concerns about improving fisheries and aquaculture management. More than 650 comments were submitted by stakeholders concerning the sustainability, costs, and benefits of fisheries and aquaculture, including several comments about the risks and benefits associated with seafood consumption. Stakeholder concerns are driven by a broad desire to see more predictable, reliable, and sustainable fisheries. Primary wild species of interest are salmon and the assemblage of groundfish that comprise the nearshore fishery. Comments indicated a need to improve stock assessments and management through the adoption of alternative management strategies including more regionally based management. Stakeholders also expressed widespread concern about the effects of commercial fishing on benthic habitats, incidentally caught species, and other marine resources, especially those impacts that have the potential to alter ecosystem dynamics. This likely reflects the growing sense that fisheries management should be approached from an ecosystem-based perspective. Fishing communities from Neah Bay to San Diego are interested in research documenting the economic value of commercial, recreational, and subsistence fishing and how this influences the socioeconomics of coastal communities.

Most stakeholders recognize that increased seafood demand will likely be met by cultured fish and shellfish and are therefore interested in aquaculture development, but many are concerned about potential environmental impacts if it is not done in a manner that provides for long-term sustainability. Research interests pertaining to aquaculture include reproduction, larval rearing, fish health, oyster seed mortality, nutrition, and genetics. Of particular interest are identification of species and conditions best suited to culture, determining and minimizing environmental impacts, and avoiding conflicts with other user groups.

WCGA Action Plan Link:

Action 3.3—Strengthen coordination among the three states and their representatives on the Pacific Fishery Management Council

Action 7.1—Support local planning efforts for sustainable communities

Action 7.3—Assess the health and economic vitality of coastal communities

Research and Information Needs

1. Identify the social and economic impacts and benefits of fishing and aquaculture.

Managers need information and informative tools about the social and economic aspects of fishing, aquaculture, and associated coastal industry, such as seafood processing, gear development, and vessel maintenance, to make informed decisions. Mapping of human uses of marine resources—as mentioned in Topic 2: Ocean and Coastal Governance and Management of Multiple Uses—should include identification of areas used by commercial and recreational fisheries, aquaculture operations, and related industries. There is a need to use common methods and consistent metrics to measure the relative economic impact of commer-

Fisheries and Aquaculture

continued

cial and recreational fisheries. This could be achieved by adding economic data to existing landings and recreational monitoring; results will elucidate the relative contributions of the fisheries and may reduce conflict over allocation and improve distribution of funds for fisheries management and enhancement programs. Given the potential economic benefits and environmental concerns associated with aquaculture development, there is a need for studies that examine the costs and benefits (in dollars and gain/loss of ecosystem services) of existing operations to determine the feasibility of proposed aquaculture development. Finally, all levels of the seafood industry, and thereby coastal communities, could benefit from "harvest to table" seafood tracking (for example, monitoring information on the origin, age, harvest vessel and techniques, processing, packaging, and thermal conditions during transport), which has high potential as a marketing tool that can add value to West Coast seafood products and enhance the economic benefits to coastal communities involved in sustainable fisheries and aquaculture.

Tools that track the path of seafood from the location of catch to the market help address consumer concerns about safety and sustainability.

2. Assess how fishing and aquaculture affect ecosystems, and vice versa.

Research is needed to understand both positive and negative effects of fishing on ecosystems, and to develop mitigation strategies where needed. Ecosystem-based approaches to fisheries management rely, in part, on an understanding of how top-down (such as predation) and bottom-up (such as primary production) trophic interactions impact fisheries and how those impacts change seasonally or interannualy. Expanded evaluation of how variability in oceanic, nearshore, and estuarine conditions—such as temperature, salinity, pH, carbon and nutrient availability, upwelling/downwelling, and large-scale ocean currents—alters the behavior, health, and population of valuable fish and shellfish species will also assist managers in developing ecosystem-based approaches.

Managers and regulators governing aquaculture would benefit from a larger body of knowledge on the impacts of fish and shellfish culture practices on wild populations (changes in genetic integrity and transmission of disease and parasites) and water quality (nutrient loading, etc.). Aquaculture development will benefit from research that demonstrates optimal species, conditions, and locations for seeding, growing, and harvest to enable design of sites to efficiently take advantage of natural conditions and minimize unnecessary environmental impacts. Experimental methods that evaluate pilot projects in comparison with reference sites will be useful to evaluate aquaculture/ecosystem interactions.

Fisheries and Aquaculture

continued

A fisherman and a researcher insert an acoustic device to track the movement of the fish. Understanding migration and movement patterns of commercially valuable species is essential to evaluating management approaches.

3. Evaluate alternative management approaches on fisheries and ecosystems.

Commercial fisheries will benefit from more-accurate stock assessments and from fisheries management that promotes sustainable harvest. A wider array of data from agency and non-agency sources, including use of experiential traditional ecological knowledge, should be incorporated into stock assessments. There is a need for nonlethal, updated stock-assessment techniques that measure stock declines and stock recoveries, include ocean and habitat conditions, and achieve finer-scale understanding of fish stocks by identifying subpopulations and natal rivers of anadromous fish through rapid genetic analysis. Investment in improved remote-sensing tools, which can link abundance and distribution of fish stocks with ocean conditions and three-dimensional habitats, can help close the gap between the need for improved stock assessments and the capacity to perform them. Continued development of selective, low-impact gear and fishing techniques should also be encouraged through experimentation and evaluation of pilot use.

4. Identify and communicate the health risks and benefits associated with seafood.

Seafood contains omega-3 fatty acids, the benefits of which are well documented. At the same time, some species bioaccumulate environmental toxins or are hosts to parasites or disease, which can compromise seafood safety and quality. Research is needed to identify the pathways of toxin uptake into the food web, impacts to human health, and how best to reduce exposure to harmful toxins. There is a need to assess how ocean, nearshore, and estuarine conditions may influence safety risks associated with consumption of wild-harvested and cultured seafood. Predictions of high-risk conditions, such as harmful algal blooms (discussed in detail in Topic 6: Ocean Health and Stressors) and presence of pathogens such as *Vibrio* spp. are needed to enable managers and harvesters to employ adaptive management techniques that reduce risk and increase safety of our West Coast seafood supply. "Harvest to table" seafood tracking (see research need 1, page 27) can also be used to track and minimize the risk of contamination.

Many of the above research and information needs can be addressed through cooperative research programs that include fishermen and take into account experiential knowledge.

Water Quality and Pollution

Poor water quality and increased marine pollution are two critical concerns for the California Current coastal and ocean ecosystem. Poor water quality can be attributed to a variety of point and nonpoint sources. These include, but are not limited to, polluted stormwater runoff from urban sources, land development, agriculture, and forestry practices; industrial effluent; modification of shorelines and streams; atmospheric deposition; inputs from marinas; and sewage and septic discharges from land sources and ocean vessels. These sources often yield high levels of contaminants, including toxins and pathogens (both bacterial and viral) that are harmful to humans and aquatic organisms alike, and excessive nutrients that can disrupt the delicate balance within ecosystems. Poor water quality can also negatively affect the economy by reducing revenue from recreation and tourism and harming fisheries and aquaculture operations. There are also increasing accumulations of marine debris, which includes plastics, polystyrene, cigarette butts, and derelict fishing gear. The Ocean Conservancy reports that more than 6 million pounds of debris were collected during the International Coastal Clean-up event of 2007; that is approximately equal to 187 pounds of trash per collected square mile. This debris poses significant health risks to aquatic organisms and reduces the quality of visitors' experiences along the coast. Harmful algal blooms, aquatic invasive species, and hypoxia, often included in discussions of water quality and pollution, are discussed in the Ocean Health and Stressors topic of this report.

Improving water quality and reducing pollution can minimize safety concerns for beach and ocean users and help to maintain tourism-based economies.

Improving water quality and reducing pollution have long been priorities for local municipalities, states, tribes, and the nation. The Federal Clean Water Act (CWA) of 1972 created the National Pollution Discharge Elimination System (NPDES), which "regulates point sources that discharge pollutants into the waters of the United States." The CWA is administered by the Environmental Protection Agency, but the states have been authorized to administer NPDES permits since 1973. CWA programs have evolved over the past decade away from individual program, source and pollutant approaches to broader watershed-based strategies. On this scale, equal emphasis is placed on protecting healthy waters and restoring impaired ones. California, Oregon, and Washington also have state regulations targeted at maintaining water quality standards and reducing marine pollution, and each state has well-established monitoring programs. Limited monitoring of biological contaminants is conducted by the outer coast Washington tribes as part of a program to protect safe harvest of commercial shellfish. Additionally, many nongovernmental organizations (local Waterkeepers and Surfrider groups, for instance) have well-established water quality monitoring and education programs.

A significant amount of research already focuses on maintaining water quality standards and reducing marine pollution. Most is directed toward measuring bacterial contaminants such as fecal coliforms, quantifying nutrient inputs, identifying sources of contaminants, or tracking the fate of anthropogenic inputs in nearshore coastal environs. Rapid identification of other contaminants, such as viruses that pose threats to human health and aquatic organisms, remains an ongoing challenge.

