PLANNING TODAY FOR TOMORROW'S SCIENCE:

The Northwest Fisheries Science Center's Research Planning Priorities

December 11, 2007

Research Planning Team

Michelle McClure
Phil Levin
Tim Beechie, EC
Barry Berejikian, REUT
Ric Brodeur, FE
Owen Hamel, FRAM
Jeff Hard, CB
Chris Jordan, CB
Todd Lee, FRAM
Dawn Noren, CB
Nat Scholz, EC
Penny Swanson, REUT
John Williams, FE

TABLE OF CONTENTS

I. EXECUTIVE SUMMARY

The Northwest Fisheries Science Center fills a unique role for NOAA as the liaison between scientists engaged in long term oceanographic and ecosystem research, and regional managers faced with daily decisions on the stewardship of living marine resources and their habitats in the Pacific Northwest. In 2007, the Center's managers requested a plan to ensure that research priorities not only reflect current scientific knowledge and methods, but are relevant to the resource management decisions being made by NOAA and others. Additionally, research at the Center should utilize a holistic approach to ecosystem management as called for by national and international oceans commissions. The Research Planning Team met with Center scientists and regional offices and identified 18 research foci for the next two to ten years. These foci are designed to support the mission of NOAA and conduct research that will emphasize ocean health and a renewed human relationship with ocean ecosystems. The research foci are grouped into four themes:

1. **Ecosystem Approach to Management for the California Current Large Marine Ecosystem:** The ecosystems of the California Current LME range from alpine streams where salmon spawn and rear, to mainstem rivers, wetlands, estuaries, continental shelves, and deep-ocean waters. The cumulative impacts from growing human populations in coastal communities have led to complex management issues from competing sectors, and the linkages of human actions and ecosystem response are not well understood. The Ecosystem Approach research theme is a shift away from current management efforts that tend to be fishery- or species-specific, compartmental, and short term, toward a future-oriented approach that will fully integrate various scientific disciplines and account for interactions within and across ecosystems. Research foci emphasize the need to conduct a comprehensive assessment of ecosystem components and develop appropriate measurement indicators; characterize the linkages and interactions between physical processes, species, and human activities; and provide a basis to measure and predict ecosystem responses and socio-economic benefits from management actions. The careful assessment and forecasting of ecosystem indicators will form a sound scientific basis to shape management practices that are flexible and sensitive to changing conditions and new information.

> *"Although 'ecosystem-based management' is clearly a national priority, we need to shed some light on what it actually means and how to go about it."*
> ---- *Comment from the draft research plan review*

2. **Habitats to Support Sustainable Fisheries and Recovered Populations:** Critical habitat areas impact the survival of species at every life-stage and influence the function of ecosystems as a whole. More regional information is needed about physical, chemical and biological habitat features by location, extent, persistence, and condition. Furthermore, NOAA Fisheries and other natural resource managers need to understand what long-term processes form and sustain riparian, riverine, estuarine,

and ocean environments. In order to manage the living resources of the California Current Large Marine Ecosystem in a sustainable fashion, habitat conditions must be linked to their biological impact on species at the nested scales of the individual organism, population, community and ecosystem. Research foci include: the linkage of habitat features to life-stage survival, growth and productivity of organisms; mapping the footprint of human activities and their impacts to species of interest; and developing restoration techniques that are compatible with large-scale processes to create diverse and dynamic habitats. As with other research themes, the development of metrics and evaluation models are needed to identify trends, improve predictive capability, and develop sustainable management approaches to habitat.

> *"Research at the Northwest Fisheries Science Center provides the basis for many of the management actions taken by NOAA Fisheries and other natural resource agencies as they strive to protect and recover aquatic ecosystems and living marine resources."*
> *--- excerpt from the full narrative of Theme 2*

3. **Recovery, Rebuilding and Sustainability of Marine and Anadromous Species:** Approximately 39 marine species (including anadromous fishes, marine mammals, and sea turtles) listed as endangered or threatened under the Endangered Species Act (ESA) occur in the Pacific Northwest. Seven Pacific Northwest marine invertebrate and fish species are designated as "Species of Concern." Moreover, seven West Coast marine fish stocks are classified as "overfished" under the Magnuson-Stevens Act. Each listing under the ESA or Magnuson-Stevens creates substantial socio-economic impacts to the region and nation by restricting activities, requiring permitting, and undertaking recovery, conservation and rebuilding measures. The populations of concern are subject to variations from natural ecosystem fluctuation, the harvest and propagation of marine organisms, and a host of human changes to the environment. Recovery and rebuilding efforts are impeded by a lack of measurement parameters and predictive models that can assess progress against this variable background. Additionally, some species are long-lived, compounding the challenge of developing effective and measurable recovery strategies. Research foci include: the characterization of vital physiological, behavioral, and demographic information for key species (e.g. data on temperature responses, nutritional requirements, prey species, response to contaminants); development of models to forecast cumulative effects on species productivity and ecosystem health; investigation of alternative management strategies and governance structures; and the role of artificial propagation in recovery efforts.

> *"An ecosystem approach to management is a critical agency objective, but it creates tension with some of the statutory responsibilities of NOAA which are specific to a particular species. Balancing these directives will require back-and-forth discussion between managers and researchers on an ongoing basis."*
> *--- Comment from the draft research plan review*

4. **Oceans and Human Health:** Residents and visitors to the Pacific Northwest enjoy various forms of recreation on the waters, beaches and coastal communities, along with nutritious seafood and other benefits of the marine ecosystem. However, pathogens, toxins from harmful algal blooms (HABs) and chemical contaminants pose significant risks to humans and wildlife. The Northwest Fisheries Science Center serves as the host institution to NOAA's West Coast Center of Excellence for Oceans and Human Health. The Center's research includes ocean and climate factors affecting the distribution, abundance and toxicity of pathogens and bio-toxin producing organisms, and studies of sentinel or surrogate species to measure the effects of contaminants. Research foci for Oceans and Human Health were derived from plans developed by OHH investigators, with the focus of Center scientists on pathogens, HABs, chemical contaminants and sentinel species. Research foci also include the investigation of technologies to improve seafood safety and quality, and the relationship between human exposure to pathogens, toxins and contaminants, and the resulting health and socio-economic effects.

> *"The Center is at the forefront of emerging technologies and long term research on oceans and human health, but we must remain poised to address immediate and critical questions when hot issues come up."*
>
> ---- *Comment from the draft research plan review*

<u>Near Term Priorities</u>

Six near-term research priorities were developed by the Research Planning Team and Center staff based on three primary criteria: 1) issues that are identified as urgent or of critical management importance in the near term; 2) projects that are likely to provide important technical or conceptual advances; and 3) compatibility with the immediate capabilities of the Center. The six near term priorities have been shaped into pilot projects, case studies, and focused research questions. Additionally, all six share a common need to consider emerging challenges to marine ecosystems from climate change and human population growth in the future. The near-term priorities are:

- Conduct an integrated ecosystem assessment of Puget Sound as a pilot project.
- Case study - salmon, people, and instream flows under climate change.
- Evaluate and implement new and alternative survey and monitoring methods for groundfish.
- Predict population and ESU-level response to management, climatic and other impacts across the life-cycle of species of concern.
- Develop rapid detection and improved prediction methods to identify pathogens, biotoxins, toxics and other marine impacts on human health.
- Initiate an ecosystem-based aquaculture research program.

Necessary Tools

The implementation of the research priorities will require the active development and improvement of technologies and models, as well as changes to agency infrastructure to ensure that information is easily disseminated and accessible. Ocean environments are notoriously challenging to observe, and the species that inhabit them occupy varying habitats across wide areas that are difficult to access. Emerging and enhanced technologies for research include large-scale observation systems such as geo-spatial remote sensing, Autonomous Underwater Vehicles (AUVs), tagging and remote sensing for individual organisms, and genetic techniques. Faster recording systems for fish catch and observer data are needed to improve the accuracy and timeliness of fisheries management decisions, particularly for groundfish. Socio-economic models addressing fisheries and ecosystem management provide decision-makers with information about impacts of alternative management regimes on net national benefits, effects on particular participant groups, and provide a common valuation basis to assess tradeoffs for human activities and ecosystem health. Ecological and evolutionary models can be used to prioritize sites for conservation, estimate future populations due to species interaction or climate change, and simulate food web dynamics. Infrastructure needs include large-scale systematic improvements to data management, enhanced laboratory facilities, and operation of an array of large and small vessels, gear, and storage facilities to facilitate field research.

Implementation Strategy

Internal and external collaboration and communication are critical components of the NWFSC research plan implementation strategy. The plan calls for the formation of clearly-defined core groups for each of the near-term priorities. Group leaders would be responsible for communicating with Congressional staff, NOAA/NMFS Headquarters and regional offices, and ensuring that milestones are being attained. Each core group will need to foster partnerships with other agencies, academic institutions, non-governmental organizations, and industry. Annual reporting on the near-term priorities must be linked to budgeting processes and eAOPs [electronic Annual Operating Plans]. Finally, the research plan recognizes that research without proper dissemination is of diminished use to the agency, the scientific community, and the nation. A series of education and outreach strategies are proposed to translate the results of Center research into products available to Regional Offices, stakeholders, scientists, and the general public.

> *"Our annual budgeting and reporting should be closely linked to our progress on the research priorities, rather than treating these as separate processes."*
> *--- Comment from the draft research plan review*

II. VISION, BACKGROUND AND PURPOSE OF THE NWFSC RESEARCH PLAN

Introduction: National Priorities for Ocean Research

The past, present, and future status of our nation's oceans were recently reviewed by both the U.S. Commission on Ocean Policy (USCOP 2004) and the Pew Oceans Commission (Pew 2003). These reviews called for a change in our nation's stewardship of the oceans and the pursuit of an ecosystem-based approach to ocean management. In response, a number of national efforts have been launched to improve the scientific basis for resource management, such as the formation of the Joint Subcommittee on Ocean Science and Technology (JSOST). The report, *Charting the Course for Ocean Science in the United States for the Next Decade: An Ocean Research Priorities Plan and Research Strategy*, was released by the JSOST in January 2007, and identified three critical scientific elements to advance the nation's relationship to our oceans:

- the development and deployment of ocean observing systems
- the capability to forecast key ocean-influenced processes and phenomena
- the central role of science in an ecosystem approach to natural resource management

Additional national priorities for ocean research have been identified in the Climate Change Strategic Plan (CCSP 2003), and the Earth Observation System Plan (CNER/IWGEO 2005). These complementary plans will contribute to local, regional and global climate forecasting and the interactions of climate with other environmental factors.

The USCOP and PEW Oceans Commissions represented the most comprehensive reviews in the decades since the National Oceanographic and Atmospheric Administration was founded as an agency. In order to align research priorities at the Northwest Fisheries Science Center (National Marine Fisheries Service) with national and NOAA goals, this Research Plan and Priorities document was prepared to guide scientific research, advance ocean stewardship, and provide information for regional and national decision-making.

Vision and Role of the Northwest Fisheries Science Center

The Northwest Fisheries Science Center operates under the vision expressed on the Center's website that *"scientists at the Northwest Fisheries Science Center conduct leading-edge research and analyses that provide the foundation for management decisions to protect, recover, restore, and sustain ecosystems and living marine resources in the Pacific Northwest."* NWFSC researchers are dedicated to producing scientific products that will strengthen decision-making at all levels, enhance socio-economic benefits, support sustainable resource use, and conserve biological diversity. The work of the Center is encompassed in two key roles:

- ***Provide current, relevant information to support science-based stewardship of natural resources.*** The primary mission of the NWFSC is to provide multi-disciplinary scientific and technical information to the Northwest Regional Office of NOAA Fisheries, other NOAA line offices, co-managers, stakeholders and other constituents to inform decision and policy-making processes.
- ***Foster scientific literacy and expertise.*** In order to achieve the national missions of NOAA, the NWFSC must ensure that Center research results reach the broader science, education, and public communities within the region and beyond. The Center has the additional responsibility to help train the next generation of fisheries scientists.

Background and Purpose of this Research Plan

NWFSC Management formed the Research Planning Team (RPT) in 2005 to develop this research plan with two primary goals:

1) Identify areas of research that are the most important for the NWFSC in achieving national goals and regional science needs of NOAA/NMFS, other federal agencies, and external constituents. These include legally-mandated investigations, science support for other NOAA offices, and contributions to emerging regional and national scientific issues.
2) Identify areas of investigation that will move critical areas of scientific inquiry and discovery forward.

The RPT solicited considerable staff input and identified priorities and challenges for the Center in the short to moderate term (2 to 10 years) as well as long term research that will remain critical for the foreseeable future. The plan supports several key internal goals and external functions as described in Box 1. The RPT followed several criteria in developing the research plan, including: staff participation and grass roots input; emphasizing integrative, multi-disciplinary research; ensuring that research is relevant to management objectives; building on Center strengths; and utilizing approaches that are proactive, independent, innovative, imaginative, and which foster excellence in scientific inquiry and communication.

Box 1.

The NWFSC Research Plan is intended to support a number of key *internal* objectives of the Center, including:

- Link specific research objectives and national or agency-wide goals;
- Provide benchmarks for implementation and evaluation;
- Contribute to a transparent process of allocating resources within the Center;
- Develop and strengthen the Center's capability to support innovative research and respond to emerging issues;
- Develop and strengthen inter-disciplinary and collaborative scientific research;
- Promote flexible research planning.

***External* uses of the NWFSC Research Plan include:**

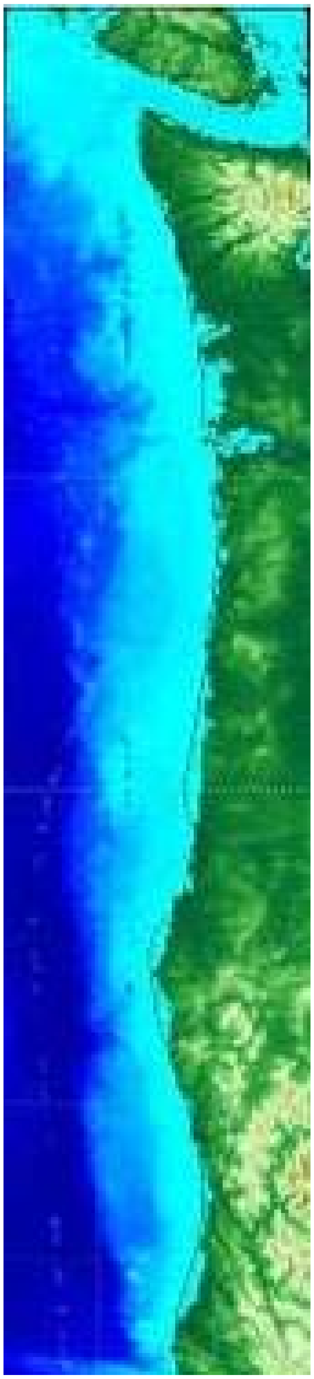
- Communicate links with scientific research at regional, national and international forums;
- Improve coordination to ensure that the results of NWFSC scientific research provide useful support to the Northwest Region, and are appropriately incorporated into management;
- Provide support for efforts to respond to emerging issues;
- Establish or enhance mechanisms to disseminate the products and accomplishments of the Center's research efforts.

III. RESEARCH THEMES AND FOCI

To identify research foci for the NWFSC, several factors were considered that were similar to those used by the Joint Subcommittee on Ocean Science and Technology in the development of the 2007 national ocean research plan: a) potential to enable significant advances for science and its application; b) high priority for ongoing and emerging management issues; c) builds appropriately on capabilities at the NWFSC; and d) provides critical support for the wise stewardship of our ocean resources. Eighteen research foci within four major themes emerged from staff input and discussion (Table 1). The eighteen research foci support both national and regional science goals, and relate clearly to the goals of NOAA and the findings of the US Commission on Oceans Policy (Appendix A). Elements common to these major themes include a holistic approach to ecosystem management, the improvement of predictive capability by characterizing linkages and advanced modeling, and providing scientific information to management practitioners within NOAA and across the nation and region.

Table 1: Summary of 18 major research foci for the NWFSC grouped into four themes.

Ecosystem Management Approach for the California Current Large Marine Ecosystem
1. Conduct integrated ecosystem assessments that produce metrics and criteria that will improve ecosystem forecasts and predictions.
2. Describe the interaction between human activities and ecosystem status and resilience.
3. Characterize linkages between climatic conditions and biotic responses.
4. Characterize ecological interactions (e.g. predation, competition, parasitism, disease, etc.) within and among species.
5. Characterize the interaction between marine, freshwater and terrestrial ecosystem components.
Habitats to Support Sustainable Fisheries and Recovered Populations
6. Characterize habitat effects on ecosystem processes, ecological interactions, and the health of organisms.
7. Characterize the interaction of human use and habitat distribution, quantity and quality.
.
8. Develop effective and efficient habitat restoration and conservation techniques.
Recovery, Rebuilding and Sustainability of Marine and Anadromous Species
9. Describe the relationship among human activities and species recovery, rebuilding and sustainability.
10. Investigate ecological and socio-economic effects of alternative management strategies or governance structures.
11. Characterize vital rates and other demographic parameters for key species, and develop and improve methods for predicting risk and viability/sustainability from population dynamics and demographic information.
..
12. Develop methods to use physiological, biological and behavioral information of organisms to predict population-level processes.
13. Clarify the role of artificial propagation (including aquaculture) in recovery, rebuilding and sustainability.
Oceans and Human Health
14. Characterize the exposure to and effects of pathogens, chemical contaminants, and marine biotoxins on humans and other species.
15. Determine how ecosystem variables, such as climate, affect the distribution, abundance and toxicity of pathogenic and bio-toxin producing organisms.
16. Ensure seafood safety and improve seafood quality.
17. Monitor the health of fish and marine mammals as sentinels for ocean health and develop new species as mechanistic models.
18. Evaluate the effects of changes in the distribution, abundance and virulence of threats to human health on socio-economic indicators.



Theme 1:

Ecosystem Approach to Management for the California Current Large Marine Ecosystem

Relevance to national and regional ocean issues:
The California Current LME provides abundant products and services essential for fisheries, climate regulation, pollution control, energy production, transportation and recreation. Yet, ensuring the resiliency and productivity of California Current ecosystems will require understanding their structure, function, and vulnerability to anthropogenic actions. Increased population growth in coastal communities from diverse, often competing sectors complicates management strategies.

Role of the NWFSC:
The Northwest Fisheries Science Center provides science support for moving resource management toward a more holistic, ecosystem-based strategy. The NWFSC's ecosystem approach promotes a shift away from current management that often focuses in the short-term on a single species. The new approach focuses on interactions within and among ecosystems, offers long-term perspectives, and fully integrates analyses across a range of scientific disciplines.

