Priority Science for Restoring and Protecting Puget Sound:

A Biennial Science Work Plan for 2011-2013

Puget Sound Partnership

Science Panel

April 2012

Executive Summary

The purpose of *Priority Science for Restoring and Protecting Puget Sound: A Biennial Science Work Plan for 2011-2013* is to provide strategic focus on the science needed to recover and protect Puget Sound. This strategic focus can help direct the allocation of the limited resources available for science to the issues and studies where they are most needed. The document is a key companion to the *Action Agenda Update*, which describes the long-term strategies and coordinated near-term actions to be implemented by state and federal agencies, tribes, cities and counties, other local jurisdictions, nongovernmental organizations, and the general public to recover and protect Puget Sound and the ecosystem services it provides.

The Puget Sound Partnership Science Panel (Science Panel) chose these actions based on a review of the questions that current research and monitoring are addressing, a review of recommendations from scientific reports and publications on the science needs for a program of ecosystem recovery in Puget Sound, and recommendations from a broad base of scientists, practitioners, stakeholders, and decision makers. Analyzing this information relative to a conceptual model of ecosystem recovery for Puget Sound illustrated where gaps in scientific attention and knowledge are likely present.

Identifying gaps in knowledge does not immediately make them priorities for funding and investigation. To decide which gaps are priorities, the Science Panel asked two sets of questions. The first set focused on scientific questions: How much do we know? What is the level of scientific uncertainty? The second set focused on policy-science questions: What are the decision-critical questions and information needed for ecosystem restoration and protection? Where is the lack of scientific information hindering progress in restoration and recovery?

To determine what decision-critical issues are important, the Science Panel used: (1) the perspectives collected from stakeholders and conservation practitioners who participated in multiple stakeholder meetings on developing the *Action Agenda Update*; (2) the lists of priorities for the *Action Agenda Update* provided by Action Area groups, who hold the perspectives of local implementing organizations, governments, and tribes about what is important in local areas and watersheds; and (3) feedback on proposed science priorities from decision makers on the Ecosystem Coordination Board, who represent a broad range of interests and values.

The Science Panel identified the following 48 science actions as high priority (Table 1). The science actions are grouped according to the strategy sections of the *Action Agenda Update*.

Table ES-1. Proposed Priority Science Areas

Focus Area	Strategy	Science Action
Protect and Restore Terrestrial and Freshwater Ecosystems		
Habitats	A1 A2 A3	• Develop analytical tools to identify options for where to protect, where to restore, and where to develop while maintaining desired ecological goods and services. • Use social science to guide development of adaptive management structures that can effectively link restoration science to management decision-making. • Develop ecological indicators; assess baseline conditions; and implement monitoring to measure ecosystem function relative to no net loss. • Conduct social science studies to describe the key institutional challenges to attaining no net loss and improvements from restoration.
Floodplains	A5	• Estimate the value of floodplains in terms of the ecosystems services they provide. • Develop key ecological indicators and implement monitoring to assess status of floodplains. • Improve understanding of the effects of vegetation on dikes and other flood control structures.
Species and Foodwebs	A6	• Develop analytical tools to evaluate whether strategies to address factors limiting the productivity of salmon are being implemented in the most effective combinations, at the right times, and with appropriate amounts of effort to lead to recovery. • Identify the causes of apparent decline in marine survival of salmon as they leave their natal rivers and exit Puget Sound. • Assess risks imposed by terrestrial and freshwater invasive species.
Freshwater	A8	• Develop robust ecological indicators and implement comprehensive monitoring for stream flows. • Evaluate and improve stream flow targets in terms of their effects on abundance, productivity, distribution, and life-history diversity of salmon.
Protect and Restore Marine and Nearshore Ecosystems		
Habitats	B2 B3	• Develop analytical tools to identify priority areas for protection, restoration, and stewardship. • Develop adaptive management structures that link restoration science to management decision making.
Species and Foodwebs	B5 B6	• Develop analytical tools and information to understand the tradeoffs in managing foodwebs of marine species and the multiple stressors affecting those foodwebs. • Implement biological and sociological studies to understand the conservation and sociological roles of marine protected areas for habitat and species protection, ecosystem restoration, and sustaining usual and accustomed tribal fishing areas. • Implement studies to identify stressors on forage fish. • Implement studies to understand the causes of declines in marine bird abundance. • Conduct studies to identify sources of nutrients that enter Puget Sound that can be used to develop strategies for maintaining water quality for Puget Sound foodwebs. • Assess risks imposed by marine invasive species.
Reduce and Control the Sources of Pollution to Puget Sound		
Contaminants	C1	• Implement studies on persistent, bioaccumulative chemicals to understand transport, trophic transfer, and associated ecological and human health risk and to ensure that Washington State's water quality standards and sediment management standards are protective of both fish and wildlife and allow human and wildlife consumption. • Describe the availability, feasibility, and safety of alternatives to products and processes that use and release toxic chemicals of concern into the Puget Sound ecosystem. • Develop integrated monitoring and assessment of toxic chemical sources, exposure, and effects. • Synthesize information on emerging contaminants of concern.
Runoff from the Environment	C2	• Develop monitoring and assessment of benthic invertebrates in small streams to evaluate stormwater management and other efforts to protect and restore streams. • Evaluate the effectiveness of low impact development (LID) projects and stormwater management best management practices and programs. • Evaluate land uses and associated pollutants that would require treatment beyond sediment removal. • Evaluate projected environmental benefits of structural stormwater retrofits given varying levels of effort to guide the extent of structural retrofits needed to help meet 2020 ecosystem recovery targets. • Evaluate individual and combined effects of commonly used pesticides on salmonids, other fish, and their foods.

Wastewater	C5 C6	• Evaluate nitrogen reduction in public domain on-site system treatment technologies. • Implement studies of human-related contributions of nitrogen to dissolved oxygen impairments in sensitive Puget Sound marine waters.
Shellfish	C7	• Establish and sustain pollution identification and correction (PIC) programs to identify and fix nonpoint pollution problems. • Research and implement monitoring to understand the specific environmental conditions that produce toxic harmful algal blooms (HABs) and pathogen events.
Oil Spills	C8	• Evaluate existing oil spill risk assessments and complete additional risk analyses of higher risk industry sectors to ensure there are appropriate levels of investment in reducing risk. • Evaluate information on baseline conditions for key species at risk from oil spills and improve these as necessary so that baselines exist that can be used in assessments of natural resource damages.
Cumulative Water Pollution	C9	• Expand monitoring of freshwater and marine water areas to assess human exposures to pollution during water-contact recreation.
Emerging Issues – Ocean Acidification		• Design and implement monitoring for ocean acidification variables across the Puget Sound to understand the status, diversity and range of conditions. • Develop and implement studies to assess the risk and vulnerability of Puget Sound species to ocean acidification. • Develop adaptation strategies given assessed vulnerability to ocean acidification.
Scientific Tools for Informing Policy	D1	• Conduct institutional analyses of the overall governance and management structures in which Puget Sound recovery strategies operate. • Conduct integrated risk assessments of the impacts of different pressures on the Puget Sound ecosystem. • Develop a systematic, transparent, and ecologically-based prioritization tool for near-term actions in the Action Agenda that will support evolutionary learning and adaptation.
Coordinated Ecosystem Monitoring	D3	• Implement and sustain a comprehensive, coordinated monitoring program to understand the status of the Puget Sound and the effectiveness of recovery actions.
Human Dimensions in Ecosystems	D7	• Develop assessments of ecosystem services to help decision makers make informed decisions about restoration and protection. • Develop socioeconomic indicators to help measure and report on the human dimensions in ecosystem recovery. • Conduct a baseline literature review of social science research and a survey of data to identify resources and gaps that can be readily available and used by ecosystem recovery planners and practitioners. • Evaluate the most effective combinations of regulatory, incentive, and educational programs for different demographics in Puget Sound.

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Introduction

Puget Sound is a complex ecosystem. Ecologically it is the southern part of the Salish Sea, which includes the marine waters of the Washington State's Puget Sound and San Juan Islands, the Strait of Juan de Fuca, and British Columbia's Gulf Islands and the Strait of Georgia. The Puget Sound encompasses 35,500 km^2 of fertile lowlands, uplands, islands, and scenic mountains; thousands of rivers and streams; a large, complex fjord-like estuary covering 2,330 km^2 with 4,000 km of shoreline; and many species of plants and animals. It is also home to approximately four million people – with a million or more expected to arrive in the next 20 years – who enjoy the natural resources and ecosystem services of Puget Sound. These resources are managed under a complex arrangement of local, regional, state, and national laws, governments, and economies. Like many other parts of the United States, Puget Sound is experiencing rapid ecological, demographic, and social change affecting land use, climate, nutrient cycles, and the abundance and distribution of its species that will change the ecosystem services it can provide (Brown et al. 2005, Lombard 2006, Ruckelshaus and McClure 2007, Office of Financial Management 2007, Climate Impacts Group 2009, Gaydos and Brown 2011).

The Washington State Legislature created the Puget Sound Partnership (Partnership) in 2007 to coordinate and lead efforts to restore the health of Puget Sound. It recognized the vital roles to be played by science in this effort. The Legislature noted, however, that although many of the state's universities, agencies, and tribes had studied Puget Sound for many decades, no process existed for prioritizing research and monitoring that could provide the information needed to coordinate restoration and protection in a systematic manner.[1]

This problem is not unique to Puget Sound. Policy makers and scientists are increasingly concerned about how to direct research and incorporate the scientific findings to solve real world conservation problems (Robinson 2006, Fleishman et al. 2011, and Rudd 2011). Several recent national efforts to identify and prioritize science questions (e.g., Sutherland et al. 2006, Fleishman et al. 2011, and Rudd et al. 2011) have attracted policy and media attention. A key characteristic of these efforts is the recognition that developing these priorities requires the active participation of policy makers as well as scientists (Bozeman and Sarewitz 2005, Rudd 2011). This has led to increased policy and academic attention on the methods for identifying and analyzing impacts of natural, physical, and social sciences on policy (Albæk 1995, Beyer 1997, Amara et al. 2004, Sutherland et al. 2011).

This report, *Priority Science for Restoring and Protecting Puget Sound: A Biennial Science Work Plan for 2011-2013*, identifies priority science and monitoring questions needed to coordinate and implement effective recovery and protection strategies for Puget Sound. The Puget Sound Partnership Science Panel (Science Panel) – an independent body created with the Partnership by the Legislature – chose to develop this report using a broad-based participatory approach that considered both the articulation of policy issues and scientific uncertainty. The report builds on the foundation provided by the *2009-2011 Puget Sound Biennial Science Work Plan* (Partnership 2008) and the *Strategic Science Plan* (Partnership 2010).

[1] Revised Code of Washington 90.71.110 et seq. (see Appendix A)

Approach

Priority Science for Restoring and Protecting Puget Sound is divided into two main sections. The first section is an analysis of gaps in scientific understanding relative to the goals of the Partnership. This includes a review of the questions that current research and monitoring are addressing, a review of recommendations from scientific reports and publications on the science needs for a program of ecosystem recovery in Puget Sound, and a survey of what scientists, practitioners, and decision makers believe are the scientific needs that will help in recovery of Puget Sound. Analyzing this information relative to a conceptual model of ecosystem recovery for Puget Sound (Figure 1) illustrated where gaps in scientific attention and knowledge are likely present.