Water Quality and Pollution

continued

Stakeholder Comments

"More research is needed to better understand the fate and impacts to aquatic life of many household chemicals that exist in wastewater treatment plant effluent (from caffeine to flame retardants)"
—Bellingham, Wash., workshop, Oct. 24, 2007

"Need a better understanding of threats; need to map point source pollution, coordinate water quality monitoring, understand non-point source pollution and toxic algal blooms, seabird die offs, duration of PSP shellfish closures, etc."
—Charleston, Ore., workshop, Oct. 12, 2007

"Support a research priority to identify better water quality indicators for human health."
—Santa Barbara, Calif., workshop, Nov. 14, 2007

Water quality and pollution topics generated more than 430 research and information requests from stakeholders. Predictably, the greatest number came in workshops near the region's largest urban centers. While a majority of comments concerned the source, impact, and fate of contaminants, stakeholders also remarked on the effects of oil spills and marine debris on marine ecosystems and human health. Research needs were expressed primarily under the theme of human health; however, many comments also focused on threats to the marine ecosystem and organisms.

WCGA Action Plan Link:

Action 1.1—Support coastal water quality programs

Action 1.2—Combat nonpoint source pollution

Action 1.4—Reduce marine debris, and prevent occurrence of future marine debris

Action 1.5—Ensure oil spill prevention, preparedness, and response

Research and Information Needs

1. Enhance understanding of the sources, transport, and fate of contaminants (toxins, pathogens, and pollutants) in and between nearshore and offshore waters and identify prevention measures.

A combination of physical and biological oceanographic research is needed to describe and model the movement of toxins from watershed to water, throughout the water column, along currents and eddies, between sediments and the water column, and in environments with limited flushing rates. Research is also needed to determine the capacity for and potential rate of release and resuspension of buried toxins in the sediments, both capped and uncapped. In addition, the sources, transport, and fate of emerging contaminants such as endocrine disputers and pharmaceuticals have yet to be thoroughly studied; however, many fish species have been shown to be highly sensitive to estrogen mimics. Similarly, there is a need to quantify the source, transport, and fate of contaminants from oil spills and the increasing accumulation of marine debris (including litter, plastics, and derelict fishing gear) in the marine ecosystem.

A youth volunteer seals up her water sample, which will be analyzed for contaminants that threaten ecosystems and human health. Citizen-science programs provide much-needed data while teaching volunteers about water quality.

Water Quality and Pollution

continued

2. Assess the health impacts of poor water quality and pollution on humans and aquatic organisms.

The effects of various contaminants on the health of both humans and aquatic organisms remain unclear. Unanswered questions persist about the effect of chronic versus acute exposure to toxic substances. There is also a need to identify sentinel species (ranging from viruses to marine mammals) as effective indicators of poor water quality. If significant movement between sediments and the water column is found, then the effects of these buried materials on primary and secondary production should be evaluated, as should the extent to which these contribute substantially to bioaccumulation in aquatic organisms.

3. Develop appropriate indicators, methods, and tools to effectively monitor water quality.

Most of the identified research needs focus on developing appropriate standards (for example, total maximum daily loads), criteria, and indicators to measure and monitor contaminants and their impacts. Moreover, there is growing interest in assessing the applicability and efficacy of the water-quality measurement tools now in use, and in developing new tools to measure contaminants not previously quantified. Research is also needed to improve technology and capacity to create rapid, on-site water-quality measurements and sanitary surveys during beach closures or spikes in pollution. Microbial source tracking represents an important new approach to identifying and preventing harmful inputs, but existing methods are not scientifically rigorous, because extensive testing is expensive, and therefore adequate sampling plans are rarely adopted.

4. Identify and evaluate preventive measures to stem the introduction of contaminants and debris into the coastal ecosystem.

Since poor water quality originates mainly from land point and nonpoint sources, there are calls to improve maintenance of community infrastructure—for example, septic system retrofits and updated/improved storm drainage systems—to reduce the introduction of contaminants and debris into the water. At the state and local levels, planners and developers need to understand the potential consequences of residential and commercial growth and how they can plan and build to minimize and control runoff and use water efficiently. The concept of low-impact development and the development of new technologies to reduce water pollution have recently emerged as potential tools for better stormwater management in the coastal zone. Research into the effectiveness of these approaches is needed. Public education partnerships involving state, tribal, and local governments; schools; and nongovernmental organizations can help reduce and prevent marine debris, augment cleanup and removal efforts, expand recycling programs, and enforce litter laws.

Beach clean-ups aim to reduce marine debris and foster stewardship.

Improved and increased coordination among human health, water quality, and aquatic organism specialists is required before the impacts on humans and aquatic life can be fully understood, predicted, and managed.

Marine Ecosystem Structure and Function

The ecological structure of the marine environment along the Pacific Coast is defined by strong interactions between the climate and ocean; among different water masses, landforms, and the benthos; and among the myriad plants and animals that inhabit the seas, the seashore, and coastal areas influenced by the seas. These interactions are complex and highly dynamic. The Pacific Coastal bioregion experiences substantial and cyclic changes in ocean conditions on a vast range of timescales from seasons to decades. Fluctuations in ocean productivity, caused by a variety of factors such as changes in wind, storm events, and the El Niño Southern Oscillation (ENSO), are an essential driver of changes in the marine ecosystems encompassed by the California Current. Substantial biogeographic differences occur in the floral and faunal communities along the Pacific Coast (that is, the northern subarctic, central, and southern California/Baja regions), and the transitions between biogeographic subregions are associated with currents and major geomorphic features (that is, Cape Blanco, Cape Mendocino, and Point Conception). Marine food webs can be controlled by top-down processes such as predation or by bottom-up processes such as primary production, or by a combination of these. Fish communities are diverse throughout the Pacific region, and their populations are determined by complex interactions between natural factors and anthropogenic perturbations, the effects of which can persist over many years. Oceanographic conditions have varied markedly over the past decade, and further variation and long-term change is anticipated in response to global climate change.

Our current understanding of the dynamics of the marine ecosystem is drawn from a rich history of federal marine-science investigations, tribal research efforts, state assessment programs, and academic studies. The National Science Foundation and the Sea Grant programs in Washington, Oregon, and California have supported fundamental and applied marine-science investigations for several decades. In addition, NOAA Southwest and Northwest Fisheries Science centers have contributed extensive information about phytoplankton and zooplankton communities, fishery populations, seabirds, and marine mammals. Recent and ongoing tri-state efforts, such as the multidisciplinary Global Ocean Ecosystem Dynamics (known as GLOBEC) California Current study, the Partnership for Interdisciplinary Studies of Coastal Oceans (known as PISCO) investigation of interactions between nearshore areas and the rocky shore, and the Environmental Protection Agency Coastal Environmental Monitoring and Assessment Program characterization of coastal ecological indicators, are examples of attempts to address common issues across Washington, Oregon, and California. Substantial local knowledge and technical information about the marine ecosystems of the Pacific Coast also have been contributed for special-use marine areas such as National Marine Sanctuaries and National Estuarine Research Reserves.

A researcher examines biological properties of seawater with a microscope.

Despite these efforts, we still lack fundamental information about the structure and function of the Pacific regional marine ecosystem that is essential for addressing pressing challenges to ocean and coastal management. For example, there is a compelling need to develop a greater understanding of the location and diversity of different seafloor habitats and their associated communities of fish, benthic invertebrates, and aquatic plants in Washington,

Marine Ecosystem Structure and Function

continued

Oregon, and California. New information about seafloor habitats will provide valuable baseline information about the structure of the coastal ocean; this information can be used as a foundation for studies that focus on key ecological functions and processes that allow for persistence and recovery of healthy and sustainable communities. Seafloor maps will also assist managers in identifying special-use areas such as sanctuaries or reserves that can serve as refugia for populations of marine organisms.

Stakeholder Comments

"What are the connections between terrestrial and coastal systems? What are the unique challenges for managing the interface of two or more ecosystems, such as marine, coastal, and terrestrial systems?"
—Depoe Bay, Ore., workshop, May 5, 2007

"Metrics for ecosystem structure and function are critical to ecosystem-based management. While no single measure will be sufficient, we need to examine existing methods (e.g., isotope analysis of food-web interactions, identification of keystone species) and explore new methods."
—Eureka, Calif., workshop, Oct. 24, 2007

"Research is needed to evaluate the effectiveness of marine protected areas. Furthermore, in the face of climate change, we need replication of MPAs (marine protected areas) for each habitat type (or bioregion) to enhance the chance for survival of marine life."
—Bellingham, Wash., workshop, Oct. 24, 2007

The Pacific coast stakeholders submitted nearly 800 comments suggesting research and information needs related to ecosystem structure and function. They approached this topic from several different perspectives, which coalesced around a central question: What are the essential components of the California Current Large Marine Ecosystem, how are they structured in time and space, and how do they interact with the physical and biotic environment?