Theme 1:
Ecosystem Approach to Management for the California Current Large Marine Ecosystem

Research Focus 1. Conduct integrated ecosystem assessments that produce metrics and criteria that will improve ecosystem forecasts and predictions.

An Integrated Ecosystem Assessment (IEA) is a synthesis and analysis of all available information on relevant physical, chemical, ecological and human processes in relation to specified ecosystem management objectives. IEAs provide an efficient, transparent means of summarizing the status of ecosystem components, screening and prioritizing potential risks, and evaluating alternative management strategies against a backdrop of environmental (e.g., temporal and spatial) variability. They also provide a means of evaluating tradeoffs in management objectives among potentially competing ocean-use sectors. The California Current LME lacks such an assessment. To achieve one will require the development of test indicators and input from a broad range of stakeholders and scientists. Careful assessment and forecasting of ecosystem indicators will provide a powerful means for assessing management efficacy and a basis for adapting and improving management practices.

Research Focus 2. Describe the interaction between human activities and ecosystem status and resilience

Humans are an integral component of the ecosystems they inhabit and exploit. They receive goods and services from these systems and may manipulate them to purposefully enhance some features. Anthropogenic actions may change systems inadvertently through the type, variety or magnitude of demands which are placed upon them. Understanding the nature of these interactions will require observational and experimental studies aimed at identifying ecosystem-level responses to human activities, both individually and cumulatively. Improved prediction and adaptive management of ecosystems will require integrating that information with socio-economic analyses of human responses (economic valuation, governance structures, etc.).

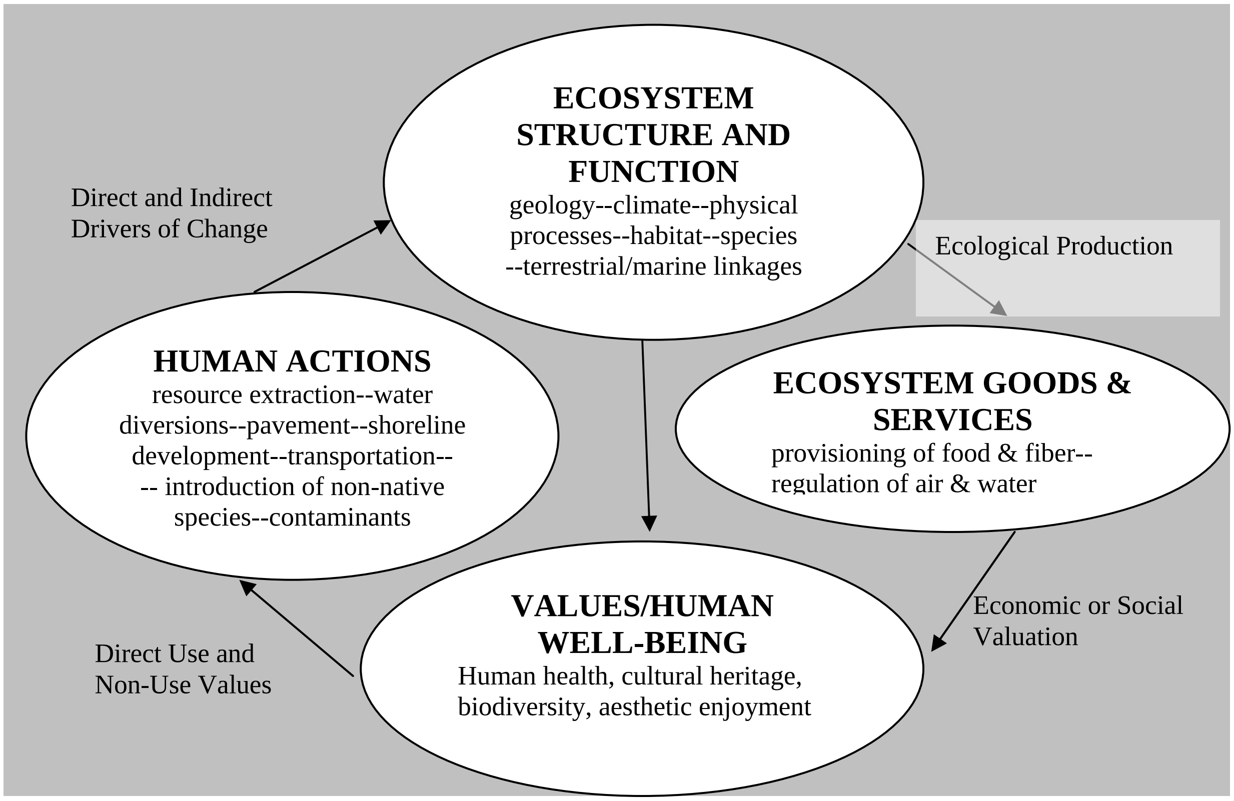


Figure 1: Relationship of Ecosystem Structure and Function and Human Well-Being (adapted from National Research Council 2004 and Millennium Ecosystem Assessment 2005).

Research Focus 3. Characterize linkages between climatic conditions and biotic responses

Identifying ecosystem management foci in the California Coastal Current LME requires an understanding of how climate change and variation will alter riverine, estuarine, and marine habitats. Models may then be used to develop predictions of how those changes will affect ecosystem status and function. Key research elements include understanding sensitivity of key species and biotic communities to expected habitat changes. These changes could include decreasing stream flow, increasing stream temperature, sea level rise, ocean acidification, shifts in ocean currents, and changed frequency and extent of deoxygenated zones. A secondary goal is to improve understanding of the effects of year-to-year and decadal climate variability on population dynamics and ecosystem variability. Achieving this goal will require identifying 'sensitive' and 'resilient' ecosystems, and providing NOAA and state and local governments the knowledge and tools needed to incorporate climate variability into decisions about living marine resources.

Research Focus 4. Characterize ecological interactions (e.g. predation, competition, parasitism, disease, etc.) within and among species to support an ecosystem approach to management of species of concern and the habitats they use.

Understanding ecological interactions at various trophic levels provides important insight into factors limiting the productivity of freshwater and marine species. Predator-prey interactions, inter- and intra-specific competition, and parasites and pathogens can influence the survival, growth, and reproductive success of anadromous and marine fishes, marine mammals and other marine organisms. Moreover, anthropogenic stressors, for example pollution and fishing, can change natural interactions among species. The extremely complex nature of these interactions makes it difficult to obtain useful data and prioritize research. Addressing questions about ecological interactions will require field and laboratory studies that complement new models including:

- conducting gut content analysis of utilized and unutilized species during surveys or harvest;
- examining direct and indirect ecological effects of fishing activities
- analysis of otolith microchemistry to assess fish growth rates and habitat use;
- use of stable isotope analysis to determine predator-prey relationships;
- integration of sample collection efforts with those of the Pacific Coastal Ocean Observing System (PaCOOS) and with the various ocean productivity indicators (e.g., PDO, ENSO, coastal upwelling);
- determination of how pollution and other environmental stressors (e.g. biotoxins, poor nutrients, low oxygen, pH) alter interactive processes such as infectious disease;
- examination of how evidence for compensatory and depensatory processes change under variable exploitation, climatic and ecosystem scenarios.

From a holistic standpoint, individual animal tracking over extended distances and durations in the marine environment will improve understanding of the spatial and temporal overlap among species and potential for competition, predation or transfer of pathogens on an ecosystem scale.

Research Focus 5. Characterize the interaction between marine, freshwater and terrestrial ecosystem components

Within the California Current LME, many species undergo dramatic habitat shifts as they move from fresh or estuarine to marine waters. Further, habitat conditions in both marine and freshwater areas are strongly influenced by flows of water, sediment, and nutrients between the two environments. While species migrations among these habitats are well known, freshwater, estuarine, and marine environments are commonly studied and managed as separate ecosystems. Moreover, many threats (e.g., pollution, habitat loss, climate change, etc.) to marine organisms cross land-sea boundaries. Successful management of marine systems thus requires an understanding of:

- the linkages among the freshwater and marine environments;
- how specific habitats (e.g., headwaters, floodplains, submerged aquatic vegetation, nearshore zones, plumes and frontal regions) contribute to the productivity and capacity of ecosystems; and
- how to prioritize habitat protection or restoration within the context of the entire freshwater-estuarine-marine ecosystem.

Theme 2:

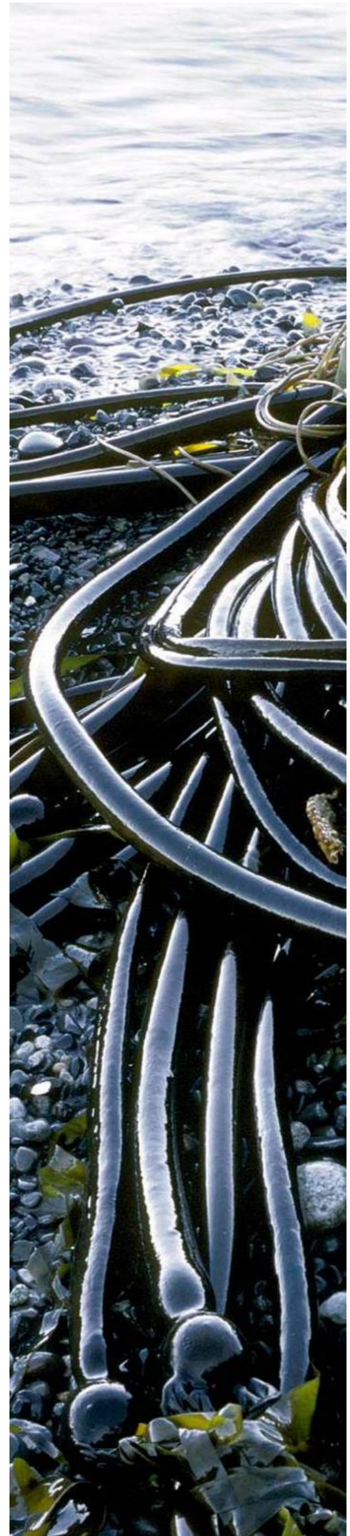
Habitats to Support Sustainable Fisheries and Recovered Populations

Relevance to national and regional ocean issues:

Healthy oceans and natural coastal and riverine habitats provide the foundation for aquatic resources that society uses daily. Coastal habitats often overlay oil and gas resources, and also serve as transportation corridors, recreational venues, waste receptors, and prime sites for residential use and manufacturing, creating intense competition between marine resources and other societal needs and values. The examination of the environmental impacts of resource use and extraction, combined with increased understanding of the factors influencing overall ecosystem health, can help balance the pressures placed on freshwater, estuarine, coastal and offshore marine ecosystems. Research will enable the restoration of degraded habitats, and ultimately, support coordinated ecosystem approaches to management and governance strategies for sustainable resource use.

Role of the NWFSC:

Habitat has tremendous influence on ecosystem structure and functioning. The ability to define the state of an ecosystem requires insight into the natural processes within habitats that form and maintain aquatic and marine ecosystems, and how anthropogenic actions on these processes can alter ecosystems and affect living marine resources. NOAA Fisheries and other natural resource managers need to understand what processes form and sustain riparian, riverine, estuarine, and ocean environments. These processes include the transport of sediment, water, and organic material from terrestrial areas through streams, to rivers, through estuaries, and into the ocean, or actions from extraction that alters benthic marine habitat. Research at the NWFSC provides the basis for many of the management actions taken by NOAA Fisheries and other natural resource agencies as they strive to protect and recover aquatic ecosystems and living marine resources.


Randy Johnson photo

Theme 2: Habitats to Support Sustainable Fisheries and Recovered Populations

Research Focus 6. Characterize habitat effects on ecosystem processes, ecological interactions and the health of organisms.

In the northern California Current, the Essential Fish Habitat for groundfish, coastal pelagic species, anadromous salmonids, marine mammals and other marine species include all marine waters and bottom habitat from the shoreline along the coasts of California, Oregon, and Washington offshore to the Exclusive Economic Zone. The upper 10-20 m of the water column across the continental shelf and slope is the primary habitat for many non-benthic species. Essential Fish Habitat for anadromous salmonids (and other diadromous species) extend inland to include the watersheds that these species utilize for spawning, rearing and migration. Characterizing how and when these species use habitat in the CCLME is important to establishing land-use and fishing policies that promote a sustainable ecosystem. Research needs include:

- Developing spatially explicit population dynamic models;
- Linking habitat features and conditions to key life-history stages, life-stage survival rates, and other demographic parameters such as growth rate;
- Tracking the movement, growth and survival of individuals across habitats;
- Mapping key habitat features by location, extent, persistence, quality and condition;
- Development of statistical modeling approaches to illuminate patterns in distribution and habitat data;
- Development of landscape classification approaches in quantifying and describing habitat;
- Continued development of tagging and tracking technologies to document the movement patterns of individual organisms through time and space.

Research Focus 7. Characterize the interaction of human use and habitat distribution, quantity and quality.

An enormous diversity of human activities directly and indirectly impacts critical freshwater, estuarine, and marine habitats. Degradation of river and stream habitats occurs from land uses and water withdrawal. Estuarine habitats are adversely impacted by contaminant runoff, industrialization, and dredging. The degradation of marine habitats is due to pollution, some fishing practices and climate change (e.g. ocean acidification). Characterizing how this collection of human activities degrade habitats, and which habitats humans are most prone to use and degrade, is critical to establishing land-use and fishing policies that promote a healthy ecosystem. To best manage the CCLME in a sustainable fashion, it is necessary to map the footprint of human activities and their direct and indirect spatial and temporal impacts, and review the potential biological impact on each species of interest. Measurement parameters will need to be developed to determine the full range of human impacts on habitat using spatial data and improved habitat classification approaches.

Research Focus 8. Develop effective and efficient habitat restoration and conservation techniques

Maintaining and re-establishing viability and sustainability of living marine resources often requires conservation and rehabilitation or restoration of habitats upon which species depend. However, available techniques for rehabilitating riverine, nearshore, and marine habitats are often only modestly effective on a small scale, and advances in understanding how to restore long-term dynamic and diverse habitats are sorely needed. Common habitat restoration approaches and techniques often presume that habitats are static features of the environment, and that creation of stable habitats is a desirable restoration strategy. However, riverine, nearshore, and marine habitats are created and sustained by dynamic landscape, climatic, and oceanographic processes and biota are adapted to changing habitats. Hence, current restoration strategies often have limited success, in part because they fail to recognize larger scale processes that drive habitat degradation, and in part because they fail to recognize intrinsic habitat potential of individual restoration sites. The main goals of this research focus are to: improve understanding of how large-scale processes create diverse and dynamic habitats that support living marine resources, better understand how human activities alter habitat-forming processes and alter habitats, develop new restoration techniques that are compatible with sustainable habitat-forming processes, and understand the variety of actions needed to adequately conserve intact critical habitats.

Theme 3:

Recovery, Rebuilding and Sustainability of Marine and Anadromous Species

Relevance to current national and regional priorities:

Approximately 39 marine species (inclusive of anadromous fishes, marine mammals, and sea turtles) listed as endangered or threatened under the Endangered Species Act (ESA) occur in the Pacific Northwest. Seven Pacific Northwest marine invertebrate and fish species are designated as "Species of Concern." Moreover, seven West Coast marine fish stocks are classified as "overfished" under the Magnuson-Stevens Act. Many of these species, such as Pacific salmon and killer whales, are iconic symbols of the Pacific Northwest. Others form the basis of critical human economies, and are harvested directly (e.g., salmon), while others are an important food source for other commercially exploited species (e.g., herring). Human sustenance, economic benefits, and ways of life are dependent upon these species. Improving their status so that they are recovered or rebuilt, and sustainable fisheries can be maintained, is essential both regionally and nationally. The economic burdens of listing species under either the ESA or Magnuson-Stevens statutes are significant. Endangered Species Act listings require additional permitting for and restrictions on a variety of activities as well as the implementation of recovery and conservation actions. Similarly, species or stocks identified as overfished or experiencing overfishing under the Magnuson-Stevens Act are subject to harvest restrictions, and rebuilding measures must be undertaken for overfished species.

Role of the NWFSC:

NOAA and other resource managers and decision-makers carry the responsibilities for preventing extinctions, improving stewardship, and managing harvest for the communities that depend on it. However, effective recovery, rebuilding, and sustainable fisheries are impeded by limitations in our ability to predict population-level responses to natural environmental variation and human alterations to the environment. NWFSC research is needed to thoroughly characterize species and population interactions with human activities and socio-economic indicators, and develop operative models for predicting population responses. The information and models would contribute to decision making, and provide benchmarks for assessing progress toward recovery.

Theme 3: Recovery, Rebuilding and Sustainability of Marine and Anadromous Species

Research Focus 9. Describe the relationship among human activities and species recovery, rebuilding and sustainability

Humans have substantially altered the ability of natural ecosystems to support key marine and anadromous species by degrading habitats, harvesting marine organisms, artificially propagating selected species, and altering climate. In order to recover, rebuild, or sustain declining species, it will be essential to understand the extent to which humans have affected physical, biological, and chemical processes in ecosystems, and the magnitude and pace of change that will be needed to restore or retain ecosystem function. Models are needed that replicate how natural and anthropogenic changes and their interactions have occurred, and which can also forecast the changes (and their interactions) that will be needed to improve conditions in the future. Restoration and recovery of declining species will also require the development of new ecosystem dynamics models that span multiple trophic levels.

Research Focus 10. Investigate ecological and socio-economic effects of alternative management strategies or governance structures

Management strategies and governance structures have a large influence on the efficiency, practicability, sustainability and distribution of natural resources used by humans. It is therefore important to understand the effects of alternative management structures such as management scale (e.g., local versus regional management), ecosystem management, and limited access privileges. Several variables including the nature of the resource, current incentive structures, and the ability to transform institutional frameworks determine whether changes can be made to management structure with positive gains. To investigate these relationships it is necessary to form collaborative research teams drawing expertise from a variety of natural and social science fields, as well as policy and management experts. It is also vital to include stakeholders in the process to understand the motivations and constraints faced by their constituents.

Research Focus 11. Characterize vital rates and other demographic parameters for key species, and develop and improve methods for predicting risk and viability/ sustainability from population dynamics and demographic information

The sustainability of a healthy ecosystem—as well as its recovery when under threat—depends heavily on the viability of key species (and vice-versa). Identifying these key species and the factors that limit their viability is necessary to understand the consequences of environmental perturbation on ecosystem structure and function. Estimates of the major demographic parameters or vital rates (e.g., birth and death rates, immigration and emigration rates, fertility, age of maturity, and age structure) necessary to assess viability in these key species are an essential step in identifying constraints on ecosystem structure and function. These estimates are difficult to obtain in free-living organisms because controlled experimentation and replication are not feasible in many natural systems. Observational and empirical studies, as well as advanced modeling of population dynamics of key species, will help to characterize the most serious threats to ecosystem structure and function and encourage more effective management and conservation. Research priorities focus on improving the characterization of demographic parameters for key species. Determining how variation in parameters such as age-specific survival, maturation, and fecundity affect population growth rates in pristine and degraded ecosystems is needed. It is also necessary to link variation in vital rates to variation in abundance and productivity and to stability of the structure of aquatic ecosystems. For ecosystems in which particular species are heavily affected by harvest, discards, and other human actions, it is essential that research focus on the ability of these species to withstand these impacts and their consequences on the abundance, productivity, and life history characteristics of the affected species.