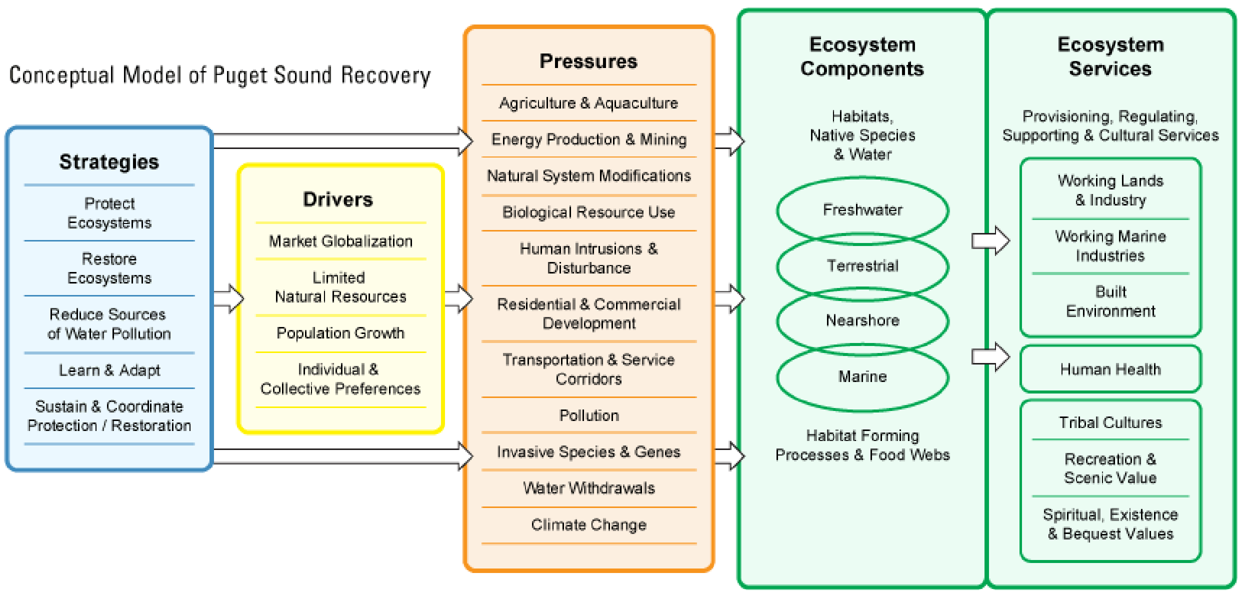

Figure 1. General Conceptual Model of Puget Sound Recovery. Ecosystem components are the major ecological characteristics used to organize information about the ecosystem (Levin et al. 2010) and the ecosystem services it provides (MEA 2003, Gomez-Baggethun et al. 2009). Pressures are human activities that impact the ecosystem leading to a change in state (EEA 1999, Carr et al. 2007). Drivers are fundamental social processes that create pressures (Lackey 2009). Strategies are suites of institutional social and economic efforts to respond to changes in the ecosystem and its services (Carr et al. 2007).

The second section of the document recommends the priority areas, questions, investigations, and capacities most needed to advance recovery and protection of Puget Sound now. Not all gaps in knowledge are priorities for funding and investigation. To determine what gaps are priorities, the Science Panel used two criteria:

- How much do we know? What is the level of scientific uncertainty?
- What are the decision critical questions and information? Where is lack of scientific information hindering progress?

Evaluation of decision-critical issues requires the perspectives of decision makers and practitioners. To understand these perspectives, the Science Panel relied on information

collected during multiple stakeholder meetings on the *Action Agenda Update*; the priorities of the Action Areas groups, who provide the perspectives of local organization and governments; and feedback from decision makers on the Ecosystem Coordination Board, who represent a broad range of interests and values.

The science priorities highlighted here intentionally do not address all the domains where science and policy interact. For the purposes of this document, the Science Panel recognized four domains of policy-oriented science (Figure 2). These domains reflect the demands on science as classified by two axes: the degree of development of scientific knowledge and the level of articulation of policy issues (Hisschemöller and Hoppe 1995, Shaxson 2009, Rudd 2011). The primary focus of *Priority Science for Restoring and Protecting Puget Sound* is on two of these domains:

- Areas where both scientific knowledge and articulation of policy issues are poorly developed (upper left quadrant of Figure 2), and
- Areas where scientific knowledge is poorly developed but consensus exists on the policy issues (upper right quadrant of Figure 2).

Areas where both scientific knowledge and articulation of policy issues are poorly developed often occur with emerging issues. Ocean acidification in Puget Sound (Feely et al. 2010, Pfister et al. 2011) is an example of such an emerging issue. Science on emerging issues can provide findings that raise new policy issues or reorient policy attention, for example. As scientific information accumulates, synthesizing results or incorporating them in analysis to evaluate risks can help policy makers understand ecological and social outcomes, which helps frame policy issues. Similarly, in areas where policy consensus exists on an issue or a problem but where technical solutions are not available or are untested, focused strategic investigations and analyses can provide information to help craft solutions to policy issues. Social science investigations and tools can also help define the nature of the policy issues more explicitly. Developing the analytical tools to identify priority habitats (Brooks et al. 2006) is an example of this kind of science-policy interaction.

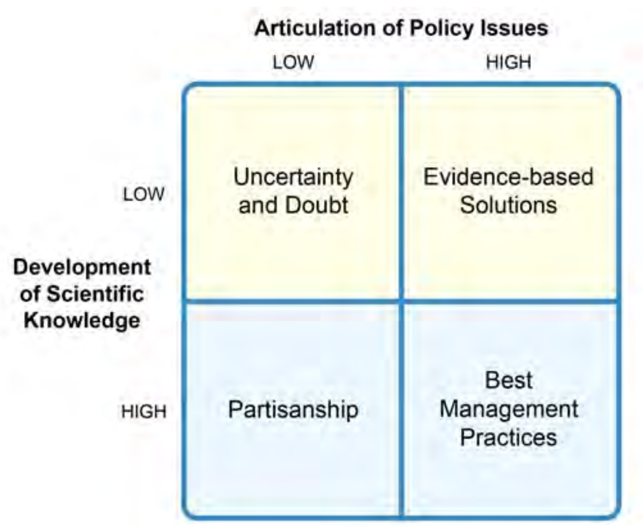

Figure 2. Demands on Policy-Oriented Science (modified from Rudd 2011)

In contrast, areas where scientific knowledge is well developed and policy issues are well understood, or where scientific knowledge is well developed but articulation of policy issues is ambiguous, are not the primary focus of this document. In the former case, the focus of science is on improving best management practices for activities in and around Puget Sound. This is part of the ongoing work and responsibilities of many state and federal agencies. This work is important and needs to continue, but it is not the focus of this report. Similarly, where scientific knowledge is well developed but articulation of policy issues is ambiguous, science is commonly used selectively to support partisan positions. Additional research or monitoring is unlikely to provide clarity to policy issues in this case. In this domain, other scientific functions, such as independent peer review, are more appropriate tools to advance science-policy interactions.

Uses of this Document

Priority Science for Restoring and Protecting Puget Sound meets a number of needs. First, this document meets the legislative requirement for the Partnership to produce both a list of science actions to be conducted during the biennium and recommendations to improve the ongoing science work in the Puget Sound (Appendix A). This means that *Priority Science for Restoring and Protecting Puget Sound* includes both new research, monitoring, or modeling and issues that may already be part of ongoing programs and studies but that need further work and refinement. Importantly, this work plan is nested within the Partnership's overall science priorities, which are described in the *Strategic Science Plan* (Partnership 2010), the framework for development and coordination of science activities necessary to restore the health of Puget Sound by 2020.

Priority Science for Restoring and Protecting Puget Sound also addresses the desire to allocate limited economic resources strategically towards the science that is most needed. The Partnership receives no money to disperse for science. State and federal agencies, Indian tribes, and non-governmental organizations, however, do receive funding from state, federal, and private sources to advance the science needed within their respective management areas. Until additional sources of funding are available, focusing existing funding on the scientific issues that advance both specific management needs and broader issues of Puget Sound recovery is the most efficient use of these resources. The Science Panel therefore intentionally selected the 48 priorities within this document to provide a list that federal, state, and non-governmental funding sources can use to direct research and monitoring toward science within their areas of responsibility (e.g., clean water, endangered species, land conservation, transportation, etc.) that also contribute to a larger, strategic effort.

The Science Panel also organized this version of the science work plan to be a key companion to the *Action Agenda Update.* The *Action Agenda Update* describes the long-term strategies and coordinated near-term actions to be implemented by state and federal agencies, tribes, cities and counties, other local jurisdictions, nongovernmental organizations, and the general public to recover and protect the ecosystem and the services it provides. *Priority Science for Restoring and Protecting Puget Sound* in turn uses the strategic categories of the Action Agenda Update to organize priority science actions. This helps demonstrate the strategic link between science needs as determined by the Science Panel and implementation actions while still preserving the

legislative intent to keep the development of the stakeholder-based *Action Agenda Update* and the identification of key science needs through scientific analyses as separate and independent processes. Consequently, *Action Agenda Update* strategies inform scientific priorities but the biennial science work plan is not simply a list of science needed to implement near-term actions in the *Action Agenda Update.*

Analysis of Needs

This section is organized into two parts. The first compares completed or ongoing scientific studies with the recommended research and monitoring topics for Puget Sound recovery. The second summarizes recommendations generated from the scientific and conservation practitioner communities.

The scientific and conservation practitioner communities were invited to participate in two ways. First, interdisciplinary teams of scientists, practitioners, policy analysts, and stakeholders that formed to develop strategies for the *Action Agenda Update* were asked to provide recommendations. Second, scientists from academia, state, federal, local agencies, tribes, and environmental organizations and other stakeholders responded to an open request for recommendations on priorities given the criteria used by the Science Panel.

The following sections are organized by the four key Action Agenda strategy areas, which are:

A. Protect and Restore Terrestrial and Freshwater Ecosystems

B. Protect and Restore Marine and Marine Nearshore Ecosystems

C. Reduce and Control the Sources of Pollution to Puget Sound

D. Sustain, Coordinate, and Adapt Puget Sound Recovery Efforts

Comparison of Recently Completed Research and Recommendations

Two inventories provide the basis for identifying needs for science and monitoring for Puget Sound. The first is an inventory developed specifically for this analysis of approximately 200 recently completed or ongoing scientific studies (Appendix B). The second is a list of over 100 recommended scientific studies in Puget Sound from literature published between mid-2008 and late 2011 (Appendix C). Both inventories are based on web searches and queries of federal and state agencies, local jurisdictions, tribal and non-profit organizations, and local universities. The inventory of recommendations started with review of recent Puget Sound Partnership peer-reviewed publications, especially the *Puget Sound Science Update* (Partnership 2011a) and the scientific literature cited therein and the *2009-2011 Biennial Science Work Plan* (Partnership 2008). It also extends to workshop summary reports, such as technical reviews of ecosystem indicators and targets and social science strategies (Social Science Advisory Committee 2011, Partnership Science Panel 2011), planning reports, and other gray literature referenced by the Partnership. Science Panel members reviewed the inventories and provided further additions.

Neither inventory is comprehensive. In particular, scientific studies being conducted at local or watershed scales or by smaller organizations may be underrepresented. It is important to identify these in future updates because they may provide key findings to the broader recovery effort. The Puget Sound Partnership Science Program is exploring tools to develop more comprehensive inventories of research, monitoring, and modeling and to describe existing functional networks of scientists working on Puget Sound issues. Taken together, however, the analyses of these two existing inventories are likely to illustrate the major gaps in science needs.

Figure 3 provides a visual comparison and summary of the recently completed or ongoing studies and the recommended studies used for this analysis. In general, human dimensions – human health, wellbeing, and ecosystem services – are the least represented of the areas of study. In contrast, marine and nearshore ecological domains are a major focus of recommended studies and recently completed or ongoing studies. Several striking differences occur; however, between recently completed or ongoing studies and recommendations. Recently completed or ongoing studies have a broader scope and focus and address more attributes of the terrestrial (includes freshwater), and nearshore domains than the scope of the recommendations for those domains. Recommendations focus on only a subset of those attributes. In contrast, recently completed or ongoing studies that focus on the human dimensions domain have a narrow scope and focus almost exclusively on human health issues related to the environment, whereas the scope of recommendations call for study of a broader suite of ways that humans benefit from the environment.