WCGA Action Plan Link:

Action 2.1—Document, describe, and map ecological communities and characterize human uses

Action 2.2—Restore estuarine habitats including wetlands

Action 3.2—Support integrated ecosystem assessments, including biological, physical, social, and economic factors

Action 6.3—Complete a seafloor map for the entire West Coast

Research and Information Needs

1. Describe how nearshore and offshore ocean conditions vary across space and time, and the extent to which variability in the ocean affects connectivity among ecosystem components.

The physical and biological linkages between nearshore and offshore environments are not clearly understood. New research is needed to gain a better understanding of local and latitudinal variation in the dynamics of nearshore and offshore systems, and to better understand and address the effects of large-scale circulation patterns, upwelling/downwelling centers, submarine canyons, capes, headlands, offshore islands, seamounts, and rocky reefs on local and regional systems. Additional research also is required to describe the circulation and exchange of waters and nutrients between nearshore and offshore water masses, between the semi-enclosed waters of Puget Sound and the outer coast, and the Davidson Current's seasonal steering of the Columbia Plume. Use of ocean observing technologies and methods can help establish oceanic connectivity among disparate locations and populations, document the magnitude and ecological impacts of recurrent ENSO events and the longer cycle of the Pacific Decadal Oscillation, and anticipate the regional manifestations of climate change.

2. Characterize the connections between land and sea, and identify how the ecological structure and function of the nearshore marine ecosystem influence habitats and communities in bays, river mouths, and estuaries.

Marine Ecosystem Structure and Function

continued

The coastline of Washington, Oregon, and California is broken by large water bodies such as Puget Sound, the Columbia River estuary, and San Francisco Bay, as well as numerous smaller river mouths, estuaries, bays, and lagoons. Ecological conditions in parts of Puget Sound and some estuaries are tightly linked with the dynamics of the nearshore ocean, while other estuaries are influenced more directly by inputs and runoff discharged through the watershed. New scientific studies are needed to determine how the ecological links between the ocean and watershed change over time, and how the characteristics of habitats and communities change at different locations along the ecological gradient from freshwater to saltwater. Applied science investigations and demonstration projects are also needed to document how land-use patterns in urban and rural settings influence the ecological structure and integrity of salt marshes, tideflats, seagrass beds, and subtidal habitats and their communities. Throughout the Pacific Coastal bioregion, historic and contemporary dredging, diking, armoring of the shoreline, and construction of jetties and causeways have amounted to a legacy of alterations that affect tidal circulation, hydrodynamic flushing, and the buildup of sediments. Renewed emphasis is needed to evaluate the cumulative ecological impacts of habitat losses and alterations in estuaries and bays. In addition, new research is needed to address the processes that contribute to depleted oxygen and hypoxia in the nearshore area, in Puget Sound, and in deep ocean waters, and to gain a better understanding of the oceanographic processes that contribute to recent observations of hypoxic nearshore waters and estuaries.

3. Discover how the different types of benthic substrata and geomorphic features of the seafloor are distributed, and analyze the relationships among bottom types, benthic habitats, and their associated communities of marine plants, invertebrates, and fish.

Coordinated interstate assessments and seafloor mapping are needed throughout the Pacific Coastal region to describe the bathymetry, geomorphology, and composition of the ocean floor and benthic habitats. It is essential that we gain a better understanding of the spatial and temporal relationships among bottom types, benthic habitats, and their associated communities of marine plants, invertebrates, and fish. Increased knowledge about the composition and diversity of bottom conditions throughout the Territorial Sea and continental shelf is critical to identification and conservation of special habitats and communities; management of sustainable recreational and commercial fisheries; tsunami planning; designing and siting of other types of marine applications such as telecommunications cables and wave-energy facilities; and marine protected areas.

Researchers collect small sharks to study anatomy, physiology, and behavior. Such information can help elucidate the role a species plays in the marine food web.

4. Examine the operation of marine food webs in nearshore and offshore waters, and how trophic dynamics and competitive interactions among marine organisms differ between years and over longer timescales.

Regional oceanographic conditions, ocean productivity, and predator-prey relationships are all interrelated components of the complex trophic dynamics that occur within the California Current Large Marine Ecosystem. Continued and coordinated coastal surveys are needed to determine the ENSO signatures of ocean waters and their communities of phytoplankton, zooplankton, fish, seabirds, and marine mammals. Synoptic,

Marine Ecosystem Structure and Function

continued

multi-state surveys should be conducted to identify and assess interannual and latitudinal differences in ocean productivity and their relationships to fisheries resources. In addition, detailed, case-history investigations should be developed to document the trophic dynamics of marine communities in regions that are characterized by persistent upwelling, in areas where nearshore waters are retained, and within the ecologically important transition zones between adjacent water masses. Finally, multi-institutional studies should be carried out to more fully investigate fundamental similarities, differences, and linkages among intertidal, nearshore, and offshore food webs along the coastlines of Washington, Oregon, and California.

5. Determine which ecological indicators can best be used to understand and predict changes in the status and conditions of marine habitats and living marine resources.

Collaborations among federal, tribal, and state agencies; academia; and nongovernmental organizations are needed to conduct periodic coastal assessments and long-term monitoring designed to evaluate status of and trends in the ecological condition of the marine and estuarine habitats and their living resources. New research is also needed to identify, refine, and validate a common suite of sensitive ecological indicators that can be used to compare and contrast conditions in the marine environment of Washington, Oregon, and California. State, tribal, and federal programs should continue to explore the application of ecological scorecards as a potential common currency to evaluate habitat conditions, and to establish and designate a system of regional benchmarks, site-specific targets, and performance measures that can be used to evaluate changes in habitat conditions. New rapid-response bioassay tools should be developed to provide early warnings of contaminants and pathogens in the marine environment, and models should be refined to evaluate anthropogenic disturbances as well as the cumulative impacts of multiple stressors. The regional coastal ocean observing systems should be encouraged to share their infrastructural and technical advancements, and to adopt a question-based approach to the acquisition and interpretation of monitoring data, particularly for strategies to address the measurement and vulnerabilities of marine habitats and communities to regional climate change.

Predator-prey relationships are important aspects of an ecosystem. Study of seabirds, like this Common Murre, is a key to understanding ecosystem dynamics.

6. Observe the relationships among top predators, seabirds, fishery resources, and the physio-chemical conditions in West Coast waters, and determine how periodic removal of top predators influences the size and age structure of populations throughout the food web.

Vessel-based investigations and tagging studies are required throughout the nearshore and offshore waters of Washington, Oregon, and California to document the abundance, distribution, behavior, and age structure of migratory and resident populations of pelagic fish, seabirds, pinnipeds, sea turtles, and cetaceans. These surveys should be coupled with enhanced and adaptive fishery observer programs to obtain better estimates of incidental mortality and by-catch for fish, marine mammals, and seabirds. Multi-year investigations of pelagic fish populations are needed to evaluate interannual differences in the diets and trophic dynamics of top predators during periods of elevated and depressed ocean productivity. The abundance, behavior, and physiological condition of predators should be further explored as potential indicators of nearshore and offshore ocean productivity, including upwelling intensity, the location and composition of zooplankton populations, and the co-occurrence of competitors. For example,

Marine Ecosystem Structure and Function

continued

Management decisions throughout the region can have profound effects (positive and negative) on migratory species such as the gray whale.

marked changes in the diet and reproductive output of 11 species of seabirds in the California Current have been shown to reflect low-frequency climate changes, with responses of each species dependent on factors such as population histories, trophic levels of prey, habitat use, life histories, and reproductive strategies.

7. Improve the coordination and sharing of information generated by taxonomic inventories and habitat surveys to establish regional baselines in marine biodiversity, and identify the shifts in marine biodiversity that can be anticipated in response to climate change.

Coordinated baseline surveys should be conducted in Washington, Oregon, and California to document the taxonomic diversity and species richness of marine organisms in habitats that range from the intertidal zone to the deep sea. Additional post-graduate and technical training programs are urgently needed to develop and maintain the level of taxonomic expertise required to identify difficult and problematic species. In addition, new molecular tools and genetic markers should be explored to evaluate diversity, latitudinal changes, and other differences among populations of native and nonnative species. The states should collaborate to develop a common marine biodiversity assessment and monitoring program that will describe and document the richness of marine flora and fauna at a series of strategic reference sites, and explore the establishment of academic centers for marine biodiversity and taxonomic assessment.

8. Evaluate the potential of a West Coast system of marine protected areas to serve as special-use sites for habitat conservation, scientific research, recovery of target species, and public education.

It is widely recognized that some type of regionally coordinated shore-zone strategy may foster an ecosystem-based approach to management of marine and coastal resources in Washington, Oregon, and California. However, the complexity of integrating objective planning criteria with fundamental ecological data and relevant socioeconomic information is overwhelming, and new streamlined approaches are needed to continue the progress that has been made along the Pacific Coast with the establishment of a system of marine protected areas (MPAs).

Marine Ecosystem Structure and Function

continued

Groundfish, like this yellow and black rockfish, are economically valuable to the region. Management strategies would benefit from a stronger understanding of the conditions required to sustain groundfish populations.