Because multiple factors influence the status (including risk and viability/sustainability) of a species, population, stock or ESU, understanding the whole spectrum of causes and consequences and their complex interactions is difficult. Models are currently being used for a range of management and recovery actions such as stock assessment, fishing impacts, and habitat diagnostics, but these generally have limited capabilities in incorporating risk factors and modeling interactions and cumulative impacts. Where possible, models should, for example, incorporate climate data and predictions of future conditions and variability, including risks of associated recruitment failure or mass mortality events. A thorough review of the assumptions, sensitivities, uncertainties, and statistical properties of current stock assessment models is needed. This will include simulation modeling of complications such as highly variable recruitment, spatial structure, changing life-history traits, and multiple stocks or populations modeled as a single stock. Other conflicting assumptions and realities about demographic rates or the relationship of survey, fishery, monitoring, and escapement data to population parameters will need to be incorporated. All of this will aid in quantifying uncertainty in stock assessments and predictive models, in defining optimal spawning stock biomass/escapement, and in creating protocols for assessing populations for which limited data exist or are infeasible to collect.

Research Focus 12. Develop methods to use biological, physiological and behavioral information of organisms to predict population-level processes.

Continuing to understand the intricate biological processes occurring within organisms is a fundamental component of identifying factors that may affect those organisms. Needed data include those on the genetics, development, physiology, ecology and behavior of organisms. Integrating this information is vital to predict how populations will respond to natural or human perturbations to the environment, and to assess the impediments to or potential success of rebuilding efforts. For example, data on thermal tolerance and physiological responses to changes in environmental temperature can be used to assess such issues as potential changes in reproductive behavior and productivity, viability, movement patterns, preferred habitat selection, and population dynamics caused by shifts in climate. Likewise, data on levels of contaminants that impact the immune system, growth, development, reproduction, and general health of organisms is critical in determining how these compounds affect population level processes and population dynamics. Information on nutritional and energy requirements can be used to assess how competition (from humans and other species) for prey resources impacts population dynamics and carrying capacity. Other factors that should be incorporated into models to predict population-level processes and dynamics are the effects of disease, parasites, and anthropogenic perturbations in the environment. Much of the information and data listed above is in the process of being collected for several species of concern, and the effort should continue and expand, particularly for protected and endangered species as well as other key species. Development of methods to incorporate these data into models in order to predict population-level processes and dynamics is needed.

Research Focus 13. Clarify the role of artificial propagation (including aquaculture) in recovery, rebuilding and sustainability.

There is considerable debate within the scientific community over whether artificial propagation programs benefit or cause harm to natural populations and recovery efforts, and under what conditions. The debate is complicated by the fact that such programs vary widely in size, rearing practices, and goals (e.g., harvest augmentation or aquaculture production vs. conservation). Aquaculture programs, which can replace or augment commercial fisheries, are also a subject of controversy, and vary widely in scale and impact. Additional information on the influence of artificial propagation on the population dynamics, growth rate, ecology of infectious disease, and the evolutionary fitness of wild fish and other marine organisms is a critical need, as is information on the impacts of aquaculture on fishing pressure and practices, and on the surrounding environment and wild fish, shellfish and marine mammals. Critical questions related to artificial propagation programs that release fish include: 1) How do broodstock management (integrated versus segregated), culture protocols, and release strategies (life history stage) influence the relative reproductive success of artificially propagated and wild fish; 2) What are the long-term effects of artificial propagation on natural population productivity, abundance, diversity (phenotypic and genetic) and spatial distribution; and 3) Do the effects differ for programs with contrasting objectives (e.g., supporting harvest vs. conservation)? Hatchery experiments conducted on an ecosystem scale, with replicate populations or locations which do or do not receive hatchery fish, are necessary to accommodate spatial and temporal variability that can confound investigations of hatchery effects. Methods to control or eliminate infectious disease transmission from hatchery to wild fish are also needed. Research efforts will provide data for ongoing hatchery reform activities to guide hatchery operations with respect to genetics, demographics, and ecological health, endangered species issues, legislated sustainable fisheries and treaty trust responsibilities. Critical questions related to aquaculture programs include: 1) What are the effects of aquaculture programs, including culture protocols, engineering and facility design, species reared, and waste disposal on species composition, habitat quality and biological and physical processes (such as nutrient cycling) of the surrounding ecosystem; 2) What practices both maximize ecological integrity of surrounding ecosystems and permit economically viable production. For both artificial propagation/hatchery and aquaculture programs, there is also a need to identify:

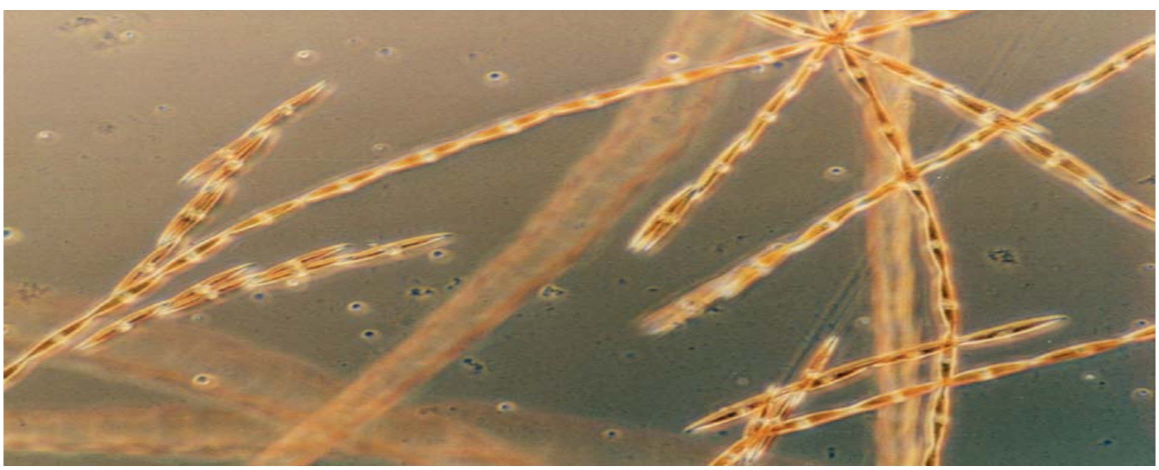
1) when and where programs could be initiated and terminated; 2) where programs should not be permitted to occur; and 3) programs that are terminating or being initiated so that appropriate experiments can be crafted around them to evaluate their effects.

Theme 4:

Oceans and Human Health

Relevance to national and regional ocean issues:
In the Pacific Northwest, much of the population lives at the coastal interface of terrestrial and marine ecosystems, with an increasing trend in the coming decades (1.4 million more residents are predicted in the Puget Sound region by 2020). The ocean and coastal environments provide numerous benefits to humans, including nutritious seafood, various pharmaceuticals and natural products, and opportunities for a multitude of recreational and commercial activities. However, pathogens, toxins from harmful algal blooms (HABs) and chemical contaminants present in marine ecosystems pose significant risks to health of both humans and wildlife. Critical gaps exist in our knowledge of what those risks are, how to forecast them, and identification of means to mitigate their impacts.

Role of the NWFSC:
In recognition of the relationships between the health of ocean ecosystems and human health, multidisciplinary research teams of Federal, academic, and non-governmental institutions were assembled by NOAA to address these critical information gaps. The Northwest Fisheries Science Center serves as host institution to NOAA's West Coast Center of Excellence for Oceans and Human Health (OHH). NOAA's research includes studies on ocean and climate factors that directly impact human health through their effects on pathogens and harmful algae blooms, and studies using sentinel or surrogate species to measure the impacts of chemical contaminants or other anthropogenic and natural stressors on human health. The research priorities listed below are largely derived from plans developed by OHH investigators, with the focus of Center scientists on pathogens, HABS, chemical contaminants and sentinel species.



Theme 4: Oceans and Human Health

Research Focus 14. Characterize the exposure to and effects of pathogens, chemical contaminants, and marine biotoxins on humans and other species

A variety of threats to human health are found in marine environments. These include microorganisms, chemical contaminants and marine biotoxins. Disease-causing microorganisms in aquatic environments with the capability of causing disease in humans are often introduced from terrestrial sources, or are natural inhabitants in marine waters. These pathogens pose risks to human health by exposure on beaches or ingestion of seafood. Chemical contaminants are ubiquitous in aquatic environments and can post risks to humans either via consumption of contaminated seafood or from contact with polluted waters. Many contaminants, including flame retardants and other emerging chemicals of concern, are not routinely monitored because of lack of methodologies for detection and quantification and lack of information on potential hazards posed to aquatic ecosystems and humans. Outbreaks of marine toxin-producing harmful algal blooms are unpredictable, and they pose an ongoing risk for seafood consumption. For each of these distinct threats to human health, improved sensor technologies and environmental monitoring is needed. Moreover, targeted research using biomedical models and key marine species (e.g., shellfish) is needed to more accurately define the adverse impacts of these agents on human health and other socio-economic indicators.

Research Focus 15. Determine how ecosystem variables, such as climate, affect the distribution, abundance and toxicity of pathogenic and bio-toxin producing organisms

Ocean and estuarine ecosystems can directly and indirectly impact the extent to which humans are exposed to pathogens or marine biotoxins originating from harmful algal blooms. The marine environment serves as a reservoir for emerging human pathogens and harmful algae whose numbers can be affected by anthropogenic inputs, climate and other environmental factors. Seafood safety thus needs to be examined in an ecosystem context, including the role of anthropogenic factors, climate cycles and climate change in the virulence of pathogens, toxicity of phytoplankton that contaminate seafood, or bioavailability and trophic transfer of toxic chemical contaminants. Research aimed at determining how virulence of microorganisms is linked to ecosystem variables (e.g., seasonal variation, water temperature, water chemistry, algal blooms) and climate cycles and trends in global climate change is needed. An understanding of the pathways by which these pathogens interact with other aquatic species is also needed. The extent to which large-scale environmental factors influence changes in assemblages of toxic algae, and the magnitude and duration of toxic blooms should be examined. This information is essential to develop environmental indicators that will provide predictive capabilities for human exposure. Models linking environmental data to seafood contamination should also be developed to enhance predictive and risk assessment capabilities.

Research Focus 16. Ensure seafood safety and improve seafood quality

The availability and safety of food sources from marine ecosystems or aquaculture industries are essential to maintain and maximize human health. Fish are an important source of high quality protein and contain omega-3 fatty acids, which have a variety of health benefits. However, consumption of seafood (wild or farmed) poses some health risks to humans because of accumulation of chemical contaminants in fish and shellfish tissues, and potential contamination with pathogenic bacteria, viruses, or biotoxins. Improved methods for monitoring presence of pathogens, toxins and contaminants in seafood products are needed. This includes development of molecular-based assays, sensors, micro-arrays and other techniques to detect and quantify levels of specific contaminants of concern (pathogens, harmful algal toxins, chemical pollutants) in seafood from all sources, that can be applied in the field and used by fish markets, fish wholesalers and restaurants. Technologies to remove chemical contaminants from fish feed and to enhance the nutritional content of aquaculture products are also needed to ensure a safer, higher quality product is available to the consumer. Since the source of contaminants in cultured fish is largely from fish meal and oil used in producing artificial fish diets, research efforts should also include evaluation of substitutes for fish meal and oil, such as materials derived from plants and microbes. The net economic benefits of improved seafood safety and quality should also be determined.

Research Focus 17. Monitor the health of fish and marine mammals as sentinels for ocean health and develop new species as mechanistic models

A variety of marine species and habitats are excellent indicators or sentinels of environmental stress and potential health threats for humans. Biological observing systems can serve as integrative indicators of: 1) the movement of toxics and pathogens through marine ecosystems; 2) the effectiveness of pollution control measures; and 3) emerging or unexpected threats. The scope and sensitivity of these observing systems needs to be improved. Marine organisms also serve as informative animal models for investigations related to human physiology and mechanisms of toxicity or disease processes. Research should focus on optimizing existing marine animal models for investigations that lead to improved understanding of human disease processes and health effects. Efforts should also be directed toward developing new species as mechanistic models for study of diseases, toxicology, physiological and biochemical processes relevant to human health. Research should integrate the use of microarray or molecular technology into sentinel surveillance systems by expanding the use of genomic and proteomic tools for rapid detection of multiple microbes and toxicants. This information is needed to unravel mechanisms of ocean-related health effects in sentinel species that are particularly indicative of likely human effects.

Research Focus 18. Evaluate the effects of changes in the distribution, abundance and virulence of threats to human health on socio-economic indicators

The consumption of certain types of seafood (sometimes within specified quantity restrictions) has been documented to have positive health effects, while consumption of other types of seafood and exposure to the marine environment is detrimental. It is important to develop a better understanding of the relationship between human exposure to pathogens, toxins and contaminants and the resulting health effects. These relationships should then be analyzed and mapped with socio-economic indicators such as loss or gain of commercial and recreational values, community impacts, and changes in health status or mortality rates.

IV. NEAR-TERM PRIORITIES

The RPT in collaboration with Center researchers, developed six near-term (2–5 years) priorities, each with equal weight, to focus initial research efforts. However, these efforts do not preclude other activities towards all 18, longer-term (2–10 years) research priorities. These near-term priorities were chosen based on three primary criteria: 1) a sense of urgency or critical management importance in the near-term; 2) the project provides technical or conceptual advances important for a range of identified research priorities; and 3) Center capabilities support the rapid development of the project. Opportunities for collaboration across NOAA line offices are present within the near term priorities, and each of the priorities reflects scientific, national, regional and local considerations. Additional information about the relationship of the near term priorities to the 18 overall research foci NOAA program components, and national plans is included in the Appendix.

These near-term priorities share a common need for the development of alternative future scenarios. For example, climate change is predicted to decrease stream flows, increase stream temperatures, raise sea level, lead to ocean acidification and alter ocean current patterns in the region. At the same time, human population growth will lead to increased loading of toxic pollutants as well as increased demands by coastal communities for clean sources of water and protection from erosion. An emerging challenge for NOAA and other natural resource management agencies at all levels is to make appropriate decisions in the face of these changes. Developing likely scenarios for future climate change, sea-level change, ocean acidification, patterns of human population growth, and other critical environmental characteristics that can be included or integrated with life-cycle, population dynamic, ecosystem, HAB and other related models is an integral part of each of these near-term priorities.

.Near Term Priority 1:

Conduct an integrated ecosystem assessment of Puget Sound as a pilot project.

<table>
<tr><td rowspan="8">
Near-Term Priority 1:

Conduct an Integrated Ecosystem Assessment (IEA) for Puget Sound</td><td>Scientific Considerations</td></tr>
<tr><td>An Integrated Ecosystem Assessment is an important cornerstone of implementing an ecosystem approach to management. A fully quantitative IEA has yet to be conducted. Initiating and completing one will provide key structure and guidance for future efforts. New scientific tools to determine ecosystem risk must be developed. Determination of appropriate benchmarks for ecosystem metrics is crucial and has never been attempted. There is a solid body of ecological information about the region that could underpin an IEA; similarly, it is tractable in scale.</td></tr>
<tr><td>National Considerations</td></tr>
<tr><td>IEAs have been identified as a NOAA-level priority and the focus of intense efforts by the Ecosystem Goal Team and the NOAA Priority Area Task Team. The NOAA Strategic Plan highlights the importance of ecosystem approaches to management, and the NOAA Ecosystem Goal Team has made IEAs a cornerstone of this effort</td></tr>
<tr><td>Regional Considerations</td></tr>
<tr><td>Current state-level efforts focus on Puget Sound restoration through the Puget Sound Partnership. NOAA's Western regional team has identified Puget Sound as the best location to conduct a Pilot IEA. The Western Governors' Agreement has also highlighted the need to develop a Puget Sound IEA as a means to address ecosystem concerns under their governance.</td></tr>
<tr><td>NWFSC Considerations</td></tr>
<tr><td>All NWFSC divisions have projects focusing on Puget Sound. The NWFSC is a leader in quantitative risk assessment and ecosystem modeling. NWFSC staff both wrote the IEA guidance documents for NOAA and led a multi-agency effort to describe the Puget Sound ecosystem and identify key research gaps. The Southern Resident Killer Whale Research Plan identifies understanding predator prey relationships as a key research need.</td></tr>
</table>

Both the NOAA 2006-2011 Strategic Plan and the Ocean Research Priority Plan highlight the importance of incorporating ecosystem principles in resource management. Specifically, a critical agency objective is to “Protect, Restore, and Manage the use of Coastal and Ocean Resources through an Ecosystem Approach to Management (EAM)” (NOAA, 2005). Integrated ecosystem assessments (IEAs) are a critical element of an EAM strategy. An IEA is a *tool* to synthesize a range of physical, chemical, ecological and socio-economic information through integrated analysis and ecosystem modeling. An IEA is also a *product* for managers and stakeholders who rely on scientific support for policy and decision making, as well as for scientists who want to enhance their understanding of ecosystem dynamics. Finally, an IEA is a *process* that begins with involvement of stakeholders to identify management priorities and objectives, moves to a quantitative assessment, and proceeds with an evaluation of management strategies. Through adaptive management, the process advances full circle by triggering an update of the assessment and identifying information and management gaps.

Puget Sound is well suited for a pilot IEA for several reasons. It provides easy access to the NWFSC, its scale is not overwhelming, and sufficient previous work in the Sound has been conducted to support substantial short-term progress. Additionally, it is currently the object of several state and regional efforts to improve ecosystem health. Finally, it will provide a means of testing how best to nest or link sub-sets of a large marine ecosystem to an IEA of the entire California Current LME.

The pilot IEA for Puget Sound will result in the following components:

1. Assessment of baseline conditions of the ecosystem
2. Assessment of stressors on the ecosystem
3. Forecast of ecosystem status with no management action
4. Forecast of ecosystem status under different management strategies
5. Evaluation of the success of management actions

IEAs will serve as a forum for integration of information collected by the NWFSC with other regional entities including other Federal agencies, states and academic institutions. IEAs will also identify critical data gaps, which, if filled, would greatly reduce uncertainty and improve our ability to fully employ ecosystem approaches to management.