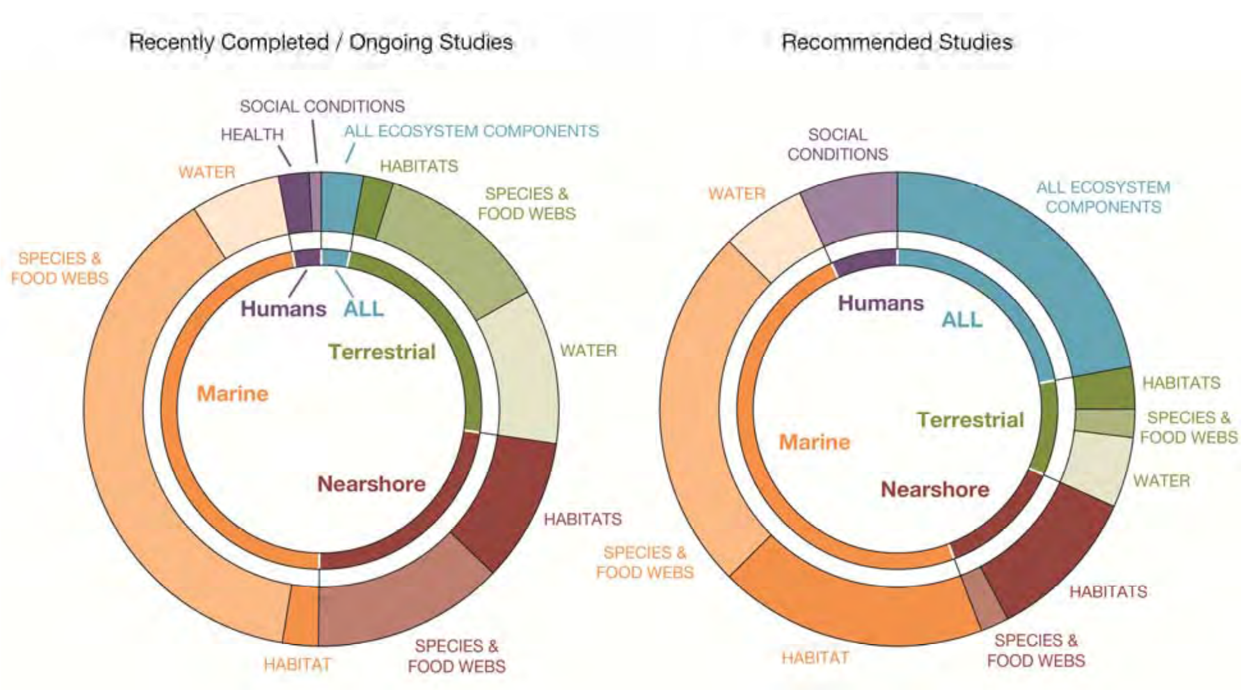

Figure 3. Summary of Recently Completed or Ongoing Studies. Ecosystem components are four major ecological domains (terrestrial, freshwater, nearshore, and marine) and humans represented by the inner ring. The proportion of studies or recommendations within the ecosystem components are classified by the primary goals of the Puget Sound recovery (habitat, species and food webs, water, and human health, well-being, and social conditions (as designated Figure 1, Levin et al. 2010).

Comparing the focus of recently completed or ongoing studies with the Puget Sound Partnership's assessment of pressures on the ecosystem is also revealing (Table 1). Most studies are focused on non-point and point source pollution, biological resource use (e.g., studies related to the use and management of salmon, shellfish, and forests), and climate change. This is generally consistent with the assessment of pressures for those areas. Climate

change and fishing and harvesting are assessed as posing “very high” or “high” impacts on the ecosystem, whereas impacts of pollution ranged from “high” to “low” depending on the source of the pollution (Partnership 2009). Gaps are also obvious, however. For example, although invasive species has a “high” impact rating, almost no studies are focused on this pressure.

Table 2. Number of recently completed or ongoing studies and recommended studies focused on ecosystem pressures on Puget Sound. Taxonomy of pressures follows the IUCN classification (International Union for Conservation of Nature 2001) as modified by Salafsky et al. (2008). Ratings are from Partnership (2009).

Rating	Pressures	Recently Completed / Ongoing Studies	Recommended Studies
Very High	Climate Change	25	12
	Residential, Commercial, Port & Shipyard Development	7	6
High	Dams, Culverts, Levees & Tidegates	8	1
	Invasive Species – Freshwater	1	
	Runoff from the Built Environment	16	12
	Transportation and Service Corridors	2	
	Marine Shoreline Infrastructure	5	3
	Biological Resource Use	38	19
Medium	Air Pollution & Atmospheric Deposition	1	
	Invasive Species – Marine	6	
	Oil & Hazardous Material Spills	1	
	Industrial & Domestic Municipal Wastewater (On Site Sewage)	4	
	Recreational Activities	1	
	Water Withdrawals & Diversions	9	4
Low	Agriculture & Livestock Grazing	7	1
	Aquaculture	4	1
	Derelict Fishing Gear	2	
	Industrial & Domestic Municipal Wastewater (Point Source)	17	
	Industrial & Domestic Municipal Wastewater (Wastewater Treatment Discharge)	5	
	None Addressed (e.g., monitoring, fundamental science Other Issues (Monitoring, basic research, etc.)	79	45

Terrestrial and Freshwater Ecosystems

Habitats and Species

The two inventories contain many more recently completed studies (34) than recommendations (5) for research in terrestrial and freshwater habitats. Only a limited number of upland habitat studies contributed to the inventories. Recently completed studies focus on multiple topics related to salmonids (e.g., effects of climate change, benefits from stream restoration, and effects of hatchery management, etc.), presence of toxicants and pesticides in freshwater fish, protection of biodiversity in urban areas, and other native species (e.g., Olympic mudminnow, pocket gopher). Recommendations in the *Puget Sound Science Update* (Partnership 2011a) propose analyses of altered hydrology and soil conditions due to impervious surface impacts, compaction, and reduced absorption. Comparison of the inventories suggests studies of impervious surface on hydrology and soil conditions are a current research gap.

Water Quality and Quantity

Similar to habitats and species, there are many more recently completed studies (27) than recommendations (5) for research specific to water quantity and quality. Recently completed studies focus on water quality of streams and lakes, sediment contamination, groundwater contamination, sediment transport and stream channel development, and freshwater flows. Key recommendations include assessing freshwater flows using improved stream gauge data and work to institutionalize agricultural best management practices in target watersheds to improve water quality. In addition, analyses suggest that studies to establish groundwater recharge volume requirements to support regional stormwater management strategies are a need.

Marine and Nearshore Ecosystems

Habitats

The inventories contain 32 recently completed or ongoing studies and 30 recommended studies specific to marine and nearshore ecosystems. Study recommendations for habitats focus on coordinating and measuring the benefit of a network of marine protected areas, understanding the effects of shoreline armoring, understanding changes in abundance and distribution of eelgrass, using adaptive management for nearshore restoration, and measuring the benefits of restoration. Analyses of the inventories suggest that research is occurring in these areas, as well as derelict fishing gear impacts, sediment quality and transport along shorelines, and effect of dams (e.g., Elwha) on beach morphology. Recommended work is needed to improve marine protected area management and effectiveness, analyze and monitor the effects of shoreline armoring, and conduct nearshore restoration in an adaptive management framework. Specifically, adaptive management recommendations suggest that restoration should be measured in ways that are compatible with land use planning models that emphasize ecological

function, and that provide feedback to decision making for future restoration planning and implementation (Partnership 2008).

Species and Food Webs

For marine and nearshore species and food webs, the inventories contain many recently completed or ongoing studies (126) as well as recommendations (28). Most recommendations were in the *Puget Sound Science Update* (Partnership 2011), the *21st Century Salmon and Steelhead Initiative* (WDFW 2008), and the *2009-2011 Biennial Science Work Plan* (Partnership 2008). Recommendations focus on salmon recovery but also include other fish, such as forage fish and mid-water species of fish. Research gaps include a long-term assessment of both major forage fish species and bentho-pelagic fish in Puget Sound, food web structure and processes, and more detailed analysis of trends in marine bird abundance. Recommendations indicate a need to identify stressors within the food web, their effects on forage fish, and food web influences on the population dynamics of valued species in Puget Sound. For salmon recovery, recommendations generally relate to improved coordination across the region to effectively and efficiently implement goals for salmon recovery, monitor juvenile fish to determine effectiveness of recovery actions, and continue work on improving the management of recreational and commercial fisheries.

Pollution

The inventories contain a moderate number of recently completed or ongoing studies (40) and recommended studies (12) specific to pollution. More inventory work could help determine additional studies and how well current work answers critical questions. Recently completed or ongoing studies focus mostly on water quality topics such as nutrients, pathogens, and toxicants; dissolved oxygen trends in Hood Canal (Newton et al. 2011), South Sound (Kolosseus and Roberts 2009), and the greater Puget Sound Region (Department of Ecology 2011a); harmful algal blooms; and the ecological coupling between the watershed and the estuarine and marine waters of the Puget Sound/Salish Sea. Recommendations are generally more specific to stormwater pressures and were from *Control of Toxic Chemicals in Puget Sound: Assessment of Selected Toxic Chemicals in the Puget Sound Basin, 2007-2011 (Norton et al. 2011)* and the *2009-2011 Biennial Science Work Plan* (Partnership 2008). Analyses of the inventories suggest that research needs are to analyze the effects of stormwater on receiving waters, habitat, biota, or human health in a watershed; study the relationship between pollution source control efforts and specific land uses; and support further understanding of the effectiveness of stormwater management techniques at the watershed scale.

Climate Change

Several studies and recommendations in the inventories identify climate change as one of the key pressures on ecosystem components. Recently completed or ongoing studies (25) and recommended studies (12) focus on specific questions about climate change that are applicable to some or all ecosystem components. These include focused climate modeling, impacts to humans, and impacts to natural resources. Recommended study topics are to focus on

collaboration, communication, and partnership of research communities to foster understanding of climate change consequences. Work yet to be done in this area includes downscaled climate projections, vulnerability assessment of local communities and infrastructure, and development of adaptation strategies.

Human Dimensions

The inventory contains few recently completed or ongoing studies (7) related directly to humans. These were specific to human health and focus on the risks of heat events and air pollution associated with climate change, recent trends in fecal coliform pollution in shellfish, and recent trends in paralytic shellfish toxins. Recommendations for research in human dimensions (7) show increasing awareness of the importance and breadth of human dimensions as part of the science agenda (Partnership 2011). Suggested studies include additional focus on environmental contributions to human health, the use of social sciences for ecosystem management; developing a human dimensions actions framework; and developing a Social Sciences Strategic Plan targeted toward ecosystem recovery in Puget Sound. The *2009-2011 Biennial Science Work Plan* (Partnership 2008) recommends specific social science research to advance understanding of how people and the environment interact. Recommendations include developing socioeconomic indicators to measure the impact of ecosystem change or restoration on human uses of ecosystem services, estimating monetary values for some ecosystem indicators using relevant economic models, socioeconomic factors and empirical studies of human uses of the ecosystem, and human response to climate changes.

Sustaining, Coordinating, and Using Science to Adapt Actions

A variety of primary sources recommend actions for sustaining, coordinating, and using science needed for adaptive management of recovery and protection actions in Puget Sound. The *Puget Sound Science Update* (Partnership Science Panel 2010, Partnership 2011), *Strategic Science Plan* (Partnership 2010), and *2009-2011 Biennial Science Work Plan* (Partnership 2008) include and summarize these. These recommendations target two fundamental issues: (1) identifying priority research and monitoring and (2) developing and sustaining the technical and institutional capacity to generate, analyze, and communicate scientific information for decision making. This section focuses on the second issue. The following key topics emerge from recommendations on this issue:

- Sustaining and improving monitoring,
- Developing an integrated set of decision support tools,
- Managing and communicating data, and
- Supporting science education and outreach.

Recommendations for monitoring occur universally in the source documents addressing adaptive management. These include sustaining ongoing programs that currently provide data on the status and trends of ecosystems. Key areas include improving status and trend

monitoring through better coordination and implementing effectiveness monitoring to test whether conservation actions are having the intended results. Other recommendations are to improve decision support tools including developing ecosystem and human well-being indicators; conducting risk assessments of the pressures on the ecosystem; using viability analyses to help decision makers identify recovery targets; and developing and using quantitative and qualitative tools for evaluating how policy decisions affect future ecosystem states and the benefits to humans.

Recommendations for management and communication of data focus on developing flexible data exchange capabilities to make indicator data and other assessment information available and accessible to broad communities of users. Recommendations for science education and outreach suggest enlisting conservation scientists to work with educational institutions in training younger scientists and practitioners, developing a network of scientists to provide advice and support to decision makers, and encouraging internships and fellowship programs.

In terms of ongoing research to sustain, coordinate, and use science to adapt actions, monitoring is occurring throughout Puget Sound via a wide variety of programs. In 2010, a matrix of current agency monitoring programs was developed for the Natural Resources Reform Workgroup (see Appendix D). The Workgroup was formed in response to the Governor's 2009 initiative (Executive Order 09-07) to better coordinate efforts of state natural resource agencies. The matrix highlights ongoing agency monitoring programs (rather than one-time studies, individual research projects, etc.) and is not an exhaustive inventory of all monitoring. For example, the inventory of recently completed and ongoing research completed for this report (see Appendix B) documented several monitoring studies not listed in the Workgroup matrix of programs, including focus on environmental stressors in lakes, pesticides in freshwater streams, eelgrass trends in areas of the San Juan Archipelago, Chinook salmon life history traits in the Nisqually River estuary, and shallow groundwater flows in the Skagit River delta. In February 2011, the Partnership Leadership Council endorsed a Puget Sound Coordinated Ecosystem Monitoring and Assessment Program to coordinate and improve ecosystem monitoring.