In particular, site-based studies are needed to document the extent to which designation as multi-use or limited-use MPAs or no-take marine reserves afford substantial ecological benefits, including habitat improvements and changes in the size, age structure, and abundance of targeted species of fish and invertebrates. Coordinated efforts should be made to document larval dispersal and recruitment among the network of protected areas, to quantify the levels of biotic spillover into areas adjacent to protected sites, and to monitor the changes in species abundance and richness as well as fishing effort within and adjacent to protected sites. Similarly, new quantitative techniques are needed to provide realistic measures of the economic impacts of MPA designation on ports, marinas, and coastal communities, and to improve the capacity of MPAs to provide ecological and economic resilience in response to coastal climate change. Research is also needed to evaluate the efficacy of MPAs, marine reserves, and other marine managed areas along the Pacific Coast to reach established conservation, research, or fisheries enhancement goals.

9. Explore and implement innovative and cost-effective solutions designed to restore lost ecological functions to damaged and degraded coastal, estuarine, and marine habitats.

The Pacific Coast bioregion has experienced substantial habitat losses and alterations that degrade the ecological structure of the marine environment and diminish essential functions and services. For example, widespread loss and alteration of shoreline habitats over the past century have contributed to precipitous declines in the spatial extent of freshwater marshes, tidal wetlands, eelgrass beds, kelp beds, and populations of native oysters and other shellfish. In some cases, alteration of the shoreline has resulted in modification of the hydrodynamic environment, resulting in nutrient loading and eutrophication. In other cases, shoreline stabilization has contributed to changes in the supplies and transport of sediments and to the loss of sandy beaches. Coordinated survey and assessment efforts are needed to accurately evaluate the extent of habitat alteration and loss along the Pacific Coast and to identify appropriate sites that can serve as baseline reference areas. Coordinated actions are also needed to identify and enforce the mitigation measures required to offset continued habitat destruction and evaluate the extent to which restoration efforts regain ecological functionality. Innovative research is needed to develop techniques to rapidly assess the extent of habitat alteration and to evaluate progress toward ecological improvement. Finally, empirical studies and long-term monitoring are required to develop and evaluate the best-management practices that can place habitats on acceptable trajectories for ecological recovery.

Ocean Health and Stressors

The oceans are subject to a multitude of natural and anthropogenic stresses, including water and airborne contaminants, runoff, and habitat modification. In addition to direct impacts on marine and coastal resources, such stressors may have broader effects on ocean and coastal ecosystem health, affecting biodiversity and trophic dynamics in ways that can threaten not only the environment but also human health, safety, and economies. While ocean health is a broad and complex topic, and the identified research needs apply broadly to ocean stressors in general, here we focus on three significant stressors to ocean health: aquatic invasive species (AIS), harmful algal blooms (HABs), and hypoxia (low oxygen conditions). Pollution and other water contamination issues are covered under Topic 4: Water Quality and Pollution.

Invasive species on the West Coast are a major environmental, economic, and public health consequence of expanded international trade and transportation, domestic travel, and habitat loss. Recent studies suggest that AIS are second only to habitat reduction (loss and degradation) as a threat to biodiversity, and are more serious than pollution and over-harvesting. In San Francisco Bay, for example, AIS dominate many important habitats in terms of species, population size, and biomass. Researchers concluded that the Bay is one of the most invaded estuaries in the world, with a new species arriving and becoming established every 14 weeks. National efforts to combat AIS include the Aquatic Nuisance Task Force and the National Invasive Species Council. The latter oversees a Western regional panel covering 19 states, including Washington, Oregon, and California. Other coordinated regional efforts have commonly focused on particular species (for example, the 100th Meridian Initiative targeting zebra mussels) or vectors (for example, the Pacific Ballast Water Group). Washington and Oregon both have interagency invasive species councils responsible for strategic efforts to prevent or eliminate invasive species, while California's Department of Fish and Game produced the state's most recent invasive management plan.

Through public education, boaters can learn how to help stop the spread of invasive species.

HABs, meanwhile, have caused human illness and death as well as fish, bird, and mammal mortality and substantial economic loss to coastal communities and commercial fisheries. The economic impact of just the most recent year-long closure of the Northwest razor clam fishery, due to high domoic acid levels, has been estimated at $13.5 million. Coastal tribes with fishing rights for razor clams have also suffered heavy losses from the closure of their commercial and subsistence fisheries. Federal funding for HABs research and monitoring is available through the Ecology and Oceanography of Harmful Algal Blooms (ECOHAB) and Monitoring and Event Response for Harmful Algal Blooms (MERHAB) programs. A Pacific Northwest

Ocean Health and Stressors

continued

Quinault Indian Nation tribal members dig for razor clams on the Washington coast. Razor clams are one of many species that can become toxic as a result of harmful algal blooms.

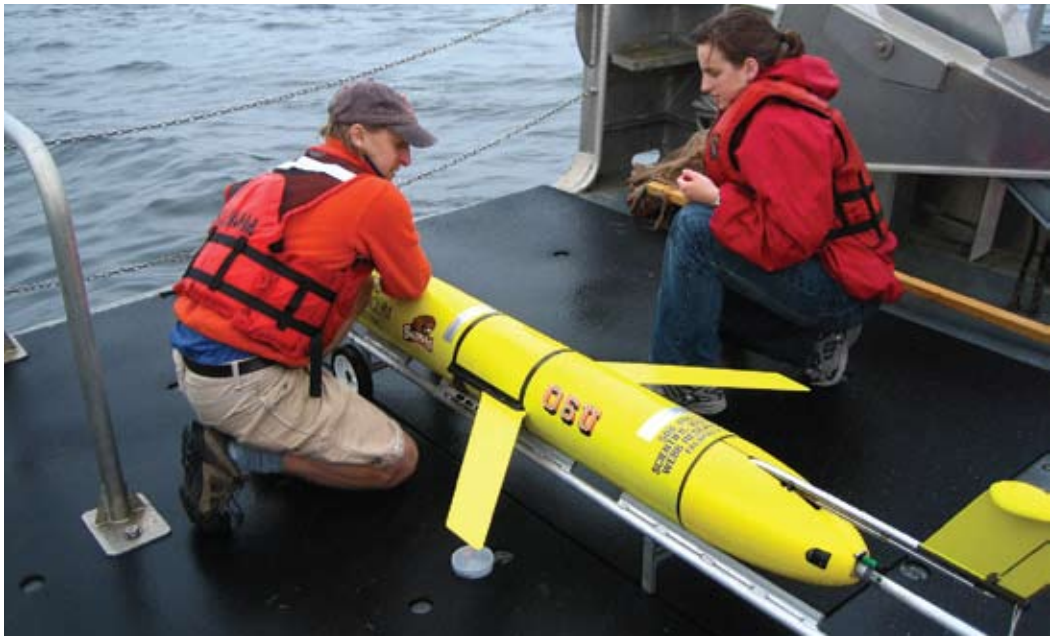
ECOHAB project focuses on *Pseudo-nitzschia* and domoic acid poisoning, while MERHAB-supported projects exist in all three West Coast states and include efforts to develop monitoring capacity and rapid detection and response methods. The West Coast also houses two national centers for research on oceans and human health: the Pacific Northwest Center for Human Health and Ocean Studies (National Institute of Environmental Health Sciences-National Science Foundation Oceans and Human Health Initiative) and the West Coast Center for Oceans and Human Health (NOAA's Oceans and Human Health Initiative). The National Sea Grant College Program sponsors a variety of HAB research and outreach projects, both through individual state Sea Grant programs and national-level initiatives.

Hypoxia has emerged in recent years as a growing concern on the West Coast. Hypoxic events in certain West Coast urban estuaries, such as Hood Canal, Washington; and San Diego, Newport, and Alamitos Bays, California, have been attributed at least in part to excess anthropogenic nutrient input from urban areas, though the duration and severity of hypoxia in such locations may be determined by additional factors such as water depth, wind, and river flow, which determine the flushing rates of deeper water. Different processes, meanwhile, are believed to be responsible for hypoxic and anoxic (no-oxygen) events off the West Coast that have reduced or eliminated populations of fish and benthic invertebrates in historically productive habitats. Though seasonal, wind-driven upwelling is known to transport nutrients and low-oxygen water to the coast, it is not yet fully understood why hypoxic events occur in some years and not others.

Reports of long-term decreases in oxygen concentrations at open-ocean and coastal locations have prompted concern that such events may become more frequent in the future. In July 2006, thousands of dead fish were found on the beaches of the Quinault Indian reservation, and several Washington crabbers reported pots full of dead crabs as a result of a hypoxic event. In August 2006, an event with severe hypoxic and anoxic conditions on the central Oregon coast led to the complete absence of all fish from normally populated rocky reefs, and high mortality of large benthic invertebrates. Federal research funds are offered through NOAA's National Centers for Coastal Ocean Sciences/Center for Sponsored Coastal Ocean Research Hypoxia and Nutrient Pollution program, which supports the Coastal Hypoxia Research Program to determine the causes of, and to develop predictive capability for, hypoxia in Puget Sound, Washington. Regional collaborations to monitor hypoxic conditions in coastal waters are currently taking shape in coastal Oregon (PISCO) and Washington (Olympic Coast National Marine Sanctuary); the only formal program at the state level dedicated to hypoxia research is the Hood Canal Dissolved Oxygen Program.