<u>Near Term Priority 2:</u>

<u>Case study – Salmon, people, and instream flows under climate change.</u>

<table>
<tr><td rowspan="8">Near-Term Priority 2:

Case study – Salmon, people, and instream flows under climate change.</td><td>Scientific Considerations</td></tr>
<tr><td>A key element of ecosystem approaches to management is the inclusion of human needs, impacts and behaviors. This is particularly true for management of resources, like water, that play a fundamental role for both humans and other species of concern, such as salmon. Assessing changes in water supplies in both an ecological and a human context can provide an example for future efforts to incorporate humans into ecosystem analysis. Additionally, the effect of climate change on environmentally functional flows has not been fully explored.</td></tr>
<tr><td>National Considerations</td></tr>
<tr><td>Nationally, changes in summer water supplies will diminish throughout much of the US; examples of how to predict ecological and agricultural consequences and devise restoration strategies that enhance multiple ecosystem services are in high demand.</td></tr>
<tr><td>Regional Considerations</td></tr>
<tr><td>Climate change effects on water supplies are high priorities for municipalities and irrigators in the Pacific Northwest. In addition, these factors have been identified as potentially limiting for anadromous salmonids in a variety of recovery plans.</td></tr>
<tr><td>NWFSC Considerations</td></tr>
<tr><td>NWFSC staff have expertise in assessing impacts on salmonids; in addition, the newly-developed socio-economic team provides expertise in evaluating drivers of human behavior. Improving collaborations between these disciplinary areas will strengthen our ability to contribute to implementation of ecosystem approaches to management.</td></tr>
</table>

The rebuilding and recovery of Pacific anadromous salmonids is a major priority for NOAA Fisheries, and an important area of expertise at the NWFSC. In this region, competition between salmon and humans for freshwater flows, particularly in the summer, is likely to increase in the very near term as the relatively simultaneous effects of climate change and increasing human population growth are felt. Importantly, assessing appropriate management strategies for these fish and the streams and rivers they rely on is not dependent on biological information alone. Socio-economic factors such as patterns of population growth, economic development, and land use strongly influence the types of management actions that will ultimately be successful. A critical challenge is framing and evaluating the tradeoffs decision makers will face in balancing the conservation of freshwater ecosystems and flows for anadromous salmonids with human demands for safe drinking water, crop irrigation, recreation, and flood control. Resolving this fundamental tension will require that NOAA develop sound physical, biological and ecosystem models allowing the prediction of likely impacts on anadromous fishes, as well as social and economic models that provide valuation systems (e.g., the cost effectiveness of water recovery systems versus the ecological consequences of extracting larger amounts of freshwater for agriculture, power generation or industrial purposes). This project will work to develop and integrate these models to inform decisions regarding allocations of a diminishing resource under alternative climate change scenarios.

Products of this research will include:

1. Evaluation of climate change impacts on water availability in Pacific Northwest river systems.
2. Evaluation of present water diversions and withdrawals from regional rivers and their impacts on salmon populations.
3. Predictions of increased water demands for human uses.
4. Prediction of combined effects of climate-altered flows and water uses on salmon populations.

Near Term Priority 3:

Evaluate and implement new and alternative survey and monitoring methods for groundfish

<table>
<tr><td rowspan="8">Near-Term Priority 3:

Evaluate and implement new and alternative survey and monitoring methods for groundfish.</td><td>Scientific Considerations</td></tr>
<tr><td>Many of the species for which NMFS has responsibility are difficult or impossible to survey using currently available methods. This, in turn, precludes both immediate management needs, such as data-based assessments and catch-limits, and the information needed to include these species in models of ecosystem structure and function.</td></tr>
<tr><td>National Considerations</td></tr>
<tr><td>The Magnuson-Stevens Sustainable Fisheries Act was recently renewed, and includes requirements for science-based Annual Catch Limits for a total of 532 species. For 261 of these species, data to support these legally mandated ACLs are unavailable, often due to the challenges of conducting surveys.</td></tr>
<tr><td>Regional Considerations</td></tr>
<tr><td>The largest group of species in the Pacific Northwest for which large-scale surveys are difficult or impossible is groundfish. Efforts to develop catch limits on any time scale, or to assess species status, are extremely limited as a result.</td></tr>
<tr><td>NWFSC Considerations</td></tr>
<tr><td>Leadership for West Coast groundfish surveys has rested to date largely at the NWFSC.</td></tr>
</table>

The vast majority of groundfish stock assessments rely heavily upon bottom-trawl data from surveys or fisheries or both. However, many groundfish species use rocky or topographically complex habitat that is not effectively sampled by bottom-trawl surveys. Evaluating the status of groundfish stocks is thus hindered by the limited knowledge concerning groundfish habitat use and an inability to conduct trawl survey samples in areas that are topographical complex. Additionally, there are concerns about the effects of research trawling on benthic habitat, and the occasional large catch of overfished species by the bottom trawl survey can result in fishery restrictions. The use of alternative survey methods that are viable in untrawlable habitat, non-lethal, or that target early life history stages will greatly improve the coverage and completeness of groundfish surveys and reduce their ecological impacts. In recent years, feasibility studies and small–scale surveys have been conducted using Autonomous Underwater Vehicles (AUVs), Remotely Operated Vehicles (ROVs), submersibles, acoustic surveys, advanced tagging technologies, towed cameras, LIDAR, hook and line gear, and egg and larval sampling. The comparative costs and utility of these alternative survey methods for groundfish assessment are still being evaluated and significant further research and testing is needed. This analysis will coincide with continued work on habitat mapping, thus allowing the design of habitat-stratified sampling programs, An additional need is more rapid availability (from collection to dissemination) of both survey and fishery data. This would improve the ability of managers to respond to events, and would enhance the ability of stock assessment scientists to incorporate the most recent data into their evaluations. An integrated electronic recording system for fishticket and logbook information would allow for such real-time estimates of landings and discards.

Products of this research will include:

1. Information on the feasibility of alternative resource surveys and the usefulness of the resultant data.
2. The implementation and improvement of new and ongoing surveys for groundfish as well as other benthic organisms and habitats.
3. More rapid and accurate transmittal of monitoring data to managers and analysts.

Near Term Priority 4:

Predict population and ESU-level response to management, climatic and other impacts across the life-cycle of species of concern

<table>
<tr><td rowspan="8">Near-Term Priority 4:

Predict population and ESU-level response to management, climatic and other impacts across the life-cycle of species of concern.</td><td>Scientific Considerations</td></tr>
<tr><td>Management of ESA-listed and other species of concern has been limited by a lack of information about the response of species (or subunits) to specific human or natural impacts across a range of conditions. This information can also support multi-species prioritization efforts.</td></tr>
<tr><td>National Considerations</td></tr>
<tr><td>Several laws, including the Endangered Species Act, call for recovery of species of concern, and for jeopardy analysis of proposed actions. Understanding likely responses to proposed actions and conservation measures underlies these efforts.</td></tr>
<tr><td>Regional Considerations</td></tr>
<tr><td>Recovery planners for listed anadromous salmonids require information about the efficacy of restoration efforts and the impact of both anthropogenic and climatic changes to plan and implement recovery actions appropriately.</td></tr>
<tr><td>NWFSC Considerations</td></tr>
<tr><td>NWFSC staff have worked with NW Region staff in the development of both recovery plans and jeopardy analyses. This priority is intended to allow the NWFSC to approach these issues more systematically and support a multi-species perspective. Southern Resident Killer Whale Research and Recovery Plans identify these research areas as critical.</td></tr>
</table>

A critical question in salmon recovery and rebuilding is: “What management actions are necessary to achieve conservation goals?” Answers to this question depend on which species are the focus of restoration efforts, as conflicting priorities may emerge when comparing single-species analyses. This research priority is a Management Strategy Evaluation -- it couples modeling with empirical research and directed field studies to compare the likely outcomes of alternative management or restoration strategies (e.g., habitat restoration, pollution reduction, hatchery reform, harvest reform, altering hydropower operations) across a range of species and life stages. The tools for this research include life-cycle models that evaluate the diverse and dynamic habitats used by salmon throughout their life cycle, as well as interactions among species. Tagging of individuals reveals habitat use and preferences for particular life stages. Combined computer models and field studies will assist in evaluating the relative importance of alternative restoration strategies to the recovery and persistence of individual listed species, life history diversity, and potential tradeoffs among species. Studies that assess the health of individual animals (e.g., in response to environmental conditions, pathogens, toxic chemicals, etc.) and extrapolate this information to the population scale will help resource managers understand the extent to which degraded water quality can limit the recovery potential of species at risk of extinction. Products of this research will include:

1. A logical approach for evaluating multi-species benefits of river restoration actions
2. A suite of modeling tools that will enable use of the approach
3. Novel methods for incorporating the health and performance of individual animals into population-scale evaluations
4. Two applied examples of the approach and models culminating in a formal Management Strategy Evaluation for these two examples.

Results of this research will allow stakeholders to more realistically prioritize restoration or recovery actions, evaluate cost-effectiveness, and identify critical population bottlenecks.

Near Term Priority 5:

Develop rapid detection and improved prediction methods to identify pathogens, biotoxins, toxics and other marine impacts on human health

<table>
<tr><td rowspan="8">Near-Term Priority 5:
Develop rapid detection and improved prediction methods to identify pathogens, biotoxins, toxics and other marine impacts on human health</td><td>Scientific Considerations</td></tr>
<tr><td>Pathogens, biotoxins, and toxics pose a substantial risk to human health, and provide indicators of ecosystem status. These events can occur rapidly, and have effects on human health shortly thereafter. Developing prediction and detection methods will assist with both human health concerns and in evaluating overall ecosystem conditions. It can also potentially contribute to more precise and/or reduced impacts of closures on the shellfish industry.</td></tr>
<tr><td>National Considerations</td></tr>
<tr><td>The Harmful Algal Bloom and Hypoxia Amendments Act of 2004 reaffirms and expands the mandate for NOAA to advance the scientific understanding and ability to detect, monitor, assess, and predict HABs and to develop programs for research into the methods of prevention, control, and mitigation of HABs. The implementation of this act is also called for in the President's U.S. Ocean Action Plan.</td></tr>
<tr><td>Regional Considerations</td></tr>
<tr><td>The Pacific Northwest, and Puget Sound in particular, are likely to face multiple pressures (climate change and human population growth) that have the potential to increase risks of HAB events, toxic accumulation and pathogens.</td></tr>
<tr><td>NWFSC Considerations</td></tr>
<tr><td>The NWFSC has been designated as a Center of Excellence for Research in Oceans and Human Health, with strong research programs in toxics, biotoxins, microbiology and disease.</td></tr>
</table>

The development and implementation of new technologies to ensure a safe and healthy supply of seafood has been a core scientific mission at the Center for decades. Recent advancements in the fields of genomics, proteomics, bioinformatics, sensor technology, analytical chemistry, and ocean observing systems have greatly expanded the potential for rapid and sensitive detection of pathogenic organisms, marine biotoxins, and chemical contaminants. As indicated by the Center's coordinated response to Hurricanes Katrina and Rita, the timely analysis of seafood quality can be critical for coastal economies (e.g., reopening the shrimp fishery in affected areas of the Gulf of Mexico). To continue to meet the regional and national analytical needs of NOAA, the Center must remain at the forefront of emerging technologies. This will require scientific expertise that spans nearly the full spectrum of biological organization, from genes to organisms to coastal ecosystems. Ongoing investments in analytical infrastructure, such as those made possible by NOAA's Oceans and Human Health Initiative, will be necessary. Moreover, the Center must meet the complex challenges posed by bioinformatics – that is, the need to navigate vast genomic, transcriptional and proteomic datasets. To this end, expanded collaborations with academia and other partners will be essential. A broad aim will be to develop new diagnostic tools and then integrate these into *in situ* monitoring programs and ocean observing systems. Components of this research include:

1. The deployment of remote sensing systems;
2. The development of more sensitive laboratory methods to detect harmful agents in water and tissues;
3. The biologically-based monitoring of sentinel species in estuaries and the nearshore marine environment.
4. Equally important is the need to develop new and more accurate forecasting capabilities. This includes forecasting over the near term (e.g., seasonal beach and shellfish closures in response to HABs, pathogens or contaminants).

Over longer timescales, the Center should continue to monitor and forecast emerging threats to human health. These emerging threats include, for example, the persistent bioaccumulation of brominated flame retardants at increasingly higher trophic levels in the marine food web.

Near Term Priority 6:

Initiate an ecosystem-based aquaculture research program

<table>
<tr><td rowspan="8">Near-Term Priority 6:
Initiate an aquaculture research program</td><td>Scientific Considerations</td></tr>
<tr><td>Improving culture techniques for marine fish larvae, juveniles and adults will also support production of fish for laboratory studies on high priority areas such as effects of ocean pH on marine organisms, bioenergetics and nutrition of marine fish, reproductive biology of marine fish, and effects of contaminants on fish behavior, growth, development, physiology, immunology, disease resistance, & reproduction. This information will be valuable to management of fish in their native habitat as well as development of aquaculture technology. Additionally, research and improved technologies focused on ‘best practices’ (in terms of sustainability, genetics, invasive species, and environmental impacts) are needed because these issues are not being addressed in many other countries with rapidly growing aquaculture industries.</td></tr>
<tr><td>National Considerations</td></tr>
<tr><td>The recently-passed National Offshore Aquaculture Act mandates the development of aquaculture in U.S. waters, with strict environmental guidelines. Given this high priority for development of marine aquaculture in the US, it is critical that NOAA Fisheries take a lead role in assessing risks and benefits, assist in development of fish culture practices that minimize negative ecological impacts, and provide science needed for regulation of this developing industry. Both the NOAA-Strategic Plan and Ocean Research Priority Plan identify marine aquaculture as a priority research area.</td></tr>
<tr><td>Regional Considerations</td></tr>
<tr><td>Recovery plans for listed species in the Pacific Northwest call for additional analysis of the ecological effects of aquaculture, and incorporation of aquaculture into ecosystem and species-specific models.</td></tr>
<tr><td>NWFSC Considerations</td></tr>
<tr><td>The Center is in a unique position to make contributions in marine aquaculture research because of its facilities for marine fish culture and expertise of staff in fish nutrition, behavior, husbandry, physiology, ecotoxicology, and marine ecology. The NWFSC has capabilities to address technological development as well as issues related to regulation. The Center is doing more aquaculture-related work than any other science center within NOAA-Fisheries and has a responsibility to take the lead in this area within the Agency.</td></tr>
</table>

Demand for seafood in the United States and worldwide is rapidly expanding and creating an incentive to increase harvest rates to meet the growing markets. The development of sustainable, ecologically-sound marine aquaculture in the United States is one of the highest priorities within the Department of Commerce. Aquaculture is a matrix program at NOAA, and Center scientists have been included on the matrix management team since its inception. The National Offshore Aquaculture Act is the top agency legislative priority. Innovative approaches to develop ecologically sound commercial aquaculture industries are needed to provide seafood for a growing human population, particularly in view of current recommendations for increased fish consumption to promote human health. Expansion of the national aquaculture industry requires research on a number of topics to ensure a minimum of ecological risk and a maximum of opportunities for economically viable development. In particular, recent proposed legislation points toward development of aquaculture in the Exclusive Economic Zone (EEZ), which will present new technological and regulatory challenges.

Aquaculture systems must be secure, efficient, cost-effective, and reliable, and their products must be healthy, free of disease and chemical contamination, lack deformities, and perform well in grow-out systems. Furthermore, aquaculture programs must be able to quantify their impacts on the natural environment within a risk management framework. The United States lags behind Europe and Asia in marine aquaculture technology and investment. There is currently no coordination in the sector in the United States and few aquaculture facilities operate above a laboratory scale. Commercial marine aquaculture finfish species that have greater potential than currently valued include Atlantic salmon, sablefish, lingcod, Atlantic and Pacific cod, red snapper, the sea breams and bass, flatfishes, mullets, and now some ocean pelagic fishes. Additional areas of important research include assessing the ecological risk of aquaculture, and identifying positive and negative links between human health and aquaculture practices.

The products of aquaculture research will include:

1. Development of culture techniques for a variety of cultured finfish and shellfish that ensure economic efficiency, seafood safety and quality.

2. Development of sustainable feeds that will reduce reliance on fish meal and fish oils as they become limiting for expansion of fish culture.

3. Development of environmental and monitoring guidelines to ensure sustainability and minimize ecological risks associated with aquaculture programs.

4. Scientific evaluation of the potential for responsible enhancement of marine stocks.

V. NECESSARY TOOLS

Implementing these research priorities will require the active development and improvement of Center capabilities in three areas: 1) technologies that allow scientists to observe and analyze ocean environments; 2) models to evaluate alternative scenarios and effects; and 3) some targeted changes in the data management, laboratory facilities, and field sampling infrastructure of the Center. A detailed description of the specific tools that the Center will need to develop is provided in Appendix C based on these three categories.

Technologies: Ocean environments and the organisms that inhabit them are notoriously challenging to observe –the scales are large, the organisms are often fragile, cryptic or unknown, and the habitat is a demanding and expensive one for humans to occupy for prolonged periods of time. Technology development that enables us to gain information remotely about oceanographic or other environmental conditions and about organisms across wide areas or in inaccessible habitats is clearly a high priority. Other key technologies include those that allow us to understand the interaction between organisms of interest, their habitats and humans.

- *Large-scale observational systems and techniques* such as ocean observation systems, remote sensing (satellites, multi-beam, LIDAR, hyperspectral imagery, etc), and remote and autonomous underwater vehicles facilitate the observation and mapping of ocean conditions at the ecosystem scale, and provide mechanisms for ground-truthing where access is difficult and costly.

- *Tagging and remote sensing technologies for individual organisms* have progressed rapidly over the past several decades as the power of computers has increased, electronic components have decreased in size, and the ability to detect signals remotely has increased. The ability to detect and identify individual animals greatly enhances the ability to track movement, survival rates and other demographic and behavioral information. These data are needed to make decisions on altering management strategies for protecting listed stocks.

- *Population structure and patterns of movement* can be determined by recent advances in genetic techniques, isotopes, and the identification of parasites.

- *Landed catch, bycatch and discard* has not been systematically monitored for some West Coast fisheries until recently. The West Coast Groundfish Observer Program (WCGOP) was established in 2001 to improve estimates of total catch and discard in West Coast fisheries. The program deploys over 40 observers and collects at-sea data from limited-entry trawl and fixed gear fleets as well as from open access, nearshore, prawn, and shrimp fleets. An integrated electronic recording system for fishticket and logbook information for the Pacific coast would vastly improve the ability to track groundfish catches in season and to produce real-time estimates of landings and discard needed for timely management decision-making.

- *Geographically or spatially linked analysis and interpretation:* Marine and freshwater research efforts increasingly rely on large geospatial data sets to address issues such as individual and population-level movement patterns, climate change effects on stream flows, ocean circulation patterns, and patterns of current and future land use. Maintaining up-to-date GIS capabilities, including software, databases and support staff, will be a critical element of conducting the landscape (and oceanscape) scale analyses that contribute to multiple goals.