In 2010, the Partnership established a Dashboard of Ecosystem Indicators (Indicators Action Team 2010) and 16 recovery targets related to these indicators to judge progress of recovery. The Partnership completed a qualitative assessment of threats (Partnership 2009) but based on the *Puget Sound Science Update* (Partnership 2011) the Science Panel recommended that the scientific basis of this be improved to inform decisions about where and when to focus on different risks to the ecosystem. Inventories indicate that qualitative and quantitative tools to evaluate policy options and future scenarios exist or are being developed, but these are often specific to an issue or topic and are not adequately integrated to address ecosystem outcomes.

Recommendations from the Scientific, Practitioner, and Stakeholder Communities

This section summarizes science recommendations offered by the scientific and conservation practitioner communities. Scientific and conservation practitioners provided their recommendations through two different processes. First, a variety of technical teams

convened during development of the *Action Agenda Update* identified science needs that were later reviewed by the Science Panel. Topic-specific interdisciplinary teams and working groups of scientists, practitioners, policy analysts, and stakeholders convened by the Partnership to develop strategies and near-term actions for stormwater, runoff from the built environment, shoreline alteration, land development, and floodplain management were asked to assess and describe areas of scientific uncertainty and decision-critical needs. Other science teams, such as the Recovery Implementation Technical Team and Nearshore Ecosystem Recovery Team, provided a list of science needs associated with salmon recovery and nearshore ecosystems, respectively. Finally, organizations implementing recovery and protection actions at the scale of local geographies and watersheds, such as Action Area caucuses, submitted recommendations to the *Action Agenda Update* that included science needs. Summaries of these recommendations are provided in Appendix E.

Second, the Partnership contacted approximately 200 scientists from academia, state, federal, local agencies, tribes, environmental organizations, and other stakeholders to request recommendations on scientific needs. Respondents were asked to identify key areas of scientific uncertainty and areas where the lack of social, natural, or physical scientific work is impeding our ability to recover Puget Sound. Approximately 45 scientists and other stakeholders responded to the request, providing over 150 responses (Table 2). Their responses are provided in Appendix F.

Table 3. Number of recommendations from the scientific community summarized by ecosystem components or pressures corresponding to key strategies of the *Action Agenda Update*.

Ecosystem Component or Pressure		# of Responses
Upland, Terrestrial & Freshwater	Habitats	12
	Species & Food Webs	7
	Mitigation	4
Marine & Nearshore	Habitats	10
	Species & Food Webs	36
	Mitigation	8
Pollution	Toxics	15
	Runoff from the Environment	10
	Wastewater	3
	Shellfish	1
	Oil Spills	0
	Other	1
Climate Change		7
Human Dimensions		8
Sustaining, Coordinating, & Using Science to Adapt Actions	Building Capacity	4
	Foundational Questions	9
	Scientific Tools for Informing Policy	5
	Integrated, Sustained Monitoring	9
	Education, Training & Outreach	3
Total		**152**

Upland, Terrestrial and Freshwater Ecosystems

Key scientific questions pertinent to upland and terrestrial habitats center on freshwater stream flows, biodiversity protection, corridors and connectivity, and soil absorption as it relates to groundwater recharge. Recommendations for stream flows include improving the scientific basis for determining water budgets needed to set low stream flow standards in critical watersheds identified in the salmon recovery plans (Shared Strategy 2007), understanding how land use patterns influence peak events across a watershed, assessing pressures that specifically affect stream flow, and linking these to ecologically more robust indicators of stream flow than the current indicator chosen by the Partnership. Other habitat recommendations focus on reducing uncertainties about the effectiveness and response of habitat restoration in estuaries and testing the assumptions about regulatory standards, such as the effectiveness of the critical area ordinances for site-scale protection of habitats and priority species, and attaining no net loss in mitigation projects.

Recommendations for species and food webs identify key needs for research and monitoring on specific factors that might be limiting recovery of salmon in freshwater (e.g., predation, harvest, hatcheries, loss of habitat), along with better analyses of how these are related and interact. Other species and food web recommendations include questions about basic distribution, habitat requirements, and abundance of native freshwater species, such as non-game fish and freshwater mussels. Suggestions also identify the effectiveness of stormwater management, as measured by the response of instream biota at different geographical and biological scales as a science need.

Marine and Nearshore Ecosystems

Approximately one-third of the recommendations are directed toward marine and nearshore ecosystems. Attention on habitat focuses on the historical abundance of eelgrass and kelp, understanding how the modification of shorelines and sediment affects nearshore biota, and research on the outcomes and effectiveness of restoration. Several suggestions focus on monitoring large-scale restoration (such as the Elwha River) while others are specific to restoration strategies such as beach nourishment.

Scientists note that the lack of long-term system monitoring has resulted in a poor understanding of food web interactions and how transboundary processes (e.g., migrations, oceanographic fluxes, runoff, human activities, etc.) influence the internal dynamics of the marine ecosystem. Recommendations include developing better species and food web indicators, understanding distribution and habitat use of forage fishes, and assessing genetic connectivity among populations of marine biota in Puget Sound with other parts of the Salish Sea and the Washington coast. Recommendations for individual species are focused on the decline of marine birds (western grebe, marbled murrelet), native oyster restoration, variability of Dungeness crab production by year, and rockfish conservation and recovery strategies.

Pollution

The majority of scientific recommendations pertaining to pollution are directly related to toxicants. Scientists and practitioners indicated there are basic uncertainties about the source of some toxic chemicals, the threshold for adverse effects on biota and humans, and the effects of these toxicants on marine species at the population and community level. Scientists recommend an assessment of the relative impacts of various toxicants along with targeted science on their specific sources, transport, and fate. Others suggest priorities for pollution that focus on runoff from the built environment. These include monitoring of bacteria and harmful algal blooms (and biotoxins) on nearshore beaches and work to understand the community structure and dynamics of phytoplankton in marine waters. Recommendations focus on the source, transport, and fate of nitrogen from upland areas and the effects of changes in dissolved oxygen concentrations on species. Scientists identify emerging contaminants (e.g., endocrine disruptors, pharmaceuticals and personal care products, Bisphenol A, etc.) in wastewater as an important priority and recommend developing analytical methods and monitoring to understand their potential to cause adverse effects on both biota and humans.

Climate Change

The submissions by science and practitioner communities highlight several key uncertainties about future impacts from climate change. They suggest a variety of indicators and monitoring studies to collect data about the degree of ongoing change. These include monitoring stream and lake temperatures, the structure of benthic communities, salinity, and pH. Scientists also raise broader questions that have not been well investigated with climate change models, such as: what will be the affects on groundwater infiltration, storage, and discharge (most analyses focus on surface hydrology); how will ocean acidification affect the food web; how will invasive species respond to a changing climate and what impacts will those changes have on ecosystem health; and in what ways will genetic variability limit or allow populations of native species to adapt?

Human Dimensions

Natural and social scientists identify significant gaps in our understanding of human dimensions in ecosystem recovery. Key recommendations include synthesizing the existing social science literature and data, and assessing the assumptions and techniques that can be used to engage the public and change behavior. Scientists and practitioners also recommend analyses of the economic and social impacts of biological resource uses. Ideas include assessing the economic values of the ecosystem and monitoring these over time. These are considered part of an overall empirical valuation of how restoration and protection activities, such as those implemented by Action Agenda strategies, affect ecosystem services.

Sustaining, Coordinating, and Using Science to Adapt Actions

This broad category includes submissions pertinent to building capacity for a coordinated ecosystem restoration program, answering foundational science questions, developing tools for

informing policy, and education and outreach. The scientific and conservation practitioner community notes that the current systems of governance and management should be analyzed to determine where programs and actions are most efficient and effective. Related to this is building capacity for better coordination between science disciplines, institutions, non-governmental organizations, and the tribes.

Scientists also identify basic research questions about the Puget Sound ecosystem that were not specifically targeted in one of the categories discussed above. One group of questions focuses on developing quantitative links between when, where, and how land-based human activities (e.g., urban development, agriculture, industrial development, or logging) influence ecosystem function in marine ecosystems. Another group is interested in understanding the natural variability of ecosystem components, such as salmonid distributions and uses of specific nearshore habitats, the role of natural sources of nitrogen on dissolved oxygen levels, and climate variability.

Developing tools to coordinate and prioritize science is also important. Recommendations consider coordinated ecosystem monitoring focused on indicators of ecosystem recovery targets to be a high priority. Other aspects of recommended monitoring include sustaining existing monitoring programs, developing and coordinating effectiveness monitoring of restoration projects, and monitoring to test the effectiveness of critical areas ordinances and other regulatory programs executed by state resource agencies. Other scientific tools that scientists recommend for informing policy included seafloor mapping, spatial analysis of stressors, and mathematical models to prioritize recovery efforts.

Priority Science for 2011-2013

This section describes priority areas for research, monitoring, and modeling that are most needed to advance recovery and protection of Puget Sound in the next few years based on the approach and analyses described above. This section is organized by the *Action Agenda Update* strategies that give rise to these priorities. The *Action Agenda Update* provides additional detail on the relationship of these strategies to ecosystem recovery targets.

Upland, Terrestrial, and Freshwater Ecosystems

Upland and Terrestrial Habitats

Strategy A1. Focus land development away from ecologically important and sensitive areas
Strategy A2. Protect and restore upland, freshwater and riparian ecosystems
Strategy A3. Protect and steward ecologically sensitive rural and resource lands

- Analytical tools to describe options for where to protect, where to restore, and where to develop are a key priority for managing how human dominated landscapes across a range of pressure intensities can best contribute to maintaining desired ecosystem goods and services. Globally, conservation efforts have used a variety of approaches that emphasize different characteristics of ecosystem function and biodiversity, usually on a spectrum of irreplaceability and vulnerability (Brooks et al. 2006). These have different strengths and weaknesses, including the inherent biases associated with the kind of data that were availabile and failure to incorporate broader ecosystem services and other factors into the assessments (Kareiva and Marvier 2003). In Puget Sound, the Department of Ecology and Department of Fish and Wildlife are developing tools that attempt to identify the most important areas to protect, restore, and develop using characteristics of water flow (surface storage, recharge, and discharge), water quality (sediment, nutrients, pathogens, and metals), and landscape assessments of terrestrial, freshwater, and marine fish and wildlife habitat (http://www.ecy.wa.gov/puget_sound/characterization) (Stanley et al. 2011). Not all of these have been completed. Additionally, no decision support tools exist to integrate assessments and data across multiple scales within an overall watershed characterization framework. For example, this could include decision support tools to resolve ambiguities or identify synergies among the different watershed characterization tools and other analyses for identifying priority habitats, such as the *Puget Sound Chinook Salmon Recovery Plan* (Shared Strategy 2007). Key priorities for this work are to:
    - Complete the watershed assessment tools that have been started.
    - Develop decision support tools to assist in resolving ambiguities or conflicts and to identify synergies among the different watershed characterization tools.
    - Improve the assessment tools by incorporating additional characteristics of the ecosystem and ecosystem services that are not in the initial tools.
    - Validate key assumptions in the models.

- Incorporate social science research to guide development of adaptive management structures that link restoration science to management decision making.

- Developing key ecological indicators, assessing baseline conditions, and implementing subsequent monitoring to measure ecosystem function is a key priority for mitigation projects to be effective. Some preliminary work on this has occurred. Agencies have suggested lists of potential indicators (Department of Ecology 2010) that can be used in conjunction with the Shoreline Management Act (RCW 90.58) and Shoreline Master Programs Guidelines (WAC 173-26-186s(8)), but more direction is needed for choosing and implementing a suite that represents the ecological function of the area.

- Conducting social science studies to describe the key institutional challenges to attaining no net loss or overall improvement is a key priority.