Ocean Health and Stressors

continued



Researchers deploy an autonomous underwater glider that takes continuous measurements of oxygen conditions in nearshore waters. Such instruments generate data that can help scientists develop methods to predict the onset of hypoxia, which can threaten coastal ecosystems.

Stakeholder Comments

"In an ideal West Coast world, we would have a coordinated approach to coastwide Spartina control, so that we don't end up spending lots of money to reduce and eliminate Spartina in Willapa Bay, only for the bay to get reinvaded from seed sources to the south in Oregon and California. This issue also applies to other introduced nonnative species."
—Olympia, Wash., Web survey response

"Toxic algal blooms are linked to paralytic shellfish poisoning (PSP)…and amnesiac shellfish poisoning (ASP), which are serious health risks. Preliminary research has indicated that agricultural runoff from watersheds into the ocean may enhance algal growth, and restoration of riparian habitat may filter such non-point-source pollution before it reaches the ocean, thus reducing the prevalence of algal growth in the nearshore marine ecosystem. Expansion of this research is a high priority to improve the quality of our coastal ocean."
—Santa Barbara, Calif., workshop, Nov. 13, 2007

"What is the extent and severity of hypoxia in the coastal ocean and how does it impact marine ecosystems and various fisheries? ….What are the physical, biological and chemical processes that contribute?"
—Depoe Bay, Ore., workshop, May 5, 2007

More than 140 comments identified AIS as a concern, with the highest interest in Washington and California, and more interest in urban than in rural areas. The regional stakeholder meetings, however, predated a major 2008 AIS public information campaign in Oregon, and subsequent Sea Grant surveys indicate that awareness of the topic is on the rise in this state. HABs were identified as a concern in about 100 stakeholder comments, mainly in California and Washington. Research on hypoxia, meanwhile, was identified as a need in about 30 stakeholder comments, mostly in Oregon and Washington.

WCGA Action Plan Link:

Action 1.3—Promote monitoring and predictive capabilities of HABs and hypoxia

Action 2.3—Prevent introduction of marine invasive species

Action 2.4—Eradicate nonnative cordgrasses

Action 3.2—Support integrated ecosystem assessments, including biological, physical, social, and economic factors

Ocean Health and Stressors

continued

A researcher returns to a location where invasive spartina (cordgrass) was removed to assess the effectiveness of her efforts. Spartina, a particularly aggressive invader, threatens productive estuaries throughout the region.

Research and Information Needs

1. Understand the causes and dynamics of ocean stressors.

The causes and dynamics of ocean stressors must be better understood to predict, prevent, quickly respond to, and reduce or eliminate impacts to ecosystems, human health, and coastal community vitality. Research on ocean stressors must be conducted in the context of current and predicted changing ocean and atmospheric processes, including climate change. Specific research needs include development and evaluation of AIS prevention mechanisms such as ballast water and vessel hull treatment methods; identification of additional pathways by which AIS are transported; and understanding of AIS life histories, community ecology, and factors that enhance or restrict spread. Understanding the fundamental biological, chemical, and physical processes underlying HABs will require research on HAB genetics, physiology, ecology, and community and ecosystem dynamics, including the influence of oceanography, environmental genomics, and human activities on the formation, frequency, and severity of HABs. Understanding the occurrence of hypoxic events will require coordinated investigation of physical processes such as stratification and upwelling, biological processes such as primary productivity and benthic respiration, and linkages between different locations (for example, between Hood Canal and the Washington coast and between the Washington, Oregon, and California coasts). Critical to all of these research needs are regionally coordinated, well-supported, high-frequency, site-specific networks of monitoring platforms, remote or in situ, with relevant technologies to measure complementary variables, including currently less well-developed biological indicators such as cells and toxins.

2. Assess risks and the ecological, social, and economic effects of ocean stressors.

Risk assessments are required to identify the vulnerability in time and space of ecosystems, including natural and human components, to ocean stressors such as AIS invasions, HABs and toxin loads, and hypoxic conditions. Research is also needed to accurately quantify and model the local and regional ecological, economic, and social consequences of AIS, HABs, hypoxia, and other ocean stressors on coastal communities. Specific research areas include understanding the functional role of AIS and resulting changes in native invaded communities; the uptake, metabolism, and acute and chronic effects of biotoxin exposure on different organisms in the marine food web, including humans; and the acute and chronic effects of hypoxia on marine organisms and coastal ecosystems. For all three stressors, economic, public health, and social effects are poorly understood. There is often a lack of local information available during invasion, bloom, or hypoxic events; the economic effects of ecological damage are difficult to document; and hidden costs or benefits related to secondary industries such as tourism and human health remain unknown.

3. Improve predictive, early detection, and rapid response capabilities.

Building on advances in understanding the causes and dynamics of ocean stressors, the development of predictive capabilities is critical to preparing for adverse events and taking proactive management action, such as selective closures of fisheries or beaches or early harvest prior to harmful events. Development of tools and technologies for early detection of and rapid response to aquatic invaders, HABs, hypoxic events, and other ocean stressors is needed for understanding and managing their ecological and

Ocean Health and Stressors

continued

economic impacts and reducing risk associated with the effects of ocean stressors. Early detection and rapid response increase the likelihood of addressing aquatic species invasions while populations are localized and can be contained and eradicated. Development of early-warning and -response systems for HABs and biotoxins in coastal waters and seafood, including rapid field tests for water, animal tissues, and human illnesses, is crucial for protecting human health. In addition, there is a significant need for the continued and accelerated transfer of technology from the HAB research community to those responsible for safeguarding coastal resources, public health, and local economies. For both AIS and HABs, there is an unmet demand for taxonomists to identify invasive and algal species using classical, more recent, and emerging techniques, as well as reference databases for identification of invasive species, algae, and toxins. Early detection of the spatial and temporal extent of hypoxic events will facilitate response and mitigation efforts. The same coordinated monitoring network needed to understand stressor dynamics is critical for predictive and early warning capabilities.

4. Develop and evaluate approaches to control and manage ocean stressors.

Research and development of control and management approaches are much more advanced for AIS; however, continued research is necessary to develop and evaluate control and eradication methods in light of climate change and variability and the ever-changing suite of invading species. For HABs and hypoxia, there has been limited or no investment on the West Coast to develop physical, chemical, or biological intervention strategies to eliminate or reduce effects, and it is uncertain whether these approaches are viable for these stressors in particular. Ideally, investments in advancing preventive approaches would minimize the need for control and management strategies.

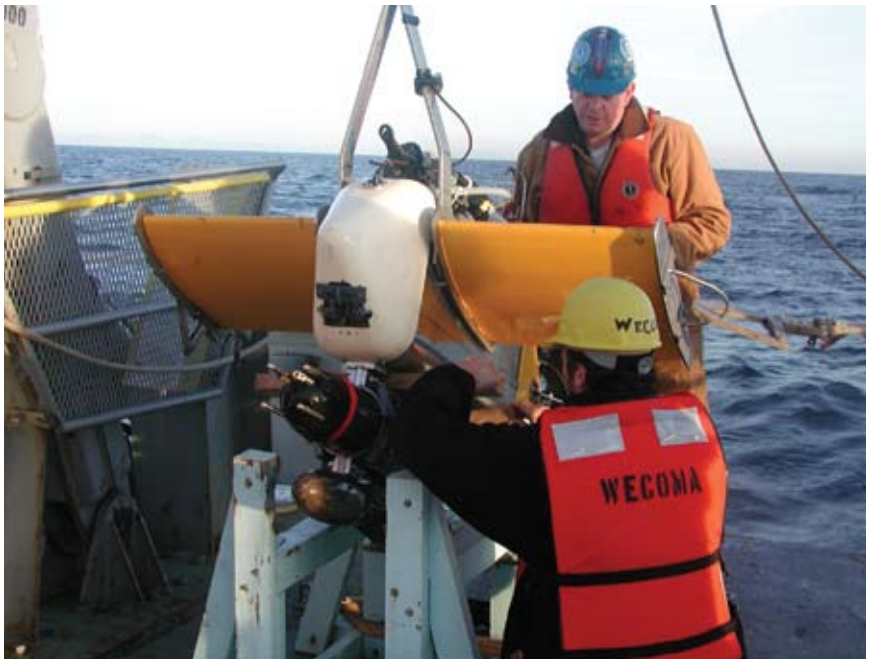
Because of the critical need for widespread monitoring, some ocean stressor issues lend themselves to the use of citizen-science and volunteer programs. For example, a coordinated, coastwide citizen-science network with specialized training to detect high-risk invasive species or HAB biotoxins could contribute substantially to early detection and rapid response to AIS and HABs. Models for this exist on local scales, with the Olympic Region Harmful Algal Bloom Partnership (known as ORHAB) and SoundToxins; diverse partnerships of industry, state, federal, and tribal agencies; and coastal communities that monitor HAB events to minimize human health risks and economic losses on the Washington outer coast and in Puget Sound, respectively. Where humans may directly stress the ocean environment (for example, acting as vectors of AIS and increasing nutrient input to the marine environment), linking research results to policy, sociology, and outreach is important for effective prevention and mitigation.