- *Socio-economic surveys* are the primary means of collecting information and data used to describe the interactions between humans and living marine resources. Two important policy themes for socio-economic analysis are commercial and recreational fisheries, and conservation and ecosystem management.

- *Bioinformatics* include advances in genomic technologies; sensors that can be used for the rapid detection of pathogens, harmful algae, and toxins; and associated instrumentation. Molecular techniques that have been used to identify species and stock structure can also be used to assess gene expression patterns in the assessment of ecosystem function. Development of shared computational bioinformatics tools requires hardware, software and personnel with specific expertise. Presently the Center has hardware and software for a bioinformatics core facility. Personnel with specific expertise in bioinformatics are needed.

Models and the Data to Support Them: Modeling provides a framework in which to describe a system in detail or in general, to evaluate the effects of alternative actions, and to characterize the sensitivity of a system to perturbations – all of which are key for effective management. However, it is critical that these models are supplemented by experiments, directed observational studies and other research efforts to develop the data to establish parameters and evaluate the models. Several types of models are being used or developed at the Center:

- *Socio-economic models* are necessary to measure the benefits provided by natural resources, and how those benefits may changes as resource flows changes. Economic valuation and behavioral are needed to evaluate both use and non-use values, as well and regional economy, community and social impacts. These models should be linked to biological and ecological models of habitat distribution, abundance and quality.

- *Risk assessment models* attempt to analyze biological information in the face of limited data, and are limited by the difficulty of capturing biological complexity through models with many parameters. Research is needed to incorporate additional biological information into simple models, and to develop methods for incorporating or specifying uncertainties.

- *Population dynamic models* can be quite sophisticated, but substantial improvement in their utility can be achieved by developing ways of including information on spatial dynamics, the role of size and age composition in population demographics, and demographic and environmental stochasticity. At the ecosystem level, forecasting these impacts requires understanding complex dynamics controlling: 1) productivity of populations within various trophic levels, 2) predator-prey interactions, 3) connectedness of sub-populations, 4) impacts of natural climate variation and change, and 5) anthropogenic pressures.

- *Evolutionary models* may be valuable for analyzing population dynamics of, and genetically-based changes in, exploited species or key components of disturbed ecosystems. Evolutionary approaches to this problem should link multivariate genetic models of life history variation to analyses of population dynamics and viability.

- *Models to support ecosystem approaches to management* have generally fallen into three categories: 1) models aimed at prioritizing sites for conservation, 2) data-driven statistical models that estimate population or community dynamics, and 3) food web simulations.

- *Models treating habitats and landscapes* contribute to effective recovery planning by analyzing how habitat restoration actions will affect population viability and sustainability. Few models are available to simulate how natural processes form and sustain habitat. Integration of data on the quantity, quality and spatial distribution of habitat can improve the predictive powers of assessment models and guide fishery management.

- *Essential Fish Habitat (EFH) designation and delineation models* are being developed in response to the requirement of the Magnuson-Stevens Fishery Conservation and Management Act that regional management councils describe EFH in their fishery management plans. The councils must minimize impacts on this essential habitat from fishing activities, and councils and other Federal agencies must consult with the National Marine Fisheries Service about activities that might harm EFH.

- *Integrated modeling approaches* overcome many of the limitations described above and achieve the crucial goal of integrating physical, chemical, ecological, and fisheries dynamics in a three-dimensional, spatially explicit domain. In these models, ecosystem dynamics are represented by spatially-explicit sub-models that simulate hydrographic processes (light- and temperature-driven fluxes of water and nutrients), biogeochemical factors driving primary production, and food web relations among functional groups. These models represent key exploited species at the level of detail necessary to evaluate direct effects of fishing, and they also represent other anthropogenic and climate impacts on the ecosystem as a whole.

Infrastructure: The Center maintains the infrastructure for many critical data management functions, laboratory facilities, and field sampling.

- *Data management responsibilities of the NWFSC* are enormous, and are used to efficiently generate science guidance products such as ESA status reviews, MSFCMA stock assessments and IEAs. The Center must also have the capacity to archive, compile and inter-relate numerous independent data types running into the millions of records. A standardized protocol for data security needs to be developed and supported to protect the Center's huge investment in electronic data. The entire Center staff needs to be involved in a discussion of how to identify and support Data Stewards for research and corporate data that are maintained by Center staff; and the Center needs to develop a data management strategy that meets the needs of multiple scales of data management.

- *Laboratory Facilities* are important in achieving research goals. Although many facilities are already operational, mechanisms to improve access and provide adequate technical support are needed. Some identified needs include:

    - Diet and tissue analysis laboratories and support personnel
    - Wet labs
    - Fish culture facilities

- *Field sampling support:* Large-scale, interdisciplinary ocean research requires the use of large, sophisticated research vessels capable of extended cruises in rough sea conditions. The broad nature of oceanographic sampling requires many sensors of atmospheric and ocean conditions and the ability to deploy and retrieve many gear types. Estuarine and riverine sampling do not pose the logistic limitations in ship size as does ocean sampling, but these other habitats also face shortages of small vessels.

- *Gear storage needs for sampling gear including ATVs, equipment, boats, nets, trawls and other gear have become more acute in recent years.*

The Center has made substantial investments into the tools necessary for long term research that will greatly benefit the near-term priorities for research. While some upgraded and new laboratory facilities, equipment and personnel are needed to achieve research objectives, the evaluation and possible reorganization of existing facilities and gear availability can help facilitate research.

IMPLEMENTATION STRATEGY

NWFSC Research Plan Vocabulary (A brief reminder):

Themes: Areas of scientific inquiry to guide the Center's research and that can be used to align this research with national directives. These are crafted to be broad and to have a relatively long life-span (10-20 years).

Research foci (formerly called 'research priorities'): More specific areas within themes that are particularly relevant for the NWFSC to pursue, given our geographic location, regional science needs and similar considerations. These specific areas are also relatively long-term.

Near-term priorities: Discrete and typically interdisciplinary research projects that will 1) provide results of immediate management relevance; and 2) provide significant advances in one or more identified theme areas and one or more research foci. These near-term priority projects are intended to be finite, produce results and disband in a 2-3 year time frame.

Goals of Implementation Process:

- Better link NWFSC research to PPBES to develop new funding lines and enhance current lines as needed.
- Provide a process that is helpful for managers in research planning, implementation, and other managerial duties.
- Minimize the administrative burden associated with PPBES by tying it to meaningful research planning.
- Close the loop on staff-level brainstorming activities conducted in FY06.
- Initiate novel research activities as prioritized in the Research Plan.

Implementation Proposal Overview:

- Budgets and personnel are maintained in the short-term, and the center moves toward developing base funding for all staff salaries in the long-term
- One-time retreat to determine administrative structure for implementation
- Near-term priority projects
    - are implemented in a staggered fashion so that there are always projects at each stage (e.g. starting, mid-way, completing)
    - include funding for one post-doc for 2-3 years (a total of $420K/year = 0.5% of annual NWFSC budget, including reimbursables)
- Regular, simple, structured reporting will assist with PPBES and other data calls.
- Annual research planning retreats serve to:
    - Identify long-term research goals and long-term data set needs.

    - Plan research goals and identify needs to complete those goals at the 2-3 year time frame (precursors for subsequent year AOPs and milestones).
    - Provide opportunities for RO and HQ staff to provide input to research projects.
    - Allow coordination across themes and near-term priority projects.
    - Confirm milestones and AOPs for the upcoming fiscal year.
- Structured updating of research plan
- Each theme and near-term priority project from its inception works with relevant outreach and education groups at the center to develop and implement outreach and education plans

A diagram of the structure for reviewing and revising the research plan is presented in Figure 2.

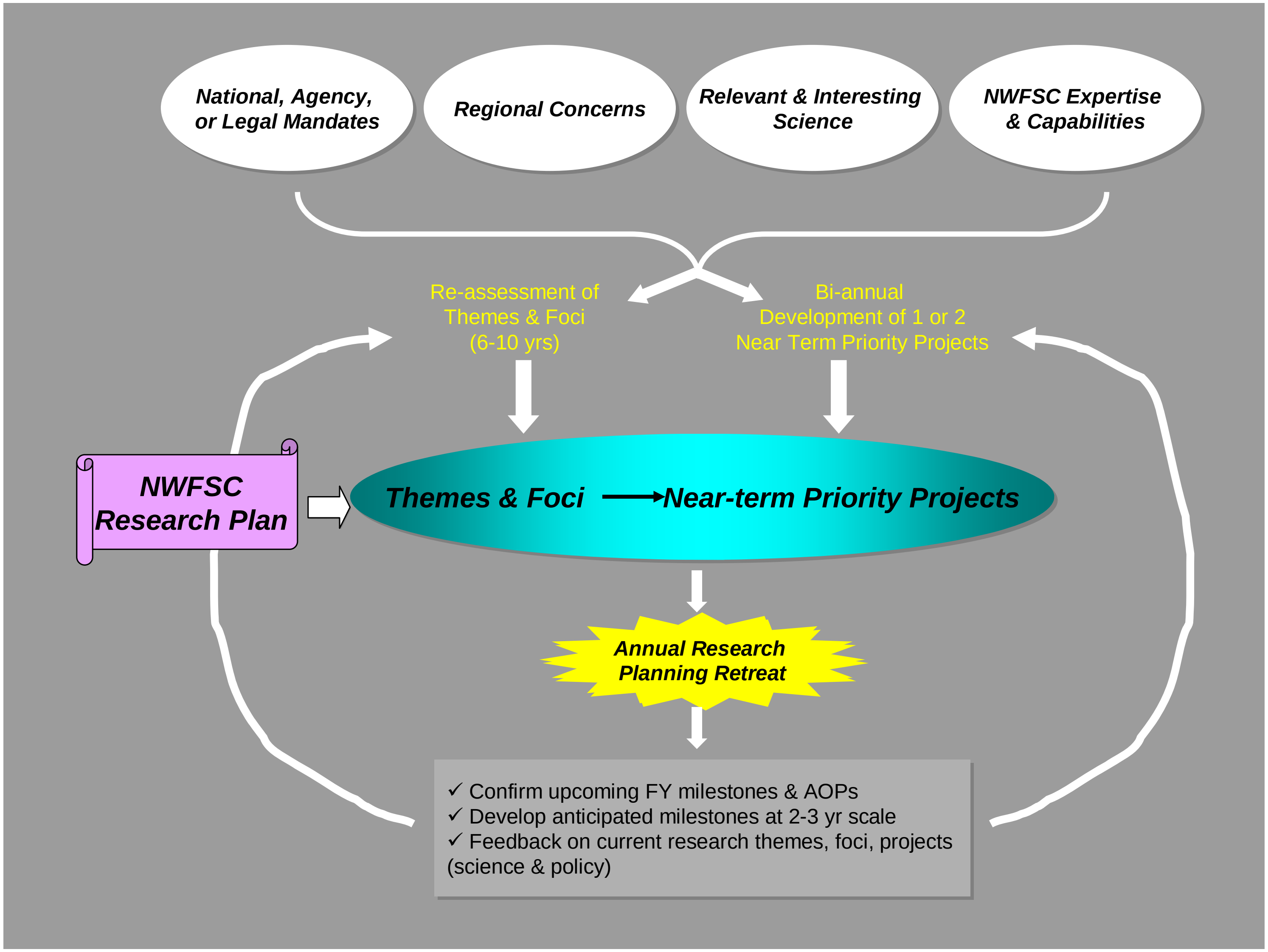

National, Agency, or Legal Mandates
Regional Concerns
Relevant & Interesting Science
NWFSC Expertise & Capabilities
Re-assessment of Themes & Foci (6-10 yrs)
Bi-annual Development of 1 or 2 Near Term Priority Projects
NWFSC Research Plan
Themes & Foci
Near-term Priority Projects
Annual Research Planning Retreat
✓ Confirm upcoming FY milestones & AOPs
✓ Develop anticipated milestones at 2-3 yr scale
✓ Feedback on current research themes, foci, projects (science & policy)

Figure 2

Specific Proposal Elements

Budgets and Personnel:

- In the short-term, divisions continue with close to current funding and structure. (This includes current plan to combine REUT and EC). SD may re-apportion some funds to ensure that near-term priority needs are met (e.g. by allocating money to pay for salary of a staff member paid off reimbursables who is contributing to a near-term priority).
- Funding line and administrative support for near-term priorities should be housed in a single division; the project lead would have control over the budget. Typically, the funding line would be administered through the project lead's division.
- Performance plans will include links to research themes, foci and near-term priorities as appropriate
  - DDs and PMs – one element includes direct ties to relevant themes, foci or near-term priorities
  - Research scientists – elements will identify specific themes, foci or near-term priorities contributed to.
  - Technical staff – position description will include list of themes and foci being supported
  - OMI/SD – will develop and fill out straightforward list of employees, affiliation with themes and foci (and thus, goals and capabilities) – this will help with various PPBES data calls.
- Performance and work plans will include time for staff to convert tech memos and reports into peer-reviewed publications.
- Moving the NWFSC toward funding all salaries with base funds.
  - Develop a committee dedicated to Center succession planning, to identify current and future gaps in expertise and skills, including gaps that will result from the attrition of current staff, and ways to recruit and fill these positions. Base funding for FTE positions should flow from support needs identified at the research planning retreat.
  - Center management will use priority information needs, coupled with personnel and other support needs developed in research retreats to further increase base funding through PPBES program. New funds should go primarily to staff salaries
  - Retirements, etc.
    - If not to be replaced, and on base funds, money goes into overall pool to cover salaries
    - If on reimbursable funds – replace with temporary or contract appointment (life of reimbursable).

Developing an Administrative Structure – a One-Time Retreat

Key to the success of implementing the research plan and linking center goals and research more explicitly to funding mechanisms at the agency level will be developing appropriate administrative and support structures that both allow the collaborative work that will be necessary both for the work that will advance identified research themes and are supported by NWFSC leadership.

We suggest a one-time retreat, to last no longer than one day to be held in the near-term

- Goal – develop methods for sharing staff and resources contributing to identified research themes and foci that division directors can and will support.
- Attendees – Division directors, SD, DSD and staff from SD, OMI and the RPT.
- Structure –
  - Facilitated
  - Provide 2-4 straw proposal structures, e.g.
    - Division directors each lead one theme, Program Managers and Supervisory Team Leaders each lead scientific and technical activities specific to a focus; or
    - Themes are each led by an individual other than DDs; or
    - Themes are overseen by a small "board of directors"
- Product – consensus agreement on specific structure to further research themes and near-term priorities (no one gets out alive until it's done).

Implementing Near-Term Priorities (NTPs):

Near-term priority projects will be led by a NWFSC researcher; funding for 2 years of a post-doc will be provided for each near-term priority. In addition, 3-5 NWFSC staff may be formally affiliated with each priority. Some guidelines for NTPs are:

- Scope of work should be attainable within 1-3 years. Typically, these projects will spawn subsequent work, but the NTP itself should be discrete, well-definited, and finite
- NTPs must include team members from at least three divisions
- External review and input must be incorporated into the workplan for each NTP
- Process for set up:
  - Identify project lead and "board of directors" (SD/OMI, subject to approval by CMT)
  - Develop scope of work (Project lead, SD/OMI, board of directors)
  - Recruit and choose team members
    - NWFSC staff (SD/OMI, board of directors)
    - Post-doc (Project lead)
    - External contributors as necessary (Project lead)
  - Develop plan of work (Project team) -- this should include time for turning products into peer-reviewed publications

Near-term priorities should be initially be implemented in a staggered fashion, so that some are finishing up while others are mid-way. Ultimately, every 1-2 years a new NTP will be initiated. Currently identified outputs for each NTP are as follows. However, we anticipate that these outputs may change as the scope and plan of work are refined.

1. Conduct an IEA of Puget Sound. (This project is underway)
   - Assessment of baseline conditions of the ecosystem
   - Assessment of stressors on the ecosystem
   - Forecast of ecosystem status with no management action
   - Forecast of ecosystem status under different management strategies
   - Evaluation of the success of management actions

First steps/products: (Team is formed)/develop more specificity in EAM goals; characterize key indicators.

2. Salmon, people and instream flows under climate change.
   - Evaluation of climate change impacts on water availability in Pacific Northwest river systems.
   - Evaluation of present water diversions and withdrawals from regional rivers and their impacts on salmon populations.
   - Predictions of increased water demands for human uses.
   - Prediction of combined effects of climate-altered flows and water uses on salmon populations.
   - Predicted evolutionary or plastic responses of salmon populations to these effects.

First steps/products: Identify team lead and board of directors/Develop database of water withdrawals, uses, and stream flows in key PNW river systems.

3. Develop new and alternative survey and monitoring methods for groundfish.
   - Information on the feasibility of alternative resource surveys and the usefulness of the resultant data.
   - The implementation and improvement of new and ongoing surveys for groundfish as well as other benthic organisms and habitats.
   - More rapid and accurate transmittal of monitoring data to managers and analysts.

First steps/products: Identify team lead and board of directors/identify 4 new resource survey methods

4. Predict population and ESU-level response to one-three anthropogenic, management, climatic and other impacts across the life-cycle of species of concern.
   - Development of a comprehensive, consistent approach for evaluating multi-species benefits of river restoration actions.

- Development of a suite of modeling tools to evaluate this approach, including life-cycle models for key species that incorporate population and community responses to restoration actions.
- Initiation of field studies that evaluate the effects of alternative restoration strategies on abundance, productivity, diversity, and special structure.
- Comparison of alternatives using formal Management Strategy Evaluation methods involving at least two examples.

First steps/products: Identify team lead and board of directors/identify one-three impacts for evaluation.

5. Improved capabilities to identify, predict, and ultimately reduce the impacts of pathogens, marine biotoxins, and chemical contaminants on human health
   - Improve analytical methods for detecting harmful agents in seafood and the environment
   - Develop and enhance ocean observing systems and the biological monitoring of sentinel species.
   - Expand the use of biomedical research models to more accurately determine the impacts of pathogens and toxics on human health.
   - Develop and refine conceptual and quantitative models to forecast risks to public health over different spatial and temporal scales.

First steps/products: Identify team lead and board of directors/identify one-three specific concerns for investigation.

6. Aquaculture research program
   - Development of culture techniques for a variety of cultured finfish and shellfish that ensure economic efficiency, seafood safety and quality.
   - Development of sustainable feeds that will reduce reliance on fish meal and fish oils as they become limiting for expansion of fish culture.
   - Development of environmental guidelines to ensure sustainability and minimize ecological risks.
   - Scientific evaluation of the potential for responsible enhancement of marine stocks.