Floodplains

Strategy A5. Protect and restore floodplain function

- Estimating the value of floodplains in terms of all the ecosystem services they provide is a key scientific priority. Floodplains are vital for storing floodwaters, recharging aquifers, filtering water, retaining sediment and nutrients, and supplying crucial habitat components for fish and wildlife (Beechie 1994, Spence et al. 1996, Benda et al. 2001, Ziemer and Lisle 2001, Collins et al. 2002). Much of the built environment also occurs in floodplains and is subject to damage from floods, slides, and other natural disasters. Floodplains are often constrained by levees and dikes to reduce these damages and enhance the built environment. However, decisions based on economic analyses of the tradeoffs between these different aspects of floodplains do not usually include the full valuation of floodplains (Batker et al. 2008).
- Developing key ecological indicators and implementing monitoring to assess key ecological functions of floodplains and to track their status is a key science priority. Although land use planners and scientists have identified many of the services and functions floodplains provide, little effort has been given to establishing a functional set of indicators and metrics for Puget Sound that can measure how floodplains are performing. Smith (2005), for example, resorted to a qualitative analysis of floodplain status in Puget Sound because of the lack of consistent data and she also noted areas where no data for floodplains were available.
- Improving the understanding of the effects of vegetation on dikes, levees, and other flood control structures is a key scientific priority for floodplains.

Freshwater Species and Food webs

Strategy A6. Protect and recover salmon

- A key priority for salmon recovery is to develop analytical tools to evaluate whether strategies to address factors limiting the productivity of salmon are being addressed in the most effective combinations, at the right times, and with the appropriate amount of effort

to lead to recovery. Ruckelshaus et al. (2002) noted that single-factor analyses of the primary pressures on salmon populations – loss of habitat quantity and quality, hydroelectric dams, artificial production, and harvest – were inhibiting salmon recovery because they failed to capture all the pressures on salmon or the interactions among pressures. In addition, single-factor analyses tend to focus on causes (and therefore blame) rather than solutions. Ruckelshaus et al. (2002) called for integrated analysis of pressures that could inform decisions about how to prioritize and sequence recovery actions. The *Puget Sound Salmon Recovery Plan* (Shared Strategy 2007) also identified this need. Efforts to collect data on intensively monitored watersheds by state, federal, and tribal scientists (http://www.ecy.wa.gov/programs/eap/imw/index.html) are underway, but analytical tools remain largely undeveloped and salmon recovery implementers are making crucial decisions without these analyses.

- Information on the causes of decline in marine survival of salmon as they leave their natal rivers and exit Puget Sound is a key priority. Growth and survival of salmon during this life-history phase are strongly correlated with overall marine survival (Duffy 2009). Evidence that survival rates of some species during the Puget Sound phase are rapidly declining (Moore et al. 2010) is a warning that the environment may be changing in unanticipated ways. This could have important effects on the success of salmon recovery.

Freshwater Ecosystems

Strategy A8. Protect and conserve freshwater resources to increase and sustain water availability for instream flows

- Developing robust ecological indicators and implementing comprehensive monitoring for stream flows is a key priority. The Partnership currently has an ecosystem target based on 30-day summer low flow trends as a measure of ecological function of water quantity in streams. An increasing number of analyses, however, conclude that a single indicator, such as summer low flows, is inadequate for representing the ecological functions that flow regimes provide (Poff et al. 1997, Bunn and Arthington 2002, Naiman et al. 2002, NRC 2007). In addition, the indicator is based on existing data for 13 rivers in Puget Sound, which only partially represents the region's key rivers and streams. Better monitoring and research will also help explain the cause of the trends and the linkage of the indicators to human impacts causing the trends.
- Evaluating and improving stream flow targets in terms of their affects on the abundance, productivity, distribution, and life-history diversity of salmon (McElhany et al. 2000) is a key priority.

Marine and Nearshore Ecosystems

Marine and Nearshore Habitats

Strategy B2. Protect and restore nearshore and estuary ecosystems
Strategy B3. Protect and restore marine ecosystems

- Developing the analytical tools to identify priority areas for protection and stewardship is a key need for these strategies. Valuable information is available on the status and historical changes in physical structure of marine and nearshore shorelines (Simenstad et al. 2011). This information can assist in making decisions about the potential for restoration and protection. However, information and analytical tools, such as marine spatial planning, linking these to other key considerations that are important are lacking or need to be improved. Important improvements include:
    - Incorporating additional physical attributes as well as biogenic structures like eelgrass, kelp, or coastal forest condition into estimates of ecosystem services provided by shorelines.
    - Assessing the impacts of barrier features on embayments.
    - Increasing understanding of the effects of protection and restoration at different spatial and ecological scales ranging from local domains (e.g., marshes, beaches, drift cells) to process domains (e.g., geomorphic units and salinity regimes) to landscape domains spanning many kilometers (Simenstad et al. 2006).
    - More robustly incorporating rare forms, species, and processes in understanding landscape composition.
    - Including landscapes and habitats used by target species.
    - Incorporating threats to ecosystem services and potential for protection.
    - Incorporating human use and values.
- As state and federal agencies, local governments, tribes, and citizen groups invest in nearshore restoration, it is a high priority to develop the adaptive management strategies and structures that link restoration science to management decision making. Four basic approaches exist for adaptive management (Anderson et al. 2003), but restoration usually begins without implementers intentionally choosing a strategy or developing an adaptive management structure to learn from their efforts. For example, nearshore areas are critical Puget Sound environments supporting salmon, forage fish, shellfish, wetlands, tribal trust uses, and crucial hydrologic and geologic inputs. Habitat features of large river deltas are particularly important in Puget Sound restoration because more than 50 percent of intertidal areas, including marshes and mudflats, in these deltas has been lost since 1850 (Bortleson et al. 1980). Nearly 33 percent of Puget Sound shorelines have some type of shoreline modification structure. Across all tidally influenced areas of Puget Sound (shorelines, estuaries and rivers) 82 percent of vegetated wetland area has been lost since historic maps were created in the 1850s to 1890s (Nearshore Habitat Program 2000, Washington Department of Natural Resources as cited in PSAT 2007, Simenstad et al. 2011). Recent research on the role of large river deltas in supporting the ecosystem as a whole emphasizes the need for restoration of these systems. Significant restoration actions are now planned or underway for several of the Sound's large deltas – for example the Skagit, Nisqually, Skokomish, and Elwha (Ellings 2008, Ellings et al. 2010, USGS 2011a, 2011b, PSNERP 2011a, 2011b). It is unclear how these or other efforts fit together as adaptive

management. Choosing and implementing the appropriate adaptive management framework so that the region can learn from these important but diverse efforts is critical.

- Information the about key stressors on eelgrass, the source of the stressors, and locations where they occur is a priority for developing a recovery strategy. Review of the scientific literature documents an extensive suite of ecosystem services associated with eelgrass (Mumford 2007, Dowty et al. 2010). In the Puget Sound, for example, eelgrass provides spawning habitat for Pacific herring, protection and cover for young juvenile salmon and important feeding areas for water birds (Phillips 1984, Simenstad 1994, Wilson and Atkinson 1995, Butler 1995) and other benefits. The Puget Sound Partnership adopted eelgrass as an indicator of the health of Puget Sound and set a target of increasing eelgrass area in the Puget Sound by 20 percent by 2020. Reaching this target will require a focused strategy that reduces stressors on eelgrass and allows eelgrass to expand geographically.

Species and Food Webs

Strategy B5. Protect and restore the native diversity and abundance of Puget Sound species

- Having information and analytical tools that allow decision makers to understand the tradeoffs in managing a suite of marine species and the multiple stressors affecting those species is a key science priority. The Partnership, for example, has adopted recovery targets independently for different marine species including eelgrass, herring, shellfish, Pacific salmon, orcas, and for reducing different stressors such as shoreline armoring and toxic pollution. Attaining all of these targets may be impossible given the food web dynamics of Puget Sound. Current food web models (e.g., Harvey et al. 2010) are largely static and not spatially explicit. Understanding how Puget Sound food webs change over time and space with respect to different stressors will greatly improve the ability to make informed, strategic decisions.
- Biological and sociological studies to understand the conservation and sociological roles of marine protected areas for habitat and species protection, ecosystem restoration, and sustaining usual and accustomed tribal fishing areas in the Puget Sound (Van Cleve et al. 2009) is a key science priority. Conversation groups and agencies often advocate for marine protected areas and reserves (WDFW 1998, Gaydos et al. 2005), but successful implementation requires understanding both the conservation and sociological benefits (Agardy et al. 2003).

- Identifying the stressors on specific groups of species in the Puget Sound food web and the potential magnitude of their individual and combined effects is a key science need. Several key groups of species are priorities for focus:
    - Forage fish - Pacific herring, sand lance, surf smelt, longfin smelt, eulachon and other schooling forage fishes occupy a key position in the Puget Sound food web. Ecological processes involving forage fish – both up and down the food chain – may control other important ecosystem processes and populations of valued species in the Sound directly or indirectly. The open-water food web provides

ecological life-support for valued species in Puget Sound such as salmon, orcas, and water birds. Forage fish are a valued economic resource themselves. Understanding the stressors on forage fish – which could include changing species compositions of prey, competitors, or predators; loss of forage fish spawning habitat; invasive species; novel disease; ocean acidification; and the driving climate change and human population impacts (Penttila 2007) – is important in identifying where stressors occur, the magnitude of their impacts, and how they can be reduced.

- The abundance of multiple species of Puget Sound marine birds has declined sharply over the last 20 years, in some cases as much as 95 percent (Nysewander et al. 2005, Wahl 2002, Bower 2009). The causes of these changes in abundances are not well known. Without understanding the causes, such as the possibility that the declines reflect changes in geographic distribution or response to stressors in the Puget Sound or elsewhere, for example, it is difficult to develop appropriate recovery strategies. Similar concerns in Canada indicate that this is an opportunity to collaborate on understanding trends in our migratory bird species.

- Information on the sources of nutrients (nitrogen compounds) that enter Puget Sound is important for developing strategies to maintain water quality for Puget Sound food webs. Decomposition of large biomasses of phytoplankton that feed on nutrients can drive dissolved oxygen concentrations to levels that can threaten marine life in late summer and early autumn in Hood Canal and other areas with low overturning circulation (Warner et al. 2001). One source of nutrients is likely from humans and other terrestrial sources (Paulson et al. 2006, Newton et al. 2011), but the largest source of nitrogen is seawater entering the Canal. Likewise, high nutrient and low oxygen water from the coast enters the Salish Sea during times of prolonged coastal upwelling. Historically, cycles of low oxygen have been occurring in Hood Canal since long before the 20^{th} century, suggesting that physical mixing from deep-water ventilation may be the most important natural process controlling oxygen levels in Hood Canal (Crecelius et al. 2007). Understanding the relative contribution of nutrient and oxygen sources seasonally and geographically is a key need for developing strategies to address low dissolved oxygen levels in Hood Canal and Puget Sound.

Strategy B6. Prevent and respond to the introduction of terrestrial and aquatic invasive species

- Assessing the risks imposed by invasive species is a key priority. The Partnership rated the impact of invasive species on the ecosystem as "high" (Partnership 2009), but more detailed taxonomic and geographic descriptions of the likelihood of impacts are lacking. The Washington Invasive Species Council currently uses a qualitative screening tool for prioritizing the most problematic species in or near Puget Sound. More precise risk assessments are needed for problematic species. Tools to do this for the Puget Sound are needed as well as the situation-specific data that many quantitative ecological risk assessment frameworks require (Andersen et al. 2004). However, relative risk can be estimated using relative risk frameworks across varying scales with existing information

without waiting for comprehensive quantitative risk assessments to better inform management actions (Colnar and Landis 2009).

- Tools for assessing the threats of invasive species are needed, as is the situation-specific data that many quantitative ecological risk assessment frameworks require (Andersen et al. 2004). However, relative risk can be estimated using relative risk frameworks across varying scales with existing information to better inform management actions (Colnar and Landis 2009).