There is also a significant demand for coordination, collaboration, and partnerships in research, monitoring, response, outreach, and education among the complicated array of scientists, managers, agencies, and legislatures operating at national, tribal, regional, state, and local levels.

A NOAA scientist pulls up a net towed to collect phytoplankton, as part of the Marine Biotoxins Program to detect toxic algae.

Physical Ocean Processes, Related Climate Change, and Physical Coastal Hazards

A dynamic coastal ocean environment characterizes the West Coast of the continental United States. Conditions range from high-energy beaches swept by cold water in the north, to calm seas, many nearshore islands, and warmer waters in the south. A distinct seasonal component is prevalent in the nearshore ocean, with coastal upwelling in the late winter and spring followed by periods of relaxation and less intense upwelling in the summer and fall. Although in general the region is characterized by the equatorward-flowing California Current, there are several variations on this physical theme that create a rich diversity of marine environments and biological communities. The result is a wide range of ocean conditions in the nearshore zones of the U.S. between the borders of Canada and Mexico.

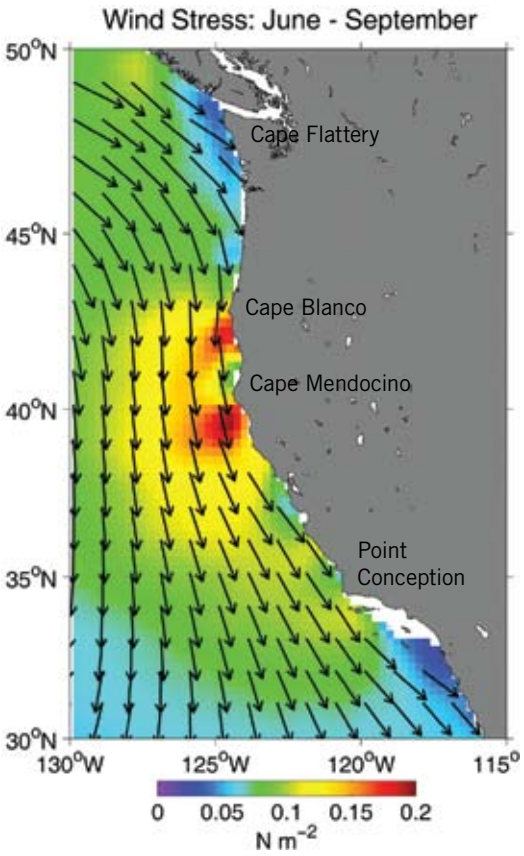


Researchers prepare to tow an instrument that will measure temperature, salinity and fluorescence in the water column. Such physical properties are key to understanding the ocean.

Observations of the coastal ocean along the West Coast of the U.S. have been conducted for more than 100 years. Originally little more than occasional forays into the coastal waters, ocean observing underwent dramatic transformation in the 20th century with the development of larger research vessels and increasingly frequent surveys. The California Cooperative Oceanic Fisheries Investigation (CalCOFI) program, for instance, commenced more than 50 years ago and is now conducted four times each year in the waters off Southern and Central California. It has been followed by other programs, including the regional associations of the Integrated Ocean Observing Systems, the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO), and the Cooperative Research and Assessment of Nearshore Ecosystems (CRANE) program. More recently, the deployment of in situ sensors has ushered in a new era of coastal ocean observations. Buoys, satellite observations, and shore-based remote-sensing permit scientists to gather information on a much finer timescale than they can from ships. Over the past decade, the ocean observing network has grown from a paper concept to early development. The net result is a rapidly increasing body of knowledge regarding the coastal ocean and its physical, chemical, and biological properties. All indications are that the pace of discovery is bound to increase as ever-more-sophisticated devices are deployed at decreasing costs.

Despite recent gains in knowledge from new observation tools and methods, many questions remain about the ocean and its physical processes. Among the most rapidly emerging issues related to physical ocean processes are those pertaining to climate change. Only a few years ago, impacts of climate change on the oceans seemed slated for the long term, whereas today we realize these changes are arriving much more rapidly than expected. Changes to the earth's climate will generate a suite of impacts including sea-level rise, changing current patterns, shifts in time and space of water temperatures and other offshore water properties, shifts in upwelling/downwelling patterns, and increases in storminess and ocean acidification.

Ocean acidification, perhaps the least-understood impact of climate change, was coined as a term in 2003 to refer to the ongoing decrease in pH (or increase in acidity) of the oceans caused by the uptake of atmospheric carbon dioxide. Recent findings show that water brought to the surface by upwelling in Northern California is relatively acidic, demonstrating that this impact of climate change has also now arrived in the



Physical Ocean Processes, Related Climate Change, and Physical Coastal Hazards continued

Left: This plot shows direction and intensity of ocean wind. Wind is one of many physical properties studied to better understand climate change and coastal hazards.

coastal ocean, and there is increasing concern this may be occurring in oceanic deepwater as well. Evidence of significant changes in the marine environment related to ocean acidification is mounting. Most alarmingly, organisms such as corals, marine plankton, shellfish, and sea urchins that rely on available calcium carbonate ($CaCO_3$) or aragonite (a chemical relative of $CaCO_3$) to construct their shells or skeletal materials in sea water may be unable to create or maintain their skeletal structures. On the West Coast, this represents a significant potential threat to a shellfish industry worth over $110 million. The commercially important salmon, herring, cod, and pollock fisheries could also be at risk, given that their major food sources are shell- and skeleton-building organisms.

Tightly interwoven with physical ocean processes in the coastal ocean and climate change impacts are coastal ocean hazards. Coastal tribes intentionally situated themselves at the mouths of salmon-rich rivers, and communities of settlers established at the interface between land and sea to take advantage of rich resources and seagoing transportation. Today, the appeal of living at the ocean's edge continues to draw people to the coasts, yet the lifestyle comes with risks. The Pacific Coast of the U.S. contains its fair share of coastal hazards that remain only modestly understood at best. Among these are hazards due to tectonic activity such as tsunamis, landslides, mudslides, and volcanic activity. Coastal inundation caused by tsunamis is a risk to coastal residents living in low-lying areas, and as such is a topic of active research. Other coastal hazards include storminess and extreme weather events, large waves, storm surges, coastal flooding, rip currents, sediment movement and erosion, bluff slumping and failure, and ocean structure failures. While some hazards such as structure failures are rapid and catastrophic, other hazards such as sediment erosion are slower moving yet equally dangerous. Finally, in Southern California and other dry regions adjacent to the coast, there is the hazard of wildfires trapping coastal residents between fire and the sea.

Stakeholder Comments

"We need information and research on how oceans will change as a result of climate change. This includes circulation patterns, acidification, and ocean physical environment (waves, storms, etc.). We also need research that links these changes to potential impacts to resources such as fish and shellfish communities."
—Ocean Shores, Wash., workshop, Oct. 12, 2007

"A wide variety of coastal research problems need quality information concerning wave statistics. Since the network of buoy measurements is relatively sparse a regional wave modeling program could be hugely beneficial. Quality models exist, but are…applied on a project-to-project basis. Research on this theme would entail the development of a nested suite of wave models that could be applied and tailored for many issues."
—Depoe Bay, Ore., workshop, May 5, 2007

"What is the ocean's response to global warming and regime shifts?"
—Santa Barbara, Calif., workshop, Nov. 14, 2007

Physical Ocean Processes, Related Climate Change, and Physical Coastal Hazards continued

Coastal stakeholders understand their dependence on a healthy coastal environment, and many are keenly aware that even small changes in ocean conditions can have a profound impact on their lives. As such, stakeholders viewed a better understanding of physical ocean conditions and coastal physical ocean processes as a key component of West Coast research and information needs.

Many stakeholders also viewed the issue of climate change as fitting closely with physical ocean processes, and saw climate change as having large-scale and substantial impact on oceanographic processes off their shorelines. Comments reflected a high level of interest in these topics. As climate changes impact the ocean, especially in the coastal environment, respondents viewed the impacts to the physical and biological processes in the ocean with concern. Likewise, concerns were raised about how the changes in the ocean from warmer conditions, changing wind patterns, or shifting rainfall regimes might affect the ocean and marine organisms.

Severe erosion threatens the safety of coastal residents. A better understanding of wave action and storm events can reduce risks and improve coastal development planning.

More than 300 comments spoke to issues related to physical ocean processes: nearshore water circulation, shoreline stability and erosion, coastal hazards, ocean acidification, and human impacts on those processes. These interests and concerns were consistent throughout the region. Meanwhile, comments from the north coast demonstrated interest in storms and other coastal hazards; in the south, there were more comments about beach and bluff stabilization, coastal development, and physical-biological coupling.