First steps/products: Identify team lead and board of directors/Identify 1-3 species for initial investigation.

Regular, Simple, Structured Reporting

A key to using the PPBES program effectively will be 1) ensuring that NWFSC inputs to the system are tied to the research plan (which, in turn is tied to relevant NOAA priorities) and key research efforts at the center; and 2) ensuring that administrative (paperwork) requirements for researchers, NTP and theme leads are simple, well-supported and meaningful.

- Annually

    - OMI/SD --Ensure that AOPs, milestones, other PPBES requirements are submitted to HQ
    - OMI/SD -- Submit upcoming projects/priorities to PPBES process (prime the pipeline)
        - Informed by research retreats, support needs
- Quarterly – Researchers, theme, focus and NPT leads report progress
    - OMI/SD – develops simple, checkbox template for reporting research progress; provides lead-specific template with relevant AOPs and milestones. This will include both "official" milestones (for the current FY) and upcoming milestones identified in the research retreat (below)
    - OMI/SD and division coordinators – provide each budget manager with a report on spending and allocations in each budget category
- Monthly – request for any changes from plans

Annual Research Planning Retreat

- Attendees include:
    - Division directors, PMs, supervisory TLs
    - Theme leads
    - Near-term priority leads
    - Key research scientists (defined by DDs, PMs, theme leads, and near-term priority leads)
    - Center management (need science director, facilities, IT)
    - Representatives from RO (One or more from each division)
    - Representatives from HQ (One from each goal team and/or Steve Murawski's shop, minimum; hopefully one from each relevant program. May involve some reps outside of NMFS)
- Pre-work
    - NWFSC
        - Near-term priority teams – develop list of proposed tasks at one year and two year scales
        - Theme leaders [Research foci leaders? No] –
            - Compile one-page "statement of necessity" for NOAA-Fisheries
            - Compile one-page "state of the science" (should not take more than two hours).
            - Work with research focus leaders to develop key information needed at the one, two and three year scales.
                - Tech advances, if any
                - Conceptual advances
                - "Information" or data needs
        - Hold one meeting (phone or in-person) with HQ reps developing links between national priorities/local concerns
            - <<perhaps the "statement of necessity" should go here?
        - OMI/SD

        - Work with facilitator to structure meeting appropriately, ensure that participants are adequately prepared
        - Develop template for information needs, and another for infrastructure, personnel, etc. needs (to be filled out at meeting).
  - RO
    - Each division develop list of priority information needs at one, two and three year scales (these will be more specific at the shorter scales, and less specific at the longer scales)

- Agenda
  - Whole group
    - Status update – each theme and each near-term priority, together with proposed tasks and information needs
    - HQ reps – <u>brief</u> discussion of national priorities, translated into needs at local scale
    - RO reps – Present priority needs
    - Facilitated discussion of areas of overlap, with the goal of ???
  - Break into theme groups
    - Near-term priority reps go to most-closely affiliated theme (or two reps split between themes if necessary)
    - RO and HQ reps go to most closely-affiliated theme or float; their role is to provide feedback about usefulness, prioritization
    - Revise one, two and three year priority information. These lists should be ordered/prioritized. Include discussion of any changes or information to be gained form near-term priority projects
    - Develop list of needs to develop priority information – infrastructure, personnel, equipment, field time (this list should also be prioritized).
  - Whole group (facilitated discussion)
    - Each theme group – overview of final prioritized list, and needs
    - Feedback and adjustments to final prioritized list of information needs/project priorities
    - Feedback, adjustments to support needs – should focus on ways to economize, double-up, etc.
  - Wrap-up
    - Identify next steps
- Products
  - Information priorities -- AOPs and milestones should be extractable from these, subsequent year AOPs and milestones should be foreshadowed
  - Prioritized list of support needs for upcoming projects
- Follow-up work
  - Theme/research focus leads
    - communicate with theme and research focus teams
    - Develop quarterly-schedule, submit to SD
  - OMI/SD – with researchers

    - Ensure that AOPs, milestones, other PPBES requirements are submitted to HQ
    - Develop and implement outreach plans for appropriate (all???) projects or themes
  - OMI/SD – with HQ reps and researchers
    - Submit upcoming projects/priorities to PPBES process (prime the pipeline)
      - Informed by support needs
  - Researchers – do the work!
  - OMI/SD – develop simple (checkbox) template for reporting quarterly progress

Updating the NWFSC Research Plan

- As needed (e.g. Hurricane Katrina, or wave power in Puget Sound)
  - CMT can opt to add a near-term priority at any time. However, when a new near-term priority is adopted 1) new monies from HQ must be received to fund the project; or 2) other projects in which relevant personnel are involved will be identified as lower priority. In both cases, budgets and performance plans will be revised as necessary.
- Annually or Bi-annually
  - Small team (appointed by SD/OMI) convenes for no greater than 2 months to identify 1-2 new near-term priorities. Source documents include:
    - Planning retreat results from previous years
    - National plans (ORPP, NOAA strategic plans)
    - State of the science reports from theme leads

    Initiation of these projects will be staggered to coincide with project completion schedules to ensure that: 1) near-term priorities at all stages of completion are underway; and 2) that a reasonable number of near-term priorities are being conducted (no more, no less) at any one time.
- Every 6-10 years
  - Small team convenes (no more than 7 months) to review science needs and revise or replace research themes and foci as necessary.

Education, Outreach, and Marketing

Ensuring that NWFSC work is used by the policy, management and public communities as well as the scientific community is critical for the ultimate use and application of NWFSC products. Because one of NOAA's missions is to develop an informed and scientifically literate population, we propose that each research theme and NTP develop an education, outreach and marketing plan at its initiation.

Definitions

Education, and in particular informal education, and outreach are often confused. While the distinction between education and outreach can be blurry, from our perspective what distinguishes education from outreach is the goal or intent of the activity or program that is undertaken. With **outreach** the goal or intent is to inspire audiences, to raise awareness of or interest in NOAA, and to develop an appreciation for and exposure to science or a specific topic area. With **education**, however, the goal or intent is to go beyond awareness, appreciation, and exposure to increase learning in specific areas.

Education is often divided into formal or informal education. In **formal education**, learning takes place as part of a structured educational system where students are required to demonstrate proficiency in the process of reaching an end goal. In contrast, with **informal education**, learning takes place outside of a structured educational system, and is the choice of an individual. Informal education can take place in a variety of settings (e.g., a museum or park), and while participants may not be required to demonstrate proficiency, all informal education activities and programs have clearly defined objectives.

Outreach and Marketing

- At the initiation of each theme and near-term priority project, lead and interested team members meet with identified member of the outreach team and education council (see below) to develop an outreach and education plan. Some aspect of at least each of the following audiences should be included:
    - Headquarters staff involved in long-range science planning and budgeting
    - Regional office end-users of new scientific information
    - Non-governmental organizations (industry, environmental, others)
    - The public (private citizens)
    - Tribal organizations
    - The regulated community
    - Educators
    - Congress/ NOAA Congressional liaisons

  Outreach and education teams should meet with each theme and NTP at least 2x/year to update and be updated.
- Outreach team and IT will also set up a website with internal and external components for each NTP and theme.
- Responsibility for education and outreach will be joint between team members and the outreach and education teams
- Outreach and education components will be included in individual performance plans
- NWFSC should consider hiring or developing expertise in media relations.

Education and Science Literacy

- Establish a NWFSC Education Council. Their role will be to promote, track, and coordinate formal and informal education activities at the NWFSC. They will ensure that education activities evolve in the direction outlined in the NWFSC Education Plan.

- NWFSC Education Council will work to ensure that one or more proposals is presented each cycle to the NOAA mini-education grants project. This may involve personal arm-twisting. They will also be available to help PIs include education components in research grants.

- Education and communication staff will work to identify the unique educational resources at the NWFSC. Many institutions are able to teach the salmon life cycle. We are unique in our technological, ocean, and freshwater expertise.

- NWFSC staff will be allowed to use work time for educational and outreach activities and will receive “credit” in their performance plans.

- Work plans may also include short-term relief to translate high-level scientific materials into curriculum that can be used in formal education settings. Such projects should involve close collaborations with formal education institutions.

- NWFSC should consider hiring or developing expertise in translating high-level scientific materials into formal and informal educational materials and opportunities.

Improving contact within NWFSC, RO, NMFS, NOAA

- Research planning retreats and outreach plans will be a primary vehicle for communicating with the NMFS NWRO.
- Implement routine announcements about papers and reports. Each time a product is completed a summary of the major findings and pdf of product sent to a set list of staff in the RO and HQ.

- Identify a point of contact or leader for each near-term research priority and/or theme at the NWFSC who will be responsible for making regular contact with a counterpart at Headquarters to provide information and discuss upcoming needs. This will form part of the outreach plan.
- Develop detail appointments, at least once per year, for NWFSC scientists at NOAA Fisheries Headquarters in Silver Spring MD. Rotational assignments lasting from 1-5 months could be designed to provide a link to Headquarters staff as they plan program budgets and execute the year’s work, and would allow Center staff to have a better understanding of Headquarters’ issues and work. Logistical support would be needed to enable most NWFSC supervisors and

managers to complete a detail, such as suitable housing, travel costs to visit or bring family members, and a period of relief from administrative duties upon return. This will require individual arm-twisting, so SD/OMI should choose a time (consistent with the rotational assignments program) that they will identify a person and develop an appropriate detail project.

- SD to suggest and work with appropriate folks to implement performance elements for staff in the RO, and HQ tied to 1) updating priority data and information needs; and 2) communication to NWFSC.

CONCLUSIONS

Preparing the Center to provide scientific leadership as the U.S. and the Pacific Northwest begin to implement ecosystem approaches to management of ocean systems can fortunately build on the strong research programs that have been developed within the organization. The Center is also fortunate to have a scientific and administrative staff that is committed not only to improving the Center, but also to making a difference—in the management of our natural resources, in the scientific community, and within our region and nation. As the Center moves forward in implementing this plan, we hope that it will reinforce and enhance this commitment, and in so doing, allow us all to contribute meaningfully to the stewardship of our interconnected environment.

ACRONYMS

AOP	Annual Operating Plan
AUV	Autonomous Underwater Vehicle
CCLME	California Coastal Large marine Ecosystem
ECC	Emerging Chemical Contaminant
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
ENSO	El Nino Southern Oscillation
EOP	Ecosystem Observation Program
ERP	Ecosystem Research Program
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
GIS	Geographic Information System
GPRA	Gov’t Paperwork Reduction Act or Government Performance & Result Act
HAB	Harmful Algal Bloom
HP	Habitat Program
IEA	Integrated Ecosystem Assessment
JSOST	Joint Subcommittee on Ocean Science and Technology
LIDAR	Light Detection and Ranging
LME	Large Marine Ecosystem
LMR	Living marine resources
MSFCMA	Magnuson-Stevens Fishery Conservation & Management Act
NWFSC	Northwest Fisheries Science Center
OHH	Oceans and Human Health
PaCOOS	Pacific Coastal Ocean Observing System
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
PDO	Pacific Decadal Oscillation
PPBES	Planning, Programming, Budgeting, and Execution System
PSP	Puget Sound Partnership
RPT	Research Planning Team
WCGOP	West Coast Groundfish Observer Program

REFERENCES:

Climate Change Science Program and the Subcommittee on Global Change Research, 2003. The U.S. Climate Change Science Program. Vision for the Program and Highlights of the Scientific Strategic Plan. 41 p.

Climate Change Science Program and the Subcommittee on Global Change Research, 2003. Strategic Plan for the U.S. Climate Change Science Program. 364 p.

Committee on Environment and Natural Resources/Interagency Working Group on Earth Observations, 2005. Strategic Plan for the US Integrated Earth Observation System. USGEO. Washington, DC.

Joint Subcommittee on Ocean Science and Technology, 2007. Charting the Course for Ocean Science in the United States for the Next Decade: An Ocean Research Priorities Plan and Research Strategy. Washington, D.C.

National Marine Fisheries Service, 2004. NMFS Strategic Plan for Fisheries Research. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS F/SPO-61, 148 p. Washington, D.C.

National Oceanic and Atmospheric Administration (U.S. Department of Commerce), 2005. New Priorities for the 21st Century -- updated for FY2006 to FY2011. http://www.ppi.noaa.gov/pdfs/STRATEGIC%20PLAN/Strategic_Plan_2006_FINAL_04282005.pdf Washington, D.C.

Pew Oceans Commission. 2003. America's Living Oceans: Charting a Course for Sea Change. A Report to the Nation. Arlington, Virginia.

U.S. Commission on Ocean Policy (USCOP). 2004. An Ocean Blueprint for the 21st Century. Washington, D.C.

APPENDICES

A. Table of the relationship of overall and near-term research priorities to the Ocean Research Priority Plan, GPRA measures, NOAA Programs and Components, and the U.S. Commission on Ocean Policy Ocean Action Plan

B. Relationship of the six near-term priority projects to the eighteen identified overall research foci

C. Details of the Tools Needed for Research

Appendix A: Relationship of themes, foci and near-term research priorities to the Ocean Research Priority Plan (numbers refer to priorities identified in that plan); GPRA measures (text refers to individual measures); NOAA Programs and Components as identified in the NMFS Strategic Plan (codes refer to Program and numbered component); and the U.S. Commission on Ocean Policy Ocean Action Plan (text refers to identified themes, numbers refer to specific tasks).

Focus		Ocean Research Priority Plan	GPRA Measures	NOAA Programs and Program Components	U.S. COP Ocean Action Plan
Ecosystem Approaches to Management for the California Current LME		Themes 1, 2, 4, 5			Achieving Sustainable Marine Fisheries
1	Conduct integrated ecosystem assessments that produce metrics and criteria that will improve ecosystem forecasts and predictions.	1, 7, 11, 12, 16, 20	% LMR with adequate assessments	EOP-1, ERP-1,2, HP-1, CEP-1,2	
2	Describe the interaction between human activities and ecosystem status and resilience	3, 5, 14, 15, 20		ERP-1,2, PSP-1,2, HP-1, CEP-1,2,3	
3	Characterize linkages between climatic conditions and biotic responses	5, 6, 11, 13, 14	% LMR with adequate assessments	EOP-2, PSP-1,2,5, CEP-1,2,3	
4	Characterize ecological interactions (e.g. predation, competition, parasitism, disease, etc.) within and among species to support ecosystem approach to management	2, 6, 14	% LMR with adequate assessments; Commercial fisheries with insignif. marine mammal mortality	ERP-1,2, PSP-1,2, CEP-1,2,3	
5	Characterize the interaction between marine, freshwater and terrestrial ecosystem components	2, 7, 14	% LMR with adequate assessments	ERP-1,2, PSP-1,2, HP-1, CEP-1,2,3	
Habitats to Support Sustainable Fisheries and Recovered Populations		Themes 1, 2, 4,5			Conserve and Restore Coastal Habitat
6	Characterize habitat effects on ecosystem processes, ecological	1, 2, 6, 13,14,16	% LMR with adequate	ERP-1, PSP-1, HP-1,2,3, CEP-1,2,3	

Focus		Ocean Research Priority Plan	GPRA Measures	NOAA Programs and Program Components	U.S. COP Ocean Action Plan
	interactions and the health of organisms.		assessments		
7	Characterize the interaction of human use and habitat distribution, quantity and quality	3, 14, 15, 20	Habitat acres restored	EOP-5, HP-1,2,3	
8	Develop effective and efficient habitat restoration and conservation techniques	3, 14	Habitat acres restored	PSP-2,4, HP-1,2,3,4, CEP-3	59
Recovery, Rebuilding and Sustainability of Marine and Anadromous Species		Themes 1, 2, 4, 5			Enhance Conservation of Protected Species
9	Describe the relationship among human activities and species recovery, rebuilding and sustainability.	3, 7, 14	Plans to rebuild stocks, Protected species with increase or stable population numbers	ERP-2, PSP-1,2, CEP-1,2,3	
10	Investigate ecological and socio-economic effects of alternative management strategies or governance structures	3, 15	Protected species with increasing or stable population numbers	EOP-8, FMP-1, PSP-1,2	
11	Characterize vital rates and other demographic parameters for key species, and develop and improve methods for predicting risk and viability/ sustainability from population dynamics and demographic information.	1, 6, 13, 16, 20	% LMR with adequate assessments	EOP-1,3, FMP-1, PSP-1,2	
12	Develop methods to use physiological and organismal information to predict population-level processes	1, 2, 16	% LMR with adequate assessments	FMP-1, PSP-1,2	
13	Clarify the role of artificial propagation in recovery, rebuilding and sustainability	3, 14, 20		ERP-2, FMP-1,PSP-1,2, AP-1,2	

Focus		Ocean Research Priority Plan	GPRA Measures	NOAA Programs and Program Components	U.S. COP Ocean Action Plan
Oceans and Human Health		Themes 1, 2, 6			Reduce Coastal Water Pollution
14	Characterize the exposure to and effects of pathogens, chemical contaminants, and marine biotoxins on humans and other species	3, 7, 14, 18	Habitat acres restored	PSP-1, HP-1.2	12, 52
15	Determine how ecosystem variables, such as climate, affect the distribution, abundance and toxicity of pathogenic and bio-toxin producing organisms	5, 6, 7, 13, 14, 17, 20		ERP-2, CEP-1,2,3	12, 52
16	Ensure seafood safety and improve seafood quality	3, 4, 7, 17, 18		FMP-2	
17	Monitor the health of fish and marine mammals as sentinels for ocean health and develop new species as mechanistic models	1, 6, 7, 14, 16, 18, 20		ERP-2, PSP-5	
18	Evaluate the effects of changes in the distribution, abundance and virulence of threats to human health on socio-economic indicators	3, 7, 15, 19, 20		EOP-8.	12
Near Term Priorities					
	Pilot Project -- Puget Sound IEA	1,2,12,16	% LMR with adequate assessments	EOP-2, ERP-1,2, PSP-3, HP-1,2, CEP-1,2,3	Achieving Sustainable Marine Fisheries, 86
	Case Study -- Salmon, People, and Instream Flows Under Climate Change	2, 3, 6, 12, 14, 15	% LMR with adequate assessments	PSP-1,2,4, HP-1,2,3, CEP-1,2,3	
	Evaluate New and Alternative Methods for Groundfish Surveys	1,3,4,16	% LMR with adequate assessments, FSSI	EOP-1,2,3,5,6,7, ERP-1,3,4, FMP-1	Achieving Sustainable Marine Fisheries

Focus		Ocean Research Priority Plan	GPRA Measures	NOAA Programs and Program Components	U.S. COP Ocean Action Plan
	Predict ESU and population level responses to natural and anthropogenic impacts for species of concern	3,14,16	% LMR with adequate assessments	ERP-1, PSP-1,2,4,5, CEP-2	Enhance Conservation of Protected Species
	Develop rapid detection and improved prediction methods to identify marine impacts on human health	17,18,19,20		ERP-1,2,3, FMP-2	52
	Initiate an aquaculture research program	4,14,15		ERP-1, FMP-1, PSP-1, AP-1,2	Advance Offshore Aquaculture
All					Advancing our Knowledge of Oceans, Coasts and Great Lakes

Appendix B: Relationship of the six near-term priority projects to the eighteen identified overall research foci. An upper-case "X" indicates that the near-term project is a primary contributor to the overall priority; a lower-case "x" indicates that the project will contribute substantially to, but not fulfill the overall priority.