Pollution

Contaminants

Strategy C1. Prevent, reduce and control the sources of contaminants entering Puget Sound

- Implement studies on persistent, bioaccumulative chemicals to better understand transport, trophic transfer, and associated ecological and human health risks and to ensure that Washington State's water quality standards and sediment management standards are protective of both fish and wildlife and allow for human and wildlife consumption. This requires using and potentially improving information on consumption rates by tribes and other subsistence fishers, improving knowledge of contaminant levels in Puget Sound crab and prawns; environmental transport and trophic transfer and accumulation of persistent toxicants; linkages between contaminant levels in the ecosystem and population-level effects on biota (Department of Ecology 2011b, Department of Ecology and King County 2011), and other health risks for the most vulnerable populations of Puget Sound residents.
- Describing the availability, feasibility, and safety of alternatives to products and processes that use and release toxic chemicals of concern in the Puget Sound ecosystem is a scientific priority. This includes information on the non-agricultural use of copper-based pesticides in Washington and evaluation of alternatives to copper for these pest control purposes; effectiveness of regulations to reduce copper in brake pads; identification and assessment of alternatives to commercial uses of phthalates; evaluation of toxic materials in roofing materials; standard practices for alternatives assessment; and development of Green Chemistry expertise and capacity in Puget Sound region institutions.
- Developing integrated monitoring and assessment of toxic chemical sources, exposure, and effects is a scientific priority. This includes status and trends in monitoring toxics in and released to Puget Sound; effectiveness of strategies and actions to reduce and prevent toxic chemicals from entering the Puget Sound environment; and annual reports that compile and synthesize information on results and effectiveness from multiple programs. Risk assessments of contaminants in Puget Sound in the context of other stressors are needed to quantify the relative magnitude of risks and to help prioritize actions appropriately. The risk analysis would also identify important data gaps and monitoring needs for evaluating the effectiveness of corrective actions. This could include synthesis efforts such as might be developed by enhancements of the Puget Sound Toxics Box Model (Pelletier and Mohamedali 2009), the Puget Sound food web toxics model (Stern et al. 2009, Condon

2007), and risk assessment (King County 2011). Validating assumptions and information needs about releases of toxic chemicals assessed in the Puget Sound Toxics Loading Study (Norton et al. 2011) is also important.

- Synthesizing information on emerging contaminants of concern and describing their risk to Puget Sound is a scientific priority. This includes investigations of the chemical causes of endocrine disruption in Puget Sound species; pharmaceuticals and personal care products, surfactants, and their degradation products, plasticizers, pesticides, and nanomaterials; and emerging pathogens and viruses.

Runoff from the Environment

Strategy C2. Use a comprehensive approach to manage urban stormwater runoff at the site and landscape scales

- Developing monitoring and assessment of benthic invertebrates in small streams to evaluate stormwater management and other efforts to protect and restore streams and their functions is a priority. Priority assessments related to this issue include establishing and maintaining a comprehensive inventory of benthic indices of biological integrity (B-IBI) in small streams; identifying data gaps; using monitoring results to identify basins for focused attention to achieve the Partnership's 2020 ecosystem target streams (basins where streams have "excellent" and "fair" B-IBI scores); and status and trend monitoring of stormwater and other sources of stressors in small streams using B-IBI and other stream quality parameters.
- Evaluating the effectiveness of low impact development (LID) projects and stormwater management best management practices and programs is a science priority. Assessment of these tools will guide the adaptation of stormwater management practices and programs by local and regional jurisdictions to ensure that stormwater does not impair receiving waters and that they progress towards the Partnership's 2020 ecosystem recovery targets for shellfish bed restoration, swimming beaches, toxics in fish, marine sediment quality, freshwater quality, and benthic invertebrates in small streams.
- Evaluating land uses and associated pollutants that would require treatment beyond sediment removal is a science priority for ensuring that stormwater management can achieve stormwater-affected 2020 ecosystem recovery targets.
- Evaluating the projected environmental benefits of structural stormwater retrofits given varying levels effort to guide the extent of structural retrofits is a priority to help meet 2020 ecosystem recovery targets and ensure that the investments are efficient. Capital costs of retrofits will likely be $8 billion and involve $300 million per year in maintenance (Parametrix 2010). Spatially explicit assessments and considerations of how the potential benefits of habitat restoration are integrated into stormwater control technologies are important components of this.
- Studies to fill the key information gaps on the direct and indirect effects of pesticides on salmon and the food web they depend on are a science priority. Pesticides interact in

complex ways with the aquatic ecosystem, affecting primary producers, macroinvertebrates, and the growth and survival of salmon and other native species of fish, and also reflecting different patterns of use by humans. Integrating knowledge of the effects of pesticides and how they can be mitigated with habitat restoration is important to ensure that investments in salmon recovery are effective (Macneale et al. 2010, Johnson et al. 2011, Spromberg and Scholz 2011).

Wastewater

Strategy C5. Prevent, reduce and/or eliminate pollution from decentralized wastewater treatment systems
Strategy C6. Prevent, reduce and/or eliminate pollution from centralized wastewater systems

- Evaluating nitrogen reduction in public domain on-site system treatment technologies is a science priority. These evaluations will help guide development and construction of decentralized wastewater treatment infrastructure that reduces the release of nitrogen (Horner 2011).
- Studies of human-related contributions of nitrogen to dissolved oxygen impairments in sensitive Puget Sound marine waters are critical to identify the need for and elements of water quality cleanup plans. This includes completing the South Sound Dissolved Oxygen Study (Kolosseus and Roberts 2009), which will clarify the need for a South Puget Sound water quality improvement plan, and completing the development of the Puget Sound Dissolved Oxygen Model (Ecology 2011a), which will help identify areas where enhanced wastewater treatment may be needed for water quality improvements.

Shellfish

Strategy C7. Abundant, healthy shellfish for ecosystem health and for commercial, subsistence, and recreational harvest consistent with ecosystem protection

- Establishing and funding sustainable pollution identification and correction (PIC) programs to identify and fix nonpoint pollution problems is a critical contribution to shellfish bed restoration, swimming beach protection and restoration, and other aspects of water body cleanup. Key factors affecting shellfish in Puget Sound – temperature, salinity, oxygen, pollutants, and food types – can be influenced by land use, stormwater and sewage discharges, introduction of invasive species, and other human activities in addition to natural changes and cycles (Dethier 2006). The ecology of shellfish, which depends on the characteristics of the water column, makes them good indicators of ecological changes and of potential threats to human health and wellbeing. Shellfish also provide multi-million dollar ecosystem services to Puget Sound (Northern Economics 2009).
- Research and monitoring are needed to understand the specific environmental conditions that produce toxic harmful algal bloom and pathogen events. Harmful algal blooms may not be as concentrated as toxic chemicals in some areas of Puget Sound, but they can produce toxins that kill fish and contaminate shellfish making them unsafe to eat (Backer and McGillicuddy 2006). Detection of HABs is increasing although the causes are not well

understood (Van Dolah 2000, Zingone and Enevoldsen 2000, Sellner et al. 2003). This information is an important complement to existing HAB monitoring by federal, state, and tribal partners and will improve the prediction and forecasting capability so that health managers can mitigate economic impact to the shellfish industry and risk to the public from consuming tainted seafood.

Oil Spills

Strategy C8. Effectively prevent, plan for, and respond to oil spills

- Evaluate existing oil spill risk assessments and complete additional risk analyses of industry sectors to ensure there is an appropriate level of investment in reducing the risk of oil spills is a high priority science action. Many valuable species, habitats, and ecosystem services of Puget Sound and much of the investment in restoration and protection to protect Puget Sound are vulnerable to oil spills. A major oil spill could cost the state's economy more than $10 billion, impact 165,000 jobs, and reverse progress in ecosystem restoration (Department of Ecology and Partnership 2010). This analysis includes identifying high-risk areas and developing strategies to mitigate risks in these areas based on models of marine traffic, assessments of incidents and near-misses, and assessments of prevention measures such as vessel inspections and improvements in oil spill prevention standards.
- Evaluate information on baseline conditions for key species at risk from oil spills and improve these as necessary so that baselines exist that can be used in assessments of natural resource damages from oil spills. These assessments are critical for not only assessing potential natural resource damages, but also understanding the value of ecosystem.

Cumulative Water Pollution

Strategy C9. Address and clean up cumulative water pollution impacts in Puget Sound

- Expanded monitoring of freshwater and marine water areas used for contact recreation will help protect human health from exposures during water-contact recreation, increase recreational services from the Puget Sound ecosystem, and engage the public in stewardship and monitoring associated with cleaning up Puget Sound's waters (e.g., O'Brien 2006). Monitoring should consider the different scientific needs in fresh and marine waters.

Emerging Issues – Ocean Acidification

In the last 250 years of industrialization, the pH of the world's oceans has changed from 8.25 to 8.14 or approximately 30 percent (Jacobson 2005). This rate may be as much as two orders of magnitude more than any changes that have occurred in the last 65 million years (Ridgwell and Schmidt 2010). Acidification may also be occurring in Puget Sound, but the link to global trends has not been well studied. Recent Puget Sound pH measurements show areas of low pH with high concern for marine species (Feely et al. 2010). These changes are likely to have major impacts on many marine-dwelling species (Raven et al. 2005).

- Designing and implementing monitoring of ocean acidification variables in and across Puget Sound to understand the status, diversity and range of conditions that stem from oceanic and regional influences.
- Developing tools to assess the risk and vulnerability of Puget Sound species to ocean acidification is a key priority.
- Developing adaptation strategies given the assessed vulnerability is a key priority.

Sustaining, Coordinating, and Using Science to Adapt Actions

Scientific Tools for Informing Policy

Strategy D1. Provide the leadership and frameworks to guide the Puget Sound recovery effort and set action and funding priorities

- An institutional analysis of the overall governance and management structure in which Puget Sound recovery strategies operate is a key social science priority of this plan. Understanding the key social factors affecting decisions, including governance systems and management networks, can help guide strategies for using adaptive management (Endter-Wada et al. 1998, Ostrom 2009) , help identify institutional reasons for actions that are inconsistent with Puget Sound recovery (called for in the Partnership's enabling legislation, RCW 90.71.370), and help identify solutions that might not otherwise be obvious. This analysis could increase the capacity for institutions, non-governmental organizations, and the tribes to work better together, recognizing the need to bridge values and management approaches.
- An integrated risk assessment of the impacts of different pressures on the ecosystem is a key science priority. Lack of a comprehensive estimate of the risks to the Puget Sound and the Salish Sea basins and the valued ecosystem services they provide is a major limitation for using science to inform recovery strategies and make decisions. Where assessments exist, they are typically based on only a few endpoints and stressors and at limited spatial/temporal scales (Hart Hayes and Landis 2004, Markiewicz and Landis 2011). Assessments are a key step in integrated ecosystem assessment (Levin et al. 2008). Conservation strategies often prioritize actions that address pressures that have potentially high impacts and that are imminent. The Partnership rated pressures qualitatively at the Puget Sound geographical scale in 2009 (Partnership 2009) using *Open Standards for the Practice of Conservation* protocol (https://miradi.org/openstandards). Although useful, the assessment needs to be improved to incorporate structural elements common to most risk assessment frameworks to make it more useful. These include incorporating different geographical scales (watershed and Puget Sound), uncertainty, interaction among pressures, consistent application of criteria, and more comprehensive data. In addition to providing an assessment of pressures by how they affect different ecological indicators, risk assessments can describe the affects on tangible services that people value. Developing the structure for this kind of analysis also provides the quantitative foundation for comparing and evaluating different strategies by how much they reduce pressures.

- The *Action Agenda Update* can have over 200 near-term actions spread across the four main strategies for recovering and protecting Puget Sound. Prioritization of these near-term actions for limited available funding based on their likely effectiveness in protecting and recovering the ecosystem is scientifically and socially challenging. Developing a systematic, transparent, and ecologically based prioritization tool that will support evolutionary learning and adaptation is a key science priority.

Monitoring

Strategy D3. Implement a transparent performance management system that tracks and reports progress in achieving ecosystem recovery targets, identifies barriers, and finds solutions to adaptively manage recovery
Strategy D4. Implement a strategic science and regional monitoring program that improves decisions about how to restore and protect Puget Sound

- Ecosystem recovery is complex, outcomes are difficult to predict, and surprises are inevitable (Christensen et al. 1997). If regional ecosystem recovery efforts are to be efficient and effective, they need to be designed to facilitate learning and improve the effectiveness of future efforts (Holling 1978, Lee 1993). This does not occur without comprehensive, coordinated monitoring supported by long-term, stable funding (Busch and Trexler 2003, Lindenmayer and G. E. Likens 2010). The Puget Sound Ecosystem Monitoring Program (PSEMP) has begun this effort for the Puget Sound. This is a key priority for the success of Puget Sound recovery.

Human Dimensions in Ecosystem Recovery

Strategy D7. Build social and institutional infrastructure that supports stewardship behaviors and removes barriers

- Developing assessments of ecosystem services (MEA 2003) to help decision makers make informed decisions about restoration and protection is a key social science priority. As more studies begin to assess the value of ecosystems (Austin et al. 2007, Naber et al. 2008, Batker et al. 2008), it is becoming obvious that many conservation decisions are made with incomplete information. For example, risk assessment can formally incorporate ecosystem services as endpoints, but this requires better information than currently exists. The availability of this information will help decision makers advocate for funding, set priorities for protection and restoration, and make better-informed decisions about the consequences of different actions.
- Developing socioeconomic indicators to help measure and report on the human dimension component of the Partnership's conceptual model for ecosystem recovery is a key science need. This framework could be refined for unique "place based" analyses to capture the stressors and valued social, economic, and cultural components of different communities and geographies.
- Social science research, reviews, literature databases, and synthesis papers relevant to ecosystem recovery have not been institutionally as available as physical and natural

science literature to inform recovery strategies. A key social science priority is to conduct a baseline literature review and survey of data to identify resources and gaps that can be readily available and can be used by ecosystem recovery planners and practitioners.