WCGA Action Plan Link:

Action 3.2—Support integrated ecosystem assessments, including biological, physical, social, and economic factors

Action 6.2—Support long-term maintenance of ocean observing systems and monitoring assets

Action 7.4—Develop regional sediment management plans

Research and Information Needs

1. Estimate how ocean circulation is changing now and how it will change in the future.

Regional-scale ocean circulation such as the California Current system, as well as smaller-scale coastal circulation such as alongshore transport and coastal upwelling, are inextricably linked to the health of ecosystems and the natural resources in West Coast waters. These circulation patterns will be altered by climate change and climate cycles such as the ENSO and the PDO. Existing long-term data sets and improved models must be used to determine changes over time, place future observation values in historical context, and predict future alteration of ocean and coastal circulation.

2. Develop a deeper understanding of how physical ocean conditions relate to ecological conditions now and how they will interact in the future.

Expanded monitoring, improved models, and a better understanding of changes in ocean circulation and climate phenomena must be coupled with ecological information to predict ecosystem conditions based in part on physical and chemical changes in the ocean environment. Forecasting can improve the ability of resource managers to identify emerging threats and respond proactively.

Physical Ocean Processes, Related Climate Change, and Physical Coastal Hazards continued

Scientists use dye to observe how ocean water moves, to better understand ocean currents.

3. Establish a better understanding of the movement of sediment along the coast and the relationship to bluff stability, slumping, and collapse.

Movement of sediment and sand along the coast has been a topic of substantial interest to many communities along the West Coast. Despite this level of interest, knowledge about sources and sinks of sediments and sand does not provide sufficient information about how to manage these vital resources. There is a need to understand the sources and movement of sand and sediment along the coast and in adjacent watersheds. Likewise, the stability of bluffs and their potential for slumping and collapse are not fully understood. There is a corresponding need to understand the contribution of bluff slumping to sand on beaches and the factors that cause bluffs to catastrophically collapse.

4. Decipher the drivers of ocean acidification and estimate how acidification impacts marine organisms and ecosystems.

Monitoring, modeling, and experimentation are needed to understand the mechanisms that create ocean acidification as well as the impacts on marine organisms. Ocean acidification monitoring needs to be included in the existing observing network, and expanded observing operations are needed to provide a baseline dataset for ocean acidification and to enhance the detection of shifts. Data from new and existing autonomous buoys and research cruises, along with coincident sampling of acidification parameters and dissolved oxygen, are needed to improve understanding of the relationship between acidification and hypoxia. Models must be used to understand future pH and carbonate availability as a function of changes in factors such as atmospheric carbon dioxide concentrations, temperature and its effects on ocean circulation and mixing, and chemical interactions with sediments.

5. Determine the primary drivers of environmental changes and hazards and how to better predict coastal hazards in relation to environmental changes.

Long-term ocean and atmosphere monitoring and modeling efforts should be expanded to provide the information needed to better understand natural and anthropogenic changes in the coastal ocean environment. This information will help determine the shifts in risk from coastal hazards such as storm surge, sea-level rise, coastal erosion, and tsunamis. In addition, these observations can be used to improve natural-hazard and environmental-change forecasting using models. The necessary level of monitoring will require expanded and improved instrumentation for ocean observing and expanded modeling capacity to put these observations to use.

Resilience and Adaptability to Hazards and Climate Change

The West Coast states are exposed and vulnerable to coastal natural hazards related to both episodic catastrophes—earthquakes, tsunamis, storms, and sudden landslides—and chronic effects wrought by climate change. In December 2007, a Pacific storm hit Oregon and Washington, causing catastrophic damage including the destruction of 200 homes, sustained power outages for 138,500 homes, and the loss of 13 lives.[4] A recent study from UC Berkeley estimates that, in California, the direct cost of climate change-related damage could reach tens of billions of dollars per year, with even higher indirect costs, exposing trillions of dollars of assets to collateral risk.[5] While many coastal hazards and effects of climate change are beyond our ability to prevent, comprehensive planning and preparedness can reduce societal and ecological harm. Reduced vulnerability and risks, as well as increased capability to respond to and recover from impacts of change, depend on our ability to understand how social and ecological systems work, what makes them robust or healthy, and how adaptable our institutions are with regard to predicted changes.

Resilience is the capacity of a system to tolerate disturbance without transitioning into a qualitatively different state that is controlled by a different set of processes. A resilient social or ecological system has adaptive capacity, meaning it can withstand perturbations and restabilize without losing its identity, structure, and key functions. Resilience of social and ecological systems has been studied for decades, and the research associates resilience with diversity, adaptability, connectivity, and functional redundancy, all of which increase the variety of possible responses to change. When systems become less complex, they become less resilient. Coastal community resilience is accordingly associated with the presence of a robust community infrastructure to support a variety of institutions that collaboratively plan for and adaptively respond to change. Similarly, ecosystem resilience is associated with diversity of species, habitats, and redundancy of ecological functions.

Current work on resilience focuses on understanding changing systems—both knowing their current status and being able to predict changes. Additional work investigates the concepts of robustness (identifying the strength of a system when subjected to change) and adaptability of human communities to change. Recently, resilience has been cited as underpinning the goals of ecosystem-based approaches to management, including maintenance of ecosystem services. Resilience research has attracted global attention, resulting in the formation of a multidisciplinary research group called Resilience Alliance. At the national level, the Ocean Research Priorities Plan highlighted the need to increase coastal community resilience to hazards and recommended research to improve forecasts of natural hazards, assess vulnerability, and develop strategies to cope with natural hazards. On the West Coast, all three states have identified resilience to natural hazards and disruptive change as a priority. A number of West Coast social and natural scientists are

Firefighters rescue residents and their pets in western Washington after the December 2007 storm that devastated Pacific Northwest coastal areas.

[4] *Data from FEMA daily situation reports, December 3–23, 2007. www.fema.gov/emergency/reports/2007*

[5] *California Climate Risk and Response, November 2008. David Roland-Holst and Fredric H Kahrl, UC Berkeley.*

Resilience and Adaptability to Hazards and Climate Change

continued

Oceanographers and engineers use wave-generation machines and coastal community models to study powerful wave phenomena such as tsunamis.

studying resilience, and are working toward using a resilience framework to assist coastal communities and coastal resource managers in identifying and incorporating adaptive elements into management programs that will enable these systems to rebound from disturbance. For example, in the Pacific Northwest, social and natural scientists are using the framework of resilience to study commercially and culturally important salmon populations, and in California, work is being done to understand the resilience of urban coastal infrastructure.

Although our understanding of resilience has grown, gaps in our knowledge and ability to incorporate resilience into managing social and ecological systems are still significant. It is clear, however, that resilience research and information needs should be addressed as an interdisciplinary endeavor that recognizes the uniqueness of social and ecological systems and empowers communities of all sizes to enhance their own resilience. Social and ecological scientists have much to learn from each other; while they may focus their resilience work exclusively on ecosystems or on social or economic systems, they must keep in mind that these systems are coupled. Resilience studies around the world offer knowledge that can be applied throughout the West Coast region; however, credence should be given to the unique social, economic, and natural context of each system. Locally specific programs will be

Stakeholder Comments

"Land use, transportation infrastructure, economic development, and resource protection decisions that get made now can be affected by and affect adjustments society makes to climate change... Land use planners, county planning, economic developers, highway planners and others need to be made aware of how their decisions will be impacted by or will affect adaptation to climate change."
—Depoe Bay, Ore., workshop, May 5, 2007

"Develop coastal hazards and sea level rise response strategies and priorities for the states coast and shoreline and factor these into any new proposals for coastal development."
—Oakland, Calif., Web survey response

"Change is certain in coastal ecosystems. Research ways for coastal economies to be more adaptable to the inevitable change to our coastal ecosystems."
—Ocean Shores, Wash., workshop, Oct. 12, 2007

Resilience and Adaptability to Hazards and Climate Change

continued

the most effective in providing the information communities need to build resilience; this is especially true in locations where catastrophic events may leave communities without access to outside resources. In these cases, capacity to respond autonomously is critical. Planning for resilience depends on the availability of information about the future and on a capability to incorporate uncertainty into planning. Results of research on resilience must be made available in the form of materials to guide institutions in overcoming barriers.

Stakeholders repeatedly expressed a need to understand and improve social and ecological resilience in the context of a shifting climate, changes in sea level, and such unpredictable catastrophic events as earthquakes and tsunamis. More than 300 individual stakeholder comments suggested practical research and information needs related to

- developing best practices for risk assessment and planning;
- increasing institutional capacity to respond and adapt to change;
- understanding more about how people perceive and respond to risk; and
- understanding the human connection and our dependence on healthy ecosystems.

Taken together, these concerns and suggestions reinforce the need for research and information on the resilience and adaptability of social and ecological systems to coastal hazards and change.