Priority		**Pilot Project -- Puget Sound IEA**	**Case Study -- Salmon, People, and Instream Flows Under Climate Change**	**Evaluate New and Alternative Methods for Groundfish Surveys**	**Predict ESU and population level responses to natural and anthropogenic impacts for species of concern**	**Develop rapid detection and improved prediction methods to identify marine impacts on human health**	**Initiate an aquaculture research program**
Ecosystem Approaches to Management for the California Current LME							
1	Conduct integrated ecosystem assessments that produce metrics and criteria that will improve ecosystem forecasts and predictions.	X		x			
2	Describe the interaction between human activities and ecosystem status and resilience	x	x		X		X
3	Characterize linkages between climatic conditions and biotic responses	x	X				
4	Characterize ecological interactions (e.g. predation, competition, parasitism, disease, etc.) within and among species to support ecosystem approach to management	x		x			X
5	Characterize the interaction between marine, freshwater and terrestrial ecosystem components	x	x				
Habitats to Support Sustainable Fisheries and Recovered Populations							
6	Characterize habitat effects on ecosystem processes, ecological interactions and the health of organisms.	x		x			
7	Characterize the interaction of human use and habitat distribution, quantity and quality		x		X		X
8	Develop effective and efficient habitat restoration and conservation techniques				x		
Recovery, Rebuilding and Sustainability of Marine and Anadromous Species							

Priority		Pilot Project -- Puget Sound IEA	Case Study -- Salmon, People, and Instream Flows Under Climate Change	Evaluate New and Alternative Methods for Groundfish Surveys	Predict ESU and population level responses to natural and anthropogenic impacts for species of concern	Develop rapid detection and improved prediction methods to identify marine impacts on human health	Initiate an aquaculture research program
9	Describe the relationship among human activities and species recovery, rebuilding and sustainability		x	x	X		
10	Investigate ecological and socio-economic effects of alternative management strategies or governance structures		X		x		X
11	Characterize vital rates and other demographic parameters for key species, and develop and improve methods for predicting risk and viability/ sustainability from population dynamics and demographic information	x		X	x		
12	Develop methods to use physiological and behavioral information of organisms to predict population-level processes			x	x		
13	Clarify the role of artificial propagation (including aquaculture) in recovery, rebuilding and sustainability				x		X
Oceans and Human Health							
14	Characterize the exposure to and effects of pathogens, chemical contaminants, and marine biotoxins on humans and other species					x	
15	Determine how ecosystem variables, such as climate, affect the distribution, abundance and toxicity of pathogenic and bio-toxin producing organisms	x		x		x	
16	Ensure seafood safety and improve seafood quality			x		X	X
17	Monitor the health of fish and marine mammals as sentinels for ocean health and develop new species as mechanistic models	x		x		X	

Priority		Pilot Project -- Puget Sound IEA	Case Study -- Salmon, People, and Instream Flows Under Climate Change	Evaluate New and Alternative Methods for Groundfish Surveys	Predict ESU and population level responses to natural and anthropogenic impacts for species of concern	Develop rapid detection and improved prediction methods to identify marine impacts on human health	Initiate an aquaculture research program
18	Evaluate the effects of changes in the distribution, abundance and virulence of threats to human health on socio-economic indicators					x	
Other	▪ Direct support of Ocean Action Plan topic: Advance Offshore Aquaculture						x

APPENDIX C.

NECESSARY TOOLS

Implementing these research priorities will require the active development and improvement of technologies and models, as well as some targeted changes in infrastructure. We have identified several specific needs in these areas that the Center will need to develop to make progress on the identified research priorities.

Technologies

Ocean environments and the organisms that inhabit them are notoriously challenging to observe –the scales are large, the organisms are often fragile, cryptic or unknown, and the habitat is a demanding and expensive one for humans to occupy for prolonged periods of time. Technology development that enables us to gain information remotely about oceanographic or other environmental conditions and about organisms across wide areas or in inaccessible habitats is clearly a high priority. Other key technologies include those that allow us to understand the interaction between organisms of interest, their habitats and humans.

Large-scale Observational Systems and Techniques

Ocean observation systems. Both the U.S. Commission on Ocean Policy (USCOP 2004) and the recent Ocean Research Priorities Plan (JSOST 2007) have called for increased effort in observing ocean conditions as a vital component of the research needed to understand and predict the effects of changing ocean conditions on marine ecosystems and their resources. This has led to the establishment of several networks involving agency and academic scientists that initiate and maintain ocean observing systems. These systems include ships of opportunity, dedicated research cruises, land and ocean-based sensors, and remote sensing technologies working in tandem to observe and measure changing ocean conditions. One such network, PaCOOS (Pacific Coastal Ocean Observing System), covers much of the California Current; the northern part of that system is monitored as part of a regional network, NANOOS (Northwest Association of Networked Ocean Observing Systems) that is responsible for designing the regional observatory and providing data products. Continuing work aimed at developing autonomous samplers of the water column and remote interdisciplinary cabled seabed observatories can increase our ability to monitor ocean conditions without the need for costly ship time. These will be particularly useful as data from these observatories are made available in near real-time through live-access servers for rapid interpretation and assimilation into ocean models.

Remote sensing (satellites, multi-beam, LIDAR, hyperspectral imagery etc.). Technology is rapidly expanding in the field of remote sensing of freshwater and marine habitats. Many satellite sensors offer the potential to synoptically survey entire ecosystems but present technology often provides data only for the surface of the ocean which may not be relevant to bottom-dwelling organisms. LIDAR from airplanes may penetrate up to 50 m of the water column and provide rapid, near-synoptic surveys of pelagic fishes and invertebrates that can be related to oceanographic variables measured from the plane or satellites. Multifrequency ship acoustics continue to develop and presently play an important role in stock assessment of pelagic fishes. Seabed habitat characterization and mapping using side-scan sonars and multibeam sounders play a critical role in establishing MPAs and other habitats of concern. All of these technologies are beyond the normal training background of most fisheries biologists and will require collaboration with specialists in these fields to maximize their utility.

AUVs, ROVs and other remotely controlled observing methods. Autonomous Underwater Vehicles (AUVs) have the ability to provide comprehensive scientific information for management of West Coast ecosystems. AUVs, individually or jointly with vessels using acoustics and other observational tools, are the excellent tools for comprehensive surveys including in untrawlable habitat. AUVs can be used to augment vessel coverage of established acoustic surveys and other routine assessment surveys and improve efficiency. AUVs also will allow closer observations of target fish to determine their acoustic backscatter and identity and can provide scouting capabilities during surveys as an adaptive sampling technique. In situ autonomous drifters or gliders are providing useful information on water column properties that may affect fish distributions. As vessel and fuel costs increase, ship time for sea truthing of remote sensors such as satellites, acoustics, or LIDAR will become more costly. Simultaneous deployment of several AUVs either from shore or from small vessels can provide a cost effective method to provide sea truthing. AUVs, when combined with other tools (e.g., sidescan and multibeam sonars, CTD, ADCP, ROVs), also provide an important means of assessing fish habitat and groundtruthing existing habitat maps. As the importance of structure forming benthic invertebrates becomes clearer, there is an increasing interest in their protection. However, information on the distribution and abundance of cold-water corals, sponges and other invertebrates off the West Coast remains sparse. AUVs will simultaneously provide information on the occurrence of corals and their associations with commercially important fish. AUVs will be used as cost effective scouting tools to identify high priority sites for directed sampling from more expensive platforms such as ships or ROVs. AUVs also offer additional capabilities for other initiatives that include the development of non-extractive fish population assessments, use as platforms to observe interactions between fish and fishing gear and evaluation of systems designed to reduce bycatch, and as a vehicle for observing and quantifying fish responses to vessel noise.

Tagging and remote sensing technologies for individual organisms

Technology related to tagging and remote sensing of marine and freshwater organisms has progressed rapidly over the past several decades as the power of computers has increased, electronic components have decreased in size, and the ability to detect signals remotely has increased. The ability to detect and identify individual animals greatly enhances our ability to track movement, survival rates and other demographic and behavioral information, information often needed to make decisions on altering management strategies for protecting listed stocks. Several technologies for tracking individuals or groups are undergoing ongoing development.

PIT-tags. Passive integrated transponder (PIT)-tag receivers that can detect individual fish in fresh and sea water have been recently developed and deployed in support of individual research projects. Further research is ongoing to increase the detection range of receivers, which will decrease the number of receivers needed and increase our ability to detect fish in large areas such as estuaries.
Radio tags. The increased power of batteries of miniature size, along with decreases in size of electronic parts and chips has led to the miniaturization of radio tags down to a size that is usable on nearly all sizes of fishes and marine mammals. Faster ping rates also allow a larger number of uniquely-identifiable fish to be tagged.

Acoustic tags. New miniaturized batteries have made possible the ability to develop very small acoustic tags that also provide the capability to follow individual fish through freshwater and into seawater. Strategically placed acoustic arrays can also provide 3-D locations of fish allowing the ability to determine organismal behavior in varying habitats.

Satellite tags. These tags are generally larger than radio tags and require that animals come to the water's surface so that data can be downloaded via satellite. This technology is used on marine mammals, some larger fish and turtles and can provide a range of data including, ocean temperature profiles, diving profiles, and geographic locations while the animal is still at sea.

Passive acoustic monitors. Moored passive acoustic monitors that stay in place for several months can record organismal and ambient sounds. These can contribute to our understanding of both organismal biology and anthropogenic impacts on the acoustic environment.

Improved physiological observation techniques. While advanced sensors for acquiring physical and chemical data are being developed and deployed (ocean observing systems), development of sensors and systems for biological data on ecosystems are lagging behind. However, because of rapid advances in nanotechnology, it is anticipated that hand-held biosensors for near -instantaneous species identification in the field will be developed within a decade. Biosensors detecting specific DNA could be used to rapidly differentiate species and stocks in stock assessment surveys. Such technology could rapidly identify eggs and larvae of commercially important marine species. Additional applications include species identification of processed fish samples (forensics), and analysis of the physiological/health status of animals (stress, growth, disease status, reproduction). In addition to important fish species, the technology could be easily applied to marine microbes, phytoplankton and zooplankton. The Center should promote and participate in the development of this technology to enhance stock assessment and, ecosystem science and observation capabilities.

A key need, given the rapid development of these technologies, and their current deployment on a project-by-project basis is a coordination effort that would distribute receivers for maximum efficiency across projects.

Determining Population Structure and Patterns of Movement

Genetic techniques. Recent developments in molecular genetics have revolutionized our ability to detect patterns of population structure resulting from migration and reproductive isolation. DNA-based technologies based on evaluating non-coding DNA variation at the sequence level include minisatellites and microsatellites, randomly amplified polymorphic DNAs (RAPDs), and variable number of tandem repeats (VNTRs); these methods have proven indispensable in characterizing evolutionary processes of migration and genetic drift. In particular, patterns of DNA microsatellite variation that reflect variable numbers of tandem repeats in base sequence are proving extremely useful in detecting these processes, identifying breeding aggregations and patterns of dispersal and gene flow on short time scales. Tools such as single nucleotide polymorphisms (SNPs) provide direct sequence information with fewer ambiguities, and they can detect very small differences between putative groups. Rapid developments in gene mapping, in identifying quantitative trait loci (QTL) associated with phenotypes of interest, in integrating quantitative and molecular genetics, and in the detection and measurement of gene expression are making possible the ability to improve our understanding of the link between genotype and phenotype—the "holy grail" of evolutionary genetics. Future efforts to develop and improve these techniques should also focus on coordinating efforts and samples and standardizing protocols at independent genetic laboratories to facilitate scientific exchange and to uncover broad evolutionary patterns.

Novel Uses of Population Movement Information – Seafood Safety and Fish Health. There is a growing concern among consumers about what species they are purchasing. Instrumentation used for species identification of fish sampled in the marketplace could easily be modified to detect toxic chemicals and biotoxins. Thus, this technology could improve seafood safety and boost consumer confidence in the nation's seafood supply.

Isotopes and parasites. Other promising techniques are also being explored and merit additional support, particularly evaluation of ratios of stable isotopes in hard parts that deposit calcified tissue incrementally with age, such as fish otoliths, and identification of parasites and measurement of parasite load and diversity. Both of these techniques can yield information regarding locations individuals resided in or passed through, and thus patterns of movement over time

Monitoring of fishing catch, bycatch and discard

It is crucial to document and quantify total fisheries removals, including landed catch and discards. Fishery-dependent sampling provides a measure of the directed and bycatch removals, and, in limited circumstances, an additional measure of the trend in stock abundance. Until recently, at-sea discard had not been systematically monitored outside of the at-sea processing hake fleet and isolated research projects. The West Coast Groundfish Observer Program (WCGOP) was established in 2001 to improve estimates of total catch and discard in West Coast fisheries. The program deploys over 40 observers and collects at-sea data from limited-entry trawl and fixed gear fleets as well as from open access, nearshore, prawn, and shrimp fleets. West Coast groundfish landings have long been documented by state fishery agencies, however this data is generally not available in what is considered a timely fashion. An integrated electronic recording system for fishticket and logbook information for the Pacific coast would vastly improve the ability to track groundfish catches inseason and to produce real-time estimates of landings and discards. An electronic fishticket system is needed to provide real-time landings data. Logbooks are used with fishtickets and WCGOP data to reconcile the total catch by area and determine bycatch rates in association with target species. Logbook data availability can lag by as much as a year, which delays input data to bycatch models and the total catch reconciliation process. Electronic logbooks, like electronic fishtickets, would increase the accuracy and timeliness of critical data needed for good management decision-making.

Geographically or spatially linked analysis and interpretation

Marine and freshwater research efforts increasingly rely on large geospatial data sets to address issues such as individual and population-level movement patterns, climate change effects on stream flows, ocean circulation patterns, and patterns of current and future land use. Maintaining up-to-date GIS capabilities, including software, databases and support staff, will be a critical element of conducting the landscape (and oceanscape) scale analyses that inform our multiple goals.

Socio-economic surveys

Socio-economic surveys are the primary means of collecting information and data used to describe the interactions between humans and living marine resources. Several different types of data collection efforts need to be developed or enhanced to better understand these relationships. The surveys should cover a broad range of socio-economic fields, answer important policy questions, and use state-of-the-art methods. The fields of study include economics, anthropology and sociology. Each of these disciplines provides useful information for sound management decisions. Even though the fields are related, the questions and approaches used by each field are different; and, thus, their data requirements are not completely overlapping. Socio-economic surveys should support the analysis of two general themes of policy questions: commercial and recreational fisheries, and *in situ* conservation and ecosystem management. Commercial and recreational fisheries data should address issues such as community profiles, community impacts, fleets costs and earns, impacts on participants, alternative management regimes (e.g., closed areas, changes in seasons, rebuilding plans, and limited access privileges), effects of environmental change (e.g., climate change, coastal dead zones, and harmful algal blooms), and seafood safety. *In situ* conservation and ecosystem management data should address issues such as the value of ESA listed species, the market and non-market value of ecosystem goods and services, the interaction of human activities and ecosystem characteristics, and management strategy evaluation. The Center should use state-of-the-art data collection methods that are appropriate for the issues being addressed. These include electronic data collection to increase timeliness and accuracy, methods to obtain high response rates (e.g., contacting respondents through personal communication in-person or over the telephone), work closely with constituents, and use local knowledge. The data required to support economic behavioral models is more complex and detailed. To serve these needs data should be collected through time and space, and include more frequent observations.

Bioinformatics

<u>Genomics technologies.</u> Significant advances in our understanding of ecosystem structure and function can emerge from the rapid development of genetic technologies. For example, development of genomic libraries to advance understanding of food web dynamics and other ecosystem processes, as well as species abundance and distribution, is now possible. Among the valuable tools in this category are in situ sensors for rapid detection of pathogens, harmful algae, and toxins, and methods to integrate biosensor data with other ocean observations. Genomic tools and supporting bioinformatics infrastructure can now be designed to elucidate effects of multiple environmental stressors on marine organisms. Efforts should focus on developing, enhancing, and applying new methods and tools at laboratories and other facilities with specialized instrumentation (e.g., for large-scale gene expression analysis) and computational resources in genomics, proteomics, and bioinformatics to expand surveying and screening capabilities for assessment of impacts to ecosystems from biotoxins, pathogens, and other sources. Work to integrate genomic, in situ biological, chemical, and bio-optical field observations, remote sensing, and numerical models into diagnostic tools for regional to global investigations is also a high priority. These efforts can be linked with developing coastal and offshore observatory efforts to maximize stakeholder participation, input, and use of the advances. In addition to using molecular techniques for identification of species/stock structure, similar approaches can be used to assess gene or protein expression patterns in marine animals to assess ecosystem function. Stress genes have been identified and related to such functions as adaptation to temperature extremes, hypoxia, lack of food, and chemical toxins among other environmental stressors. Gene expression

may also indicate relative states of growth and reproduction. Individuals from populations can be analyzed to indicate which stressors may be acting to affect population growth and juvenile recruitment.

Global assessment of gene expression is more advantageous than studies surveying a few genes, because many physiological processes including impacts of toxins typically involve a cascade of gene interactions rather than a change in a few or in single genes. If a sufficiently diverse set of genes is monitored, toxicant and mode of action-specific responses can be identified and used as a molecular fingerprint for environmental monitoring. However, there has been minimal application of these techniques to marine shellfish and finfish, which are more suitable for environmental monitoring and ecotoxicological testing. This is due to the limited knowledge of the genome of most fish and shellfish. The recent development of high-density fish DNA microarrays has allowed exploration of this technology for bioassessment of contaminants. Research should be directed toward, expanding development of DNA arrays, laboratory assessments, and validation for field monitoring.

<u>Develop capabilities for biological computational analyses (bioinformatics).</u> The advances in biotechnology mentioned above also present distinct challenges. As a result of the rapidly changing scientific environment, regulatory agencies must quickly develop the capability to adopt these new methodologies and evaluate the quality of data generated both within the Agency and by the scientific community at large. The significance of specific changes and performance characteristics of new methods, as well as their strengths and limitations, must be fully understood to avoid misinterpretation of data that could lead to inappropriate conclusions. As these applications and their uses expand, there is an ever-increasing need for computational analyses and subsequently computational power, along with data and database storage, sharing, and retrieval. Biological computational analyses, generically called **bioinformatics**, include storage, comparisons and characterizations of DNA and protein (amino acid) sequence data, and analysis of microarray expression data. Although different research groups throughout the Agency approach research topics through a variety of directions and disciplines, research data analyses often intersect at the level of bioinformatics. Therefore, there is a need to have these resources and tools available to NOAA scientists.