- A key science need is to evaluate the most effective combination of regulatory, incentive, and educational programs for different demographics in Puget Sound. Characterizing the role and connections of different communities and age groups to different ecosystem services and the Puget Sound environment provides key information for engaging citizens in stewardship. Understanding where incentive programs will or will not work and the characteristics that motivate changes in behavior as they relate to tradeoffs between the natural and built environment is key strategic information. This is important for engaging public support.

Summary

Purpose and Approach

The purpose of *Priority Science for Restoring and Protecting Puget Sound: A Biennial Science Work Plan for 2011-2013* is to provide strategic focus on the science needed to recover and protect Puget Sound. This strategic focus can help direct allocation of the limited resources available for science to the issues and studies where they are most needed. The document is a key companion to the *Action Agenda Update*, which describes the long-term strategies and coordinated near-term actions to be implemented by state and federal agencies, tribes, cities and counties, other local jurisdictions, nongovernmental organizations, and the general public to recover and protect the ecosystem and the services it provides.

The Puget Sound Partnership Science Panel chose these actions based on a review of the questions that current research and monitoring are addressing, a review of recommendations from scientific reports and publications on the science needs for a program of ecosystem recovery in Puget Sound, and recommendations from a broad base of scientists, practitioners, stakeholders, and decision makers. Analyzing this information relative to a conceptual model of ecosystem recovery for Puget Sound (Figure 1) illustrated where gaps in scientific attention and knowledge are likely to occur.

Identifying gaps in knowledge does not immediately make them priorities for funding and investigation. To decide which gaps are priorities, the Science Panel asked two sets of questions. The first set focused on scientific questions: How much do we know? Where is the level of scientific uncertainty greatest? The second set focused on policy-science questions: What are the decision-critical questions and information? Where is lack of scientific information hindering progress in restoration and recovery?

Scientists are trained in evaluating scientific uncertainty. Evaluation of decision-critical issues, however, requires dialogue with decision makers and conservation practitioners. To determine which decision-critical issues are important, the Science Panel used (1) the perspectives collected from stakeholders and conservation practitioners who participated in multiple stakeholder meetings on developing the *Action Agenda Update*; (2) the lists of priorities in local areas and watersheds from the *Action Agenda Update* provided by Action Area groups, who hold the perspectives of local implementing organizations, governments, and tribes; and (3) feedback on proposed science priorities from decision makers on the Ecosystem Coordination Board, who represent a broad range of interests and values.

Scientists and decision makers often have different expectations about how science helps in making decisions about complex natural resource issues (Lee 1993). To minimize confusion about the expectations of science in this prioritization process, the Science Panel focused explicitly on two domains where science and policy interact (Figure 2, Rudd 2011). The first domain is where both scientific knowledge and articulation of policy issues around a topic are poorly developed. This domain is often characteristic of emerging issues. Science has a key role in providing more information on these issues to help elucidate the policy questions. The

second domain is where science is used for evidence-based problem solving. Many non-scientists expect all science to fall in this domain, but this domain is characteristic of issues where scientific knowledge on a topic is relatively poorly developed but consensus exists on the policy issues.

Strengths and Weaknesses

The Science Panel used two different approaches to identify ideas and recommendations for priority science actions. Each approach has different strengths and weaknesses. The first approach was to identify recently completed or ongoing studies focused on Puget Sound and compare the goals of these studies with recommendations from the scientific literature to identify discrepancies or gaps. The enabling legislation that created the Science Panel and Puget Sound Partnership directs the Science Panel to use this approach. Because of the limitations of the gap analysis, the Science Panel added a second, civic and community-based approach for gathering information on science needs.

Review of Recent Studies

The strength of this approach is that it builds on existing work of universities, state and federal agencies, tribes, and non-governmental research groups. Several challenges exist in relying only on this approach, however. First, no comprehensive list exists of recently completed or ongoing studies. The analyses of recently completed and ongoing studies presented here came from extensive web searches and queries, but it is almost certainly incomplete and biased toward larger research groups, agencies, and universities. Building inventories of projects at different scales, by different groups, with different levels of collaboration, from different funding sources, and for different purposes is logistically and institutionally challenging (Katz et al. 2007). The Partnership is exploring tools for improving the inventory.

Second, the analysis presented here used the number of studies as the basis for identifying gaps rather than funding levels, number of reports produced, or a more detailed analysis of individual results. This provides a qualitative indication of whether current scientific efforts are well aligned to contribute to ecosystem recovery efforts. Comparing studies in detail based on content produced, relevance to ecosystem recovery, and utility of the information for making decisions is much more difficult. Depending on the issue and where the study needs to be done (e.g., in a laboratory or in open water), studies have vastly different scopes, use different techniques, have very different ultimate objectives, and require different levels of investment and resources. In addition, some issues have a trajectory of investigation that can be difficult to change because of a long history of work at universities and agencies, whereas others can adapt more easily because the issues, techniques, and questions are new. This analysis could be improved in the future by developing ways to standardize across studies.

Third, recommendations in the scientific literature do not share a common framework for how strategies and pressures affect recovery of Puget Sound. Consequently, in conducting this analysis, the Science Panel used the Puget Sound Partnership conceptual model (Figure 1) as a framework for identifying gaps and emphases.

Finally, comparison of recently completed and ongoing studies with recommendations in the scientific literature relies on information from a very small, specialized portion of society compared to the community that ultimately depends on these results. In contrast, conservation efforts are increasingly incorporating broader civic and community representation in identifying scientific questions and conservation solutions (Lee 1993, Ghimire and Pimbert 1997, Berkes et al. 2003).

Civic and Community-Based Approach

The Science Panel asked interdisciplinary teams of scientists, practitioners, policy analysts, and stakeholders that formed to develop strategies for the *Action Agenda Update* to provide recommendations. In addition, the Science Panel solicited recommendations and ideas from scientists from academia, state, federal, local agencies, and tribes; conservation practitioners from local governments and environmental organizations; and stakeholders.

To prioritize science actions, the Science Panel used a framework that identified four science-policy domains (Figure 2). A major strength of this framework is that it allowed the Science Panel to explore the different roles of science and policy in each domain and to identify domains in which science would contribute most to decision-critical issues. The framework is based on assessing how well policy issues are articulated relative to how well developed scientific knowledge is. However, the framework currently lacks clear definitions for how to apply such judgments. Consequently, consistent application of the framework depends on how well Science Panel members understood or interpreted an issue. Because of this, the priority science section may contain actions that other scientists might judge as not high priority because they believe that articulation of both the policy issues and scientific knowledge are relatively well developed. Likewise, some scientists may believe that scientific issues that deserved to be included were not. A particular weakness of the approach as it was applied for this analysis is that it required the Science Panel to judge how well articulated policy issues are. All these weaknesses can be addressed in future analyses by developing criteria that can be consistently applied and by using science-policy dialogue to assess how well articulated policy issues are.

Summary of Priority Science Actions

Priority Science for Restoring and Protecting Puget Sound contains 48 high-priority scientific actions. Twelve priority science actions are associated with upland, terrestrial, and freshwater ecological domains, which corresponds to *Action Agenda* strategy group A. The marine and nearshore ecological domain (*Action Agenda* strategy group B) has nine priority actions. Pollution issues have 16 science actions (*Action Agenda* strategy group C). The Science Panel highlighted one key emerging issue – ocean acidification – that has three science actions. Finally, nine key science actions are important for sustaining, coordinating, and adapting actions, which corresponds to *Action Agenda* strategy group D.

A striking result of the gap analysis is the small proportion of scientific studies focused on the human dimensions in ecosystem recovery. In the current list of priority science actions, almost one-third (17) address at least one aspect of the human dimension.

The priority science actions in this list are not focused exclusively on new research. Within the two science-policy domains emphasized by the Science Panel, the actions in this list represent five different kinds of information that contribute in different ways to decisions. The five kinds of information are:

1) reviews and synthesis of existing information
2) development of analytical and decision support tools
3) monitoring of status and trends
4) monitoring of actions to assess their effectiveness
5) research to understand mechanisms and relationships.

One-third (33 percent) of the science actions rely on existing information to do reviews, synthesis, and develop decision support tools. Almost one-fourth (23 percent) are focused on status and trends monitoring and effectiveness monitoring. Less than one-half (44 percent) of the science actions focus on research that is needed to understand mechanisms and relationships.

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Appendices

Appendix A: Puget Sound Partnership Science Program Legislation – RCW 90.71.290

Appendix B: Inventory of Recently Completely and Ongoing Research

Appendix C: Inventory of Recommended Research

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APPENDIX A: PUGET SOUND PARTNERSHIP SCIENCE PROGRAM LEGISLATION – RCW 90.71.290

Appendix A – Legislation

RCW 90.71.290

Science panel — Strategic science program — Puget Sound science update — Biennial science work plan.

(1) The strategic science program shall be developed by the panel with assistance and staff support provided by the executive director. The science program may include:

(a) Continuation of the Puget Sound assessment and monitoring program, as provided in RCW 90.71.060, as well as other monitoring or modeling programs deemed appropriate by the executive director;

(b) Development of a monitoring program, in addition to the provisions of RCW 90.71.060, including baselines, protocols, guidelines, and quantifiable performance measures, to be recommended as an element of the action agenda;

(c) Recommendations regarding data collection and management to facilitate easy access and use of data by all participating agencies and the public; and

(d) A list of critical research needs.

(2) The strategic science program may not become an official document until a majority of the members of the council votes for its adoption.

(3) A Puget Sound science update shall be developed by the panel with assistance and staff support provided by the executive director. The panel shall submit the initial update to the executive director by April 2010, and subsequent updates as necessary to reflect new scientific understandings. The update shall:

(a) Describe the current scientific understanding of various physical attributes of Puget Sound;

(b) Serve as the scientific basis for the selection of environmental indicators measuring the health of Puget Sound; and

(c) Serve as the scientific basis for the status and trends of those environmental indicators.

(4) The executive director shall provide the Puget Sound science update to the Washington academy of sciences, the governor, and appropriate legislative committees, and include:

(a) A summary of information in existing updates; and

(b) Changes adopted in subsequent updates and in the state of the Sound reports produced pursuant to RCW 90.71.370.

(5) A biennial science work plan shall be developed by the panel, with assistance and staff support provided by the executive director, and approved by the council. The biennial science work plan shall include, at a minimum:

(a) Identification of recommendations from scientific and technical reports relating to Puget Sound;

(b) A description of the Puget Sound science-related activities being conducted by various entities in the region, including studies, models, monitoring, research, and other appropriate activities;

(c) A description of whether the ongoing work addresses the recommendations and, if not, identification of necessary actions to fill gaps;

(d) Identification of specific biennial science work actions to be done over the course of the work plan, and how these actions address science needs in Puget Sound; and

(e) Recommendations for improvements to the ongoing science work in Puget Sound.