WCGA Action Plan Link:

Overarching Action 2—Facing the effects of climate change

Action 6.3—Complete a seafloor map for the entire West Coast

Action 7.1—Support local planning efforts for sustainable communities

Action 7.3—Assess the health and economic vitality of coastal communities

Research and Information Needs

1. Assess the vulnerability of our social and ecological systems to coastal natural hazards.

Predictive indicators of the function and health of social and ecological systems need to be identified and used to effectively study long-term cumulative impacts of coastal hazards and climate change and measure the vulnerability of coastal communities and ecosystems. An integrated natural- and social-science approach is needed to identify the attributes of populations, ecosystems, and natural and human communities that promote resilience. In addition, fine-scale baseline data, combined with forecasting, models, and simulations, are needed for risk assessments. Understanding the fundamental attributes that account for resilience and an improved ability to predict changes and risk will pave the way for a better understanding of the thresholds, beyond which function and health are compromised and social and ecological systems can no longer absorb the impacts of change. These studies should also take into account how human alterations to natural habitats may ameliorate or exacerbate hazards and the effects of climate change. Such research should lead to the creation of practical tools to improve coastal community capacity to prepare for, respond to, and recover from the impacts of hazards and climate change. Communities empowered with the knowledge and tools to assess their own level of resilience and to respond locally are more likely to achieve stability and preserve key functions of social and ecological systems.

2. Identify how coastal hazards and climate change will impact social and ecological systems, and which mitigation, adaptation, and response strategies will be successful.

Coastal hazards and the effects of climate change will have many expected and unexpected impacts on communities, economies, and coastal infrastructure related to storm damage, inundation from sea-level rise, tsunamis, and alteration of fisheries stocks, among many others. Research into the most effective tools and technologies to reduce these impacts will help to improve land-use planning and best-management practices. Research into the range of ac-

Resilience and Adaptability to Hazards and Climate Change

continued

tivities to mitigate those drivers of hazards and climate change within our capacity to change will be necessary to enable coastal communities to prepare for long-term resilience. Adaptability is a key element of resilience, and exploration of effective and creative incentives and strategies can assist regional, tribal, state, and local institutions in adapting to hazards. For example, in some locations it may be appropriate to relocate emergency care and first-responder facilities away from tsunami inundation zones, while remaining close enough to effectively serve at-risk communities.

in regional and local planning and response systems. Institutions currently responsible for management (tribal governments, federal agencies, state agencies, and local government) as well as novel ones (civic groups, churches, nongovernmental organizations, etc.) must be taken into account when identifying capacity to plan for and respond to hazards and change—a task that may include expanding or altering infrastructure and institutions. It is also important to learn from successes and failures of institutional approaches and to examine policy actions that have played a role in improving

Understanding the resilience of animals, such as these Pacific salmon, may serve as a model for understanding broader issues of ecosystems and economies.

3. Assess human, governmental, and institutional understanding of risks and motivations necessary for reduction of risk behavior.

A community's ability to respond to hazards and other changes depends, in part, on how humans perceive and respond to risks. Research is needed to understand the factors that support or prevent resilient behavior. Grassroots-level outreach and education are needed to foster resilient behaviors and support local champions of resilience who can make a significant impact in their communities. Mapping of institutions, including information about their relative roles and capacity to prepare for and respond to change, should also be done to identify gaps

resilience of social and ecological systems. Additional research and information needs related to coastal management institutions, policies, and governance can be found in Topic 2: Ocean and Coastal Governance and Management of Multiple Uses.

Significant progress toward resilient social and ecological systems will require interdisciplinary, collaborative efforts to improve economy of scale and increase the ability of communities and institutions to learn from each other. The West Coast would benefit from an interdisciplinary, resilience-focused entity responsible for conducting research, training, and capacity-building to overcome the barriers to resilience.

Methods and Approach

The four West Coast Sea Grant programs have worked together since late 2006 not only to engage a wide range of stakeholders, but also to learn from the vast body of knowledge that stakeholders shared with us and to incorporate it into this report in a meaningful way. This was accomplished by building flexibility into our process and conducting an in-depth analysis of more than 5,200 stakeholder comments.

Workshops

The Sea Grant regional process was based on extensive communication with stakeholders throughout Washington, Oregon, and California. Sea Grant solicited comments from a wide range of interests, including government officials and scientists from local, state, tribal, and federal agencies; academic scientists from West Coast colleges and universities; interest groups; fishing communities; marine industries; recreational users; nongovernmental organizations; and other members of the public. Sixteen workshops, attended by more than 600 participants, were held across the three states between May 2007 and January 2008.

The workshops were organized around the seven central themes listed below.

- The social and economic vitality of coastal communities
- Coastal natural hazards
- Oceans and human health
- Ecosystem health
- The ocean and climate variability
- Marine transportation and security
- Ocean education and environmental literacy

These themes are, by design, similar to the priorities outlined by the Joint Subcommittee on Ocean Science and Technology in the Ocean Research Priorities Plan, with the addition of ocean education and environmental literacy. In addition, they relate to the issues and actions identified in the WCGA Action Plan. We aligned our workshop themes with national and state research priorities to ensure continuity among federal research prioritization efforts and funding schemes, state priorities, and the regional Sea Grant effort.

List of Workshops

Depoe Bay, Ore.	May 2007
Charleston, Ore.	August 2007
Astoria, Ore.	August 2007
Orange County, Calif.	September 2007
Ocean Shores, Wash.	October 2007
Bellingham, Wash.	October 2007
Union, Wash.	October 2007
Eureka, Calif.	October 2007
Santa Barbara, Calif.	November 2007
San Francisco, Calif.	November 2007
Gold Beach, Ore.	December 2007
Portland, Ore.	December 2007
Seattle, Wash.	December 2007
Olympia, Wash.	December 2007
Corvallis, Ore.	January 2008
Port Angeles, Wash.	January 2008

Participants in the regional workshops provided both written and oral input, using the themes as organizing principles. Workshops were designed to fit the specific needs and cultures of different regions along the West Coast. In all, 3,655 comments on research and information needs were gathered from these workshops (another 238 were received in writing or outside of the workshops, by personal contact).

Web-based Survey

In addition to the workshops, a Web-based survey was developed and made available through Sea Grant program Web sites from July 2007 through January 2008. The survey was designed in an open-ended format, which allowed respondents to list their own research or information needs in the same seven thematic areas as those of the public workshops. More than 350 respondents contributed an additional 1,406 comments through this vehicle.

Methods and Approach continued

Analysis of Stakeholder Comments

The stakeholder engagement process, including workshops and the Web-based survey, yielded 5,299 comments, most of which identified specific research and information needs (Table 1). Sea Grant used these comments to aggregate the insights of stakeholders by identifying common concerns across the region and threads of research and information needs. The process involved entering each comment into a database and then conducting a comprehensive analysis that

- identified in the comments more than 60 distinct categories of research and information needs;
- assigned each comment to a category; and
- organized the categories into the three foundational themes and eight research and information topics presented in this report.

Coordination with the West Coast Governors and Federal and Tribal Partners

An integral component of this Sea Grant process was close coordination with the state leads and federal partners from the West Coast Governors' Agreement and with other federal partners. Whenever possible, representatives of the hosting state and federal liaisons attended the regional workshops. In several cases, state representatives presented at the workshops, highlighting the integration of complementary efforts and the expectation that this Sea Grant report will inform state and regional research prioritization and planning. State support for this Sea Grant West Coast Regional Research and Information planning process is highlighted in Action 6.1 of the WCGA Action Plan, which states that the governors will develop a research agenda in partnership with Sea Grant and will seek federal support to fill major marine research needs identified in this report.

A federal working group was created to help coordinate the federal involvement with the states in developing the West Coast Governors' Action Plan. The federal group's role is to partner with the states in determining how federal agencies can better respond and organize to help states with regional ocean governance. The federal group has been engaged in this Sea Grant regional process through its support of the priority actions defined in the WCGA Action Plan. NOAA and the other federal agencies will consider the research and information needs identified by Sea Grant when determining what regionally significant research to conduct in support of the WCGA Action Plan.

Washington tribes also played a formal role as collaborators throughout the Sea Grant process. Tribal representatives helped determine Washington workshop strategies, attended workshops, and acted as invaluable liaisons to Washington tribal communities, providing access to their unique history, perspectives, knowledge, and needs.

Types of stakeholder comments of 5,299 total comments	Number
Specific research and information needs	3,661
General support for research within themes	402
Suggestions for educational programs, standards, and tools	611
Need for data management and accessibility	146
General comments on research planning, policy, or collaboration	479

Table 1.—*Sixteen stakeholder workshops in Washington, Oregon, and California, plus a Web survey, yielded 5,299 comments from nearly 1,000 participants. Most comments identified specific research and information needs; however, many comments provided general support for more research within the seven central themes, expressed a need for education programs and improved data management and accessibility, provided feedback about regional planning, posed non-research suggestions to policy makers, or articulated the need for collaboration. The stakeholders' comments are available to the public via the Web at http://seagrant.oregonstate.edu/research/RegionalPlanning.*

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