Development of shared computational tools for biological applications (bioinformatics), requires hardware, software and personnel with specific expertise. While there is no single central repository or server of bioinformatics applications (software applications, data and database storage and retrieval), many tools are available through web-based servers hosted by university research groups or government agencies. While this resource is extremely powerful, the growing server loads are resulting in increasing times for the analyses to be carried out. Development of a centralized bioinformatics core facility is more cost-effective and efficient. Presently the Center has hardware and software for the bioinformatics core facility. Personnel with specific expertise in bioinformatics are needed.

Models and the Data to Support Them

We emphasize model development in this section because modeling provides a framework in which to describe a system in detail or in general, to evaluate the effects of alternative actions, and to characterize the sensitivity of a system to perturbations – all of which are key for effective management. However, it is critical that these models are supplemented by experiments, directed observational studies and other research efforts to develop the data to parameterize and evaluate the models. These experiments and studies are implicitly included in the discussion of needed models.

Integrating social and biological sciences

Economic participation and valuation models. Economic valuation models are needed for both use and non-use values. Examples of use values include recreational fishing, whale watching, recreational enjoyment of the ocean or associated ecosystems, and viewing a pristine environment. These models rely on revealed or stated preference data. It will be important to be able to map changes in resource characteristics or availability to changes in valuation estimates. This will provide a link between the state of the resource, changes in participant values, and the effect of management actions. These models should also include participation estimates, and be able to forecast changes in participation associated with changes in resource characteristics or availability. Changes in participation should then be linked to regional input-output models to forecast changes in economic activity. The valuation of human health or health risks is another type of use value. These values could be positive (e.g., the positive heath effects of seafood consumption) or negative (e.g., the effect of mercury consumption through seafood). Non-use values include resource and ecosystem existence value. Examples include the value of protecting ESA listed species and habitat protection. These models rely on stated preference data. Similar to use value models, these models should provide a link between changes the level of the good being valued and changes in the level of the non-use value.

Socio-economic models linking habitat distribution, abundance and quality with human activities. Humans interact with the environment in a dynamic process. Humans not only affect the distribution, abundance and quality of habitat, but are also affected by these same habitat characteristics. These relationships are not well understood and much progress could be made in increasing our understanding of them. Behavioral models that forecast changes in human actions associated with changes in habit need to be developed. These types of models require either a long time-series of data that capture observed changes in human behavior, or stated preference data. The most fruitful avenue of research is likely the construction of a model that combines both types of data. These models also require observational habitat data that quantifies the state or changes in habitat variables such as distribution, abundance and quality. In addition, it is necessary to model the link between changes in habitat and changes in variables that drive human action (e.g., species distribution and abundance). It is also necessary to develop a model that relates changes in human action to changes in habitat. Completing this type of integrated model will require the collaborative work of social scientists, ecologists, biologists and stock assessors.

Risk assessment models

There are two critical problems facing the state-of-the art for quantitative risk assessments. First is data limitation. Capturing biological complexity means building models with many parameters, but most biologists feel very uncomfortable building a model that relies on parameters for which they have no direct data for the species in question. Collection of more data is often not feasible, and statistical approaches to risk assessments are needed. These approaches rely on estimation of relationships between environmental drivers and population responses without building intricate models. In addition, we need much more research to understand both the implications of ignoring biological detail and how to incorporate the biological detail we know. Currently the only option to incorporate more biological information is to use a more complex model, which usually entails additional—often untested—assumptions. How to incorporate additional biological information to improve a simple model is largely unknown. Additionally, much more work needs to be conducted on methods for incorporating uncertainty into risk assessments, specifying uncertainty, and making decisions under uncertainty.

Population dynamic models

Population dynamic models can be quite sophisticated, but substantial improvement in their utility can be achieved by developing ways of including information on spatial dynamics, the role of size and age composition in population demographics, and demographic and environmental stochasticity. At the ecosystem level, research should facilitate application of quantitative frameworks to data sets to synthesize dynamics across ecosystems and to conduct investigations with theory, design, observations, and experiments to interpret the ecosystem and socioeconomic impacts of alternative strategies. Ecosystem approaches emphasize interactions among components and the impacts that various human activities have on productivity and organization. Forecasting these impacts requires understanding complex dynamics controlling: 1) productivity of populations within various trophic levels, 2) predator-prey interactions, 3) connectedness of sub-populations, 4) impacts of natural climate variation and change, and 5) anthropogenic pressures. Because the dynamics of marine ecosystems are complex, a variety of approaches are warranted. First, viability and extinction risk models that incorporate assessment of abundance, productivity, genetic and phenotypic diversity, and spatial structure are useful in identifying limits to viability at the population and species levels. Application of various classes of energy-budget and dynamic models at the ecosystem level can improve understanding of the impacts of human activities on ecosystem structure and function by contrasting biomass changes according to trophic level. Another valuable approach is to compare systems where managed areas have been enacted to conserve species, habitats and ecosystems. Such comparisons should include before and after area designation contrasts where sufficient data are available, and inside versus outside comparisons for established managed ecosystems.

Evolutionary models

The importance of evolutionary processes in population dynamics is still widely underappreciated, particularly for exploited species or key components of disturbed ecosystems. Evolutionary approaches to this problem should link multivariate genetic models of life history variation to analyses of population dynamics and viability. Promising models include linking genetic covariance structures for traits under natural or artificial selection (e.g., through sexual selection on breeding grounds or through size-selective fishing) to size- and age-structured population dynamic structures such as projection matrices, and exploring the consequences of selection on size or age for 1) evolutionary change in life history, 2) pre-harvest abundance, 3) breeding abundance and 4) sustainable yield. When they directly incorporate genetic information, such approaches can provide a useful glimpse into how adaptation will affect future abundance and productivity. Analyses like these can support management strategy evaluation by identifying alternative management strategies that maintain yield without compromising viability.

Models to support ecosystem approach to management

Models are mathematical or conceptual caricatures of reality, and as such are tools that allow us to project the future state of an ecosystem or guide further inquires. Attempts to develop tools to support ecosystem approaches to management have generally fallen into three categories: 1) models aimed at prioritizing sites for conservation, 2) statistical models that estimate population dynamics within the context of species interactions or changes in climate-driven demographic rates, and 3) food web simulations.

> Site Prioritization Models. Site prioritization models are used for siting marine protected areas based on algorithms that attempt to maximize biodiversity targets. Such models operate by finding efficient solutions to the problem of selecting a system of spatially cohesive sites that meet a suite of conservation goals (e.g. biodiversity). While these models have proven useful in selecting sites for conservation action, they are based only on a data 'snapshot.' As a result, they cannot take ecological interactions or dynamics into account, and therefore do not attempt to predict future ecosystem states under different management regimes.

> Statistical Models. Statistical models have traditionally been used to estimate trends in population size of single species can be augmented with predator or prey abundance or environmental correlates. Examples include stock assessments that are improved by inclusion of climate indices or including predator and prey abundance as predictors of the abundance of single target species. Statistical models have also been extended to estimate the abundance of a few target species.

However, the complexity of such models is severely limited by the need to estimate many parameters from limited, noisy data.

Food web simulations. Food web simulations are theoretical models that are more complex than statistical models, and do not involve estimation of parameters such as abundances or rates of growth or reproduction. Instead, parameters are estimated outside the model and then used as model input. The added complexity of the models allows increased realism, but this comes at the cost of increasing the uncertainty of predictions. Among these models, Ecopath with Ecosim (EwE) is especially notable. EwE considers changes in food consumption and predation that might accompany changes in food web structure and how those changes alter the productivity of harvested stocks. Other simulation models include nutrient-phytoplankton-zooplankton models of the whole food web and biogeochemical system models. In the past, typical implementations of any of these modeling frameworks involved simplifications such as aggregating species at lower trophic levels, a lack of spatial resolution, and crude representations of oceanography, nutrients, and fleet dynamics. Nonetheless, these models are useful for generating hypotheses about past and future impacts of altered fishing and predation rates, and for screening potential management policies.

Models Treating Habitats and Landscapes

Landscape process models, particularly at a range of scales. Effective recovery planning for ESA-listed anadromous species requires that we understand how habitat restoration actions will affect population viability and sustainability. However, there are few models available to simulate how natural processes form and sustain riverine habitats, or how watershed or stream restoration actions will alter processes and habitats at reach scales. Development of such models is a critical component of cost-effective habitat restoration for anadromous species.

Integration of habitat into assessment models. Integration of data on the quantity, quality and spatial distribution of habitat can improve the predictive powers of assessment models and guide fishery management. The necessary data are difficult to obtain because of practical limitations of observation, controlled experimentation and replication in natural systems. Before habitat can be integrated into assessment models, relationships between the distribution, quantity and quality of habitats and demographic rates will have to be investigated. Investing in observations, process studies, and advanced modeling will expand current understanding of impacts at appropriate temporal and spatial scales, and help identify crucial data and process-understanding gaps. The Pacific Coast Groundfish FMP has recently been amended to describe Essential Fish Habitat (EFH) for the managed groundfish stocks as well as all waters and substrates within areas with a depth less than or equal to 3,500 m as well as seamounts in depths greater than 3,500 m. In addition to EFH, Habitat Areas of Particular Concern (HAPC) are identified along the coast based on the importance of the ecological function provided by the habitat, the extent to which the habitat is sensitive to human-induced environmental degradation, whether and to what extent development activities are or will be stressing the habitat type, and the rarity of the habitat type. More detailed mapping and linking of habitats to the species that use them is needed before the relative importance of different benthic habitats can be determined. Of particular importance in the future will be the determination of the distribution and abundance of biogenic species and their role and importance to the groundfish ecosystem, as well as the integration of ocean habitat conditions into salmon assessment models.

Essential Fish Habitat (EFH) designation and delineation models. The Magnuson-Stevens Fishery Conservation and Management Act requires that regional management councils describe EFH in their fishery management plans, that Councils minimize impacts on this essential habitat from fishing activities, and that Councils and other federal agencies consult with the National Marine Fisheries Service about activities that might harm EFH. The Magnuson Act defines "essential fish habitat" as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity."

Presently, the definition of EFH in the Coastal Pelagic Species, Highly Migratory Species, and Salmon Fisheries Management Plans is quite broad. For instance, the definition of essential fish habitat for Coastal Pelagic Species is based on the temperature range where they are found, and on the geographic area where they occur at any life stage, and takes into account where these species have been found in the past, and where they may be found in the future. Thus, the EFH for the Coastal Pelagic Species Fisheries Management Plan includes all marine and estuary waters above the 10^o thermocline, from the coast to the limits of the Exclusive Economic Zone. Similarly, freshwater EFH for the salmon management plan includes all the lakes, streams, ponds, rivers, wetlands, and other bodies of water that have been historically accessible to salmon. To identify EFH for groundfish, NMFS used a GIS-based assessment model that looked at the occurrence of groundfish in relation to depth, latitude, and substrate type. Despite the complexity of the model, a lack of data resulted in EFH including all waters from the high tide line to 3,500 m in depth. Simple assessments that produce broad EFH designations may have heuristic appeal, but do not aid, and may actually hinder, the work that needs to occur. We need to develop tools and datasets that allow us to understand what habitats fish use, the demographic rates associated with these habitats, and the factors that make some habitats more valuable than others. While initially such approaches may be rough, they acknowledge that successful management of fisheries resources depends not only on protecting sites where animals occur, but also on protecting the ecological processes that allow populations to persist or expand.

Integrated modeling approaches

Integrated modeling approaches overcome many of the limitations described above and achieve the crucial goal of integrating physical, chemical, ecological, and fisheries dynamics in a three-dimensional, spatially explicit domain. In these models, ecosystem dynamics are represented by spatially-explicit sub-models that simulate hydrographic processes (light- and temperature-driven fluxes of water and nutrients), biogeochemical factors driving primary production, and food web relations among functional groups. These models represent key exploited species at the level of detail necessary to evaluate direct effects of fishing, and they also represent other anthropogenic and climate impacts on the ecosystem as a whole.

These sorts of models are intended as a strategic management tool that allows one to identify tradeoffs between species, fleets, and management goals, and to identify effects of management policies. They are ideal tools for management strategy evaluation (MSE), in which management scenarios are tested against simulations that represent a real ecosystem and its complexities. In this framework, these models are useful in that they reproduce qualitative behavior of the system, and exhibit a range of dynamic responses similar to that observed in the ecosystem. The ecosystem model can thus serve as a filter to identify which policies and methods are promising and which appear flawed.

Infrastructure

Data management

The Center has important and critical data management needs and responsibilities. We must effectively manage the enormous amount of information necessary to efficiently generate science guidance products such as ESA status reviews, MSFCMA stock assessments and IEAs. We must also have the capacity to archive, compile and inter-relate numerous independent data types running into the millions of records. If we also consider the data management challenges inherent in applying GIS-based analysis tools, Center staff routinely manipulate terabytes of data – ignoring the institutional requirements that such activities present today will certainly handicap the Center tomorrow. Fortunately the Center has invested in enterprise-level data management and IT tools and the staff to design and implement them. These investments have paid off with a number of important data management products developed for the region; however, a much stronger parallel effort needs to be applied to the mid-level or sub-enterprise data management needs of Center staff. Desktop computer based data management products must be available for staff as: bridges towards enterprise level products as individual databases scale up; designs or scoping templates for future enterprise level efforts; or, simply for data management needs that will not ever be at the enterprise level. While the software to generate desktop scale databases is readily available to staff, the expertise to use these products in a manner consistent with standard database design theory and practice is not in the typical skill-set of Center research staff. Therefore, the Center should support access to the power of relational databases through a multi-level program of designing both desktop and enterprise level data management tools. Currently staff engage with the Center data management group for the design of enterprise databases and contract externally for smaller, individual scale databases – we can be more efficient at Center-wide data management if the Center Data Management and IT teams could support a multiple-scale approach to the development and implementation of data management tools.

In addition to large-scale systematic enhancements to our approach to data management, there are a number of items that could be acted on in the short-term that would make significant contributions to staff. To raise the awareness and level of sophistication that Center staff have of designing and implementing effective data management systems the Center could establish formal data management design working groups for both spatial and tabular data users. There is a large body of expertise and experience within the Center with respect to the use and management of spatial and tabular data – formalizing the sharing of this knowledge and developing an infrastructure for the dissemination of knowledge and training will be very beneficial to all. Large volumes of data are regularly shared or transferred in and out of the Center; having an effective method, such as an FTP-site, to perform these tasks safely and efficiently would be very useful to staff. Millions of dollars have been spent on data collection at the Center and most of this data is in an electronic format. A standardized protocol for data security needs to be developed and supported to protect our huge investment in electronic data. Finally, the entire Center staff needs to be involved in a discussion of how to identify and support Data Stewards for research and corporate data that we agree to maintain; the Center needs to develop a Data Management Strategy that meets the needs of multiple scales of data management within the Center, outlines a consistent and scaleable approach to maintaining these databases, and is compatible with our ongoing and projected needs for data sharing at the Center and with our collaborators and constituents.

Laboratory Facilities

A number of laboratory facilities were identified as being important to achieving these goals. Many of these facilities do exist, at least in part. However, mechanisms to provide access to the facilities and to provide adequate technical support for those facilities are greatly needed.

<u>Diet and Tissue Analysis Laboratories and Support Personnel.</u> Details of the life history and other characteristics of marine species are difficult to observe in their natural habitats. Recent advances in the use of new methods and technologies to investigate the physiology, foraging ecology, susceptibility to lethal contaminants, and other life history details of marine species are providing new and important information. The ability to fully utilize these powerful methods would be greatly improved by a dedicated diet and tissues analysis laboratory and support. This laboratory should allow identification of species or processing of tissues in a variety of ways:

- Morphological examination of digested prey parts;
- Genetic identification;
- Chemical analysis of tissues for contaminants, stable isotopes and other techniques that can inform diet analysis, demographic studies, nutritional

status and studies aimed at human health, as well as other novel uses of chemicals as indicators;
- Otolith analysis, both morphological and chemical.

Many components of this laboratory are already present at one or more of the NWFSC's facilities. However, making them more readily accessible to Center scientists is important.

Wet Labs. The Center's laboratory facilities were the focus of an external panel review in July of 2005 that highlighted the need for freshwater and marine flow-through systems. Establishing this capacity (possibly at Mukilteo) remains a critical need for experiments relying on fish culture.

Fish culture facilities. The ability of Center scientists to address several issues in fish biology and conservation would be enhanced by improved access to fish culture facilities that can support fresh- and salt-water rearing. Scientific questions that can be addressed using fish culture techniques includes many in in reproductive biology, behavior, inheritance and evolution of phenotypes, and nutrition. As key projects are identified, support for facilities providing an adequate supply of high-quality water, rearing containers (tanks, raceways, and ponds), food storage, and sampling and diagnostic facilities will be important.

Field sampling support

Large-scale, interdisciplinary ocean research requires the use of large, sophisticated research vessels capable of extended cruises in rough sea conditions. The broad nature of oceanographic sampling requires many sensors of atmospheric and ocean conditions and the ability to deploy and retrieve many gear types. Although chartered commercial fishing vessels can still be used for trawl surveys which require little sampling besides trawling and a minimum of scientific crew, many oceanographic programs require deployment of physical and biological sensors and multiple gears sampling everything from plankton to large nekton. Large survey vessels capable of extended diel operations and containing sufficient laboratory space to process samples at sea are critical to this work.

Estuarine and riverine sampling do not pose the logistic limitations in ship size as ocean sampling, but these other habitats also face shortages of sampling platforms. Small boats can be towed on trailers to various sites but often have conflicts in scheduling and may need to be modified depending on the needs of various investigators. Having a small fleet of such vessels that can be quickly modified and deployed to various systems will allow greater flexibility in sampling many smaller systems.

Gear storage

Over the past several years, broadening research needs along with increased staffing have required acquisition of a variety of new gear types, including ATVs and well-drilling equipment for freshwater research, small boats, nets, and trailers for nearshore research, and plankton gear, trawls and camera sleds for marine research. Space for maintenance and storage is required to protect substantial monetary investments in this equipment, but space at the NWFSC is at a premium. Particularly acute needs include garage storage space for small boats, well drilling equipment, ATVs, and trailers, and covered spaces for net drying and storage. Storage and maintenance spaces for a variety of small gear types, including tagging and sensor equipment and dive gear, are also needed.