APPENDIX B: INVENTORY OF RECENTLY COMPLETELY AND ON-GOING RESEARCH

Inventory of Recently Completed/Ongoing Scientific Studies

Ref #	Ecosystem Component	Primary Pressure	Action Area	Study Title	Date	Author(s) or Study Contact	Supporting Agency	General Study Design/Methods	Study Results	Weblink	Journal Citation (if applicable)
C0356	Terrestrial - Water	Agriculture & Livestock Grazing	San Juan/Whatcom	Quality Assurance Project Plan: Effects of Conventional versus Minimum Tillage on Groundwater Nitrate at a Manured Grass Field	2009	Carey, B.	Washington Department of Ecology	This is the study plan for effects of conventional versus minimum tillage on groundwater nitrate at a manured grass field.	The field has been divided in half for the 2009-11 study, with three shallow monitoring wells in each half. One half received conventional tillage, and the other half minimum tillage. Groundwater monitoring will be conducted four times per year for both years.	http://www.ecy.wa.gov/biblio/0903126.html	
C0357	Terrestrial - Water	Agriculture & Livestock Grazing	San Juan/Whatcom	Nitrate Trends in the Central Sumas-Blaine Surficial Aquifer	2008	Redding, M.	Washington Department of Ecology	This groundwater quality monitoring study was designed to determine nitrate trends and to establish the framework for a long-term groundwater monitoring network in the central Sumas-Blaine surficial aquifer in Whatcom County. During 2003-05, groundwater was sampled for nitrate-nitrogen every other month for two years from 35 wells.	The results of this study reinforce findings from previous studies: groundwater contains elevated nitrate concentrations, with concentrations as high as 43 mg/l. Additionally, it was determined that there is an increasing nitrate trend at a rate of 0.46 mg/l per year.	http://www.ecy.wa.gov/biblio/0803018.html	
C0363	Terrestrial - Water	Agriculture & Livestock Grazing	All	Surface Water Monitoring Program for Pesticides in Salmonid-Bearing Streams, 2009 Data Summary	2011	Sargeant, D., D. Dugger, P. Anderson, and E. Newell	Washington Department of Ecology	This report presents 2009 pesticide results for two urban basins, Thornton Creek (Cedar-Sammamish basin) and Longfellow Creek (Green-Duwamish basin), as well as four agricultural basins: lower Skagit-Samish basin, lower Yakima basin, and the Wenatchee and Entiat basins	A triennial review of pesticide data collected from 2007-09 is included for the Wenatchee-Entiat basins. During 2007-09 few pesticides were detected at the Wenatchee-Entiat basin sites with the exception of Brender Creek. Brender Creek endosulfan levels indicate potential chronic health effects to aquatic life during mid-March through May	http://www.ecy.wa.gov/biblio/1103004.html	
C0374	Terrestrial - Species & Food Webs	Agriculture & Livestock Grazing	Whidbey	Skagit-Samish Basin Intensive Surface Water Sampling for Pesticides in Salmon-Bearing Streams, 2009	2010	Sargeant, D. and P. Anderson	Washington Department of Ecology	Pesticide results from three sampling regimes during 2009 were compared: daily sampling for seven consecutive days; weekly sampling; and continuous sampling using a continuous low-level aquatic monitor (CLAM).	Results compared pesticides detected during the current weekly sampling regime to seven days of consecutive sampling. The study results indicate that prior knowledge of the pesticide-use practices is needed to target specific pesticides. The current regime of weekly sampling throughout the application season captures a variety of pesticide detections. CLAM results showed inconsistent pump rates throughout the placement period; the device did provide information on the presence or absence of selected pesticides	http://www.ecy.wa.gov/biblio/1003043.html	
C0375	Terrestrial - Species & Food Webs	Agriculture & Livestock Grazing	All	Surface Water Monitoring Program for Pesticides in Salmonid-Bearing Streams, 2006-2008 Triennial Report	2010	Sargeant, D., D. Dugger, E. Newell, P. Anderson, and J. Cowles (WSDA)	Washington Department of Ecology	This report presents results of a multi-year study to characterize pesticide concentrations in salmon-bearing surface waters. Monitoring occurred in five basins: one urban basin (Thornton Creek in the Cedar-Sammamish) and four agricultural basins (lower Skagit-Samish, lower Yakima, Wenatchee, and Entiat).	During 2006-2008, 71 pesticides were detected. Seven of these failed to meet an assessment criterion: permethrin; chlorpyrifos; diazinon; azinphos-methyl; malathion; endosulfan; and total DDT. Pesticide concentrations found likely do not directly affect salmonids, but at some sites may affect aquatic invertebrate populations. During 2010, an anomaly in the 2006-2009 analytical method for carbamates was found. This anomaly caused the false positive identification of the degradate compounds 1-naphthol, aldicarb sulfone, and aldicarb sulfoxide. The corrected report and appendices were posted on October 22, 2010.	http://www.ecy.wa.gov/biblio/1003008.html	
C0406	Terrestrial - Habitats	Agriculture & Livestock Grazing	King County	A Study of Agricultural Drainage in the Puget Sound Lowlands to Determine Practices which Minimize Detrimental Effects on Salmonids	2008	Washington State University and the University of Washington	King County Department of Natural Resources and Parks	A multidisciplinary team of researchers from Washington State University and the University of Washington conducted a 5-year investigation of various practices related to agricultural watercourse maintenance. The primary focus of the investigation was related to how maintenance practices affect salmonid utilization in King County drainage systems. Four broad areas of study (fish biology, instream habitat, riparian, and sediment) were identified by KCDNPR staff during initial contract negotiations. Within each of these areas, two to four research questions were developed with methodologies and quality assurance procedures approved by King County in the project Sample Analysis Plan. Consequently, a total of twelve specific questions were addressed in this study.	Ditch maintenance is an important process for drainage and providing juvenile salmonid rearing habitat in King County. Post-maintenance water quality testing found significant improvements in dissolved oxygen levels; the temperature model predicted of temperature improvements as riparian buffers grow; and visual reports of salmonids using much larger sections of the Mullen Slough/Boscolo complex all strongly suggest that maintenance activities benefit the fish. Furthermore, reports also support the assumption that better drainage help the farmers by allowing better use of their lands. By following the general processes discussed in this report, farming and salmonids should be able to successfully co-exist.	http://www.kingcounty.gov/environment/waterandland/agriculture/drainage-assistance/agricultural-drainage-study.aspx	
C0474	Terrestrial - Water	Agriculture & Livestock Grazing	King County	Manual of Best Management Practices for Maintenance of Agricultural Waterways in King County	2010	King County	King County	This manual is meant as a starting point to assist farmers as professional and cost-conscious land stewards. It provides an agglomeration of thinking to date on how to (1) classify waterways according to channel structure and existence of fish and (2) link best management practices (BMPs) to those waterway classes.	The goal for the BMPs is to improve water flow and drainage from fields, minimize negative impacts on fish during and after dredging, and help improve or maintain water quality. For many activities, BMPs are described in the manual; for a few activities, a range of BMPs is provided to be field-tested by pilot projects conducted in 2010 and discussed further; for a few others, discussions are under way as part of the larger effort.	http://www.kingcounty.gov/environment/waterandland/agriculture/documents/bmp-ag-waterway-maintenance-manual.aspx	
C0367	Marine - Water	Air Pollution & Atmospheric Deposition	All	Control of Toxic Chemicals in Puget Sound, Phase 3: Study of Atmospheric Deposition of Air Toxics to the Surface of Puget Sound	Jul-10	Brandenberger, J.M., P. Louchouarn, L-J Kuo, E.A. Crecelius, V. Cullinan, G.A. Gill, C. Garland, J. Williamson, and R. Dhammapala	Washington Department of Ecology	this study provided revisions to prior estimates or first reported atmospheric deposition fluxes of polycyclic aromatic hydrocarbons (PAHs), polybrominated diphenyl ethers (PBDEs), and select trace elements for Puget Sound. Samples representing bulk atmospheric deposition were collected during 2008 and 2009 at seven stations around Puget Sound spanning from Padilla Bay south to Nisqually River including Hood Canal and the Straits of Juan de Fuca. Revised annual loading estimates were calculated for each of the toxics and demonstrated an overall decrease in the atmospheric loading estimates except for PBDEs and total mercury (THg).	In summary, four major conclusions are derived from this study: 1) the depositional fluxes of a majority of the selected toxic elements (trace metals) and compounds (PAHs) in the urban/industrial area of Tacoma have decreased significantly (close to an order of magnitude for most) in the last ~20 years, 2) deposition fluxes directly to the waters of Puget Sound are spatially homogenous except in industrial regions and are not necessary representative of watershed deposition rate over a large range of land use and land cover classifications, 3) direct atmospheric deposition of trace elements and PAHs on the Puget Sound surface contributes only 1-5% of total inputs to sedimentary repositories, and 4) first-order estimates of sedimentary fluxes of Pb and PAHs in the Puget Sound system suggest that revised annual surface runoff estimates may be appropriate based on the sedimentary fluxes representing the last decade of inputs.	http://www.ecy.wa.gov/biblio/1002012.html	
C0460	Nearshore - Species & Food Webs	Aquaculture	All	Effects of geoduck aquaculture on the environment: A synthesis of current knowledge	2008	Straus, K. M., L. M. Crosson, and B. V. Vadopalas	Washington Sea Grant	Literature review.	Review covers biological and environmental status of geoduck in Puget Sound and the ecological effects of geoduck aquaculture, including: abiotic and biotic effects, disease, and genetic effects on wild conspecific.,	http://www.wsg.washington.edu/research/geoduck/geoduck_literaturereview.pdf	
C0461	Nearshore - Species & Food Webs	Aquaculture	All	2008 Annual Report: Commercial and Recreational Shellfish Areas in Washington State	2009	Washington Department of Health	Washington Department of Health	The report describes several of the main programs and services of the Washington State Department of Health's Office of Shellfish and Water Protection, including the office's work monitoring and classifying the state's prized shellfish harvest areas and related efforts to safeguard these areas for continued use by current and future generations. A poster-size map of the state's shellfish growing areas accompanies this publication. The map includes information on commercial growing area classifications, major water bodies and cities, sewage treatment plants, and recreational shellfish beach classifications.	n/a	http://www.doh.wa.gov/ehp/sf/pubs/annual-inventory.pdf	
C0565	Nearshore - Species & Food Webs	Aquaculture	All	Effects of Geoduck Aquaculture On the Environment: A Synthesis Of Current Knowledge. 25th Jan 2008. (Produced for the 2007 WA State Legislature)	2008	Straus KM, Crosson LM and Vadopalas B	Washington Sea Grant				
C0568	Nearshore - Species & Food Webs	Aquaculture	All	Factors influencing recruitment variability in estuarine bivalves		Ruesink, Jennifer	Washington Sea Grant	Washington state, particularly Willapa Bay, has experienced dramatic declines in oyster recruitment for the past four years. Commercial bivalve hatchery production has also declined, and harvests continually exceed seed renewal rates. This project will evaluate more than 80 years of historical data on oyster and clam reproduction in Willapa Bay, Puget Sound and British Columbia and use these data to guide research directed at determining the key mechanisms controlling reproduction in Washington's cultured bivalves.			

Inventory of Recently Completed/Ongoing Scientific Studies

Ref #	Ecosystem Component	Primary Pressure	Action Area	Study Title	Date	Author(s) or Study Contact	Supporting Agency	General Study Design/Methods	Study Results	Weblink	Journal Citation (if applicable)
C0341	All	Climate Change	All	The Washington Climate Change Impacts Assessment	2009	M. McGuire Elsner, J. Littell, and L. Whitely Binder (eds)	UW Climate Impacts Group (Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle, Washington)	The Washington Climate Change Impacts Assessment (WACCIA) involved developing updated climate change scenarios for Washington State and using these scenarios to assess the impacts of climate change on the following sectors: agriculture, coasts, energy, forests, human health, hydrology and water resources, salmon, and urban stormwater infrastructure. Adaptation in each of these sectors was also discussed.	see specific chapters for results	http://cses.washington.edu/db/pubs/allpubs.shtml#Year2009	Sections of the WACCIA were also published in a 2010 issue of Climatic Change 102(1-2)
C0342	All	Climate Change	All	Future climate in the Pacific Northwest	2009	Mote, P.W., and E.P. Salathé	UW Climate Impacts Group	Chapter 1 in The Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate, Climate Impacts Group, University of Washington, Seattle, Washington.	Climate models used in the IPCC AR4 project increases in annual temperature of, on average, 1.1°C (2.0°F) by the 2020s, 1.8°C (3.2°F) by the 2040s, and 3.0°C (5.3°F) by the 2080s, compared with the average from 1970 to 1999, averaged across all climate models. Rates of warming range from 0.1 to 0.6°C (0.2° to 1.0°F) per decade. Projected changes in annual precipitation, averaged over all models, are small (+1 to +2%), but some models project an enhanced seasonal cycle with changes toward wetter autumns and winters and drier summers.	http://cses.washington.edu/db/pubs/allpubs.shtml#Year2009	Climatic Change 102(1-2): 29-50, doi: 10.1007/s10584-010-9848-z.
C0344	Terrestrial - Species & Food Webs	Climate Change	All	Impacts of climate change on key aspects of freshwater salmon habitat in Washington State	2009	Mantua, N.J., I. Tohver, and A.F. Hamlet	UW Climate Impacts Group	Chapter 6 in The Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate, Climate Impacts Group, University of Washington, Seattle, Washington	The combined effects of warming stream temperatures and altered streamflows will very likely reduce the reproductive success for many salmon populations in Washington watersheds, but impacts will vary according to different life history-types and watershed-types. Salmon populations having a stream type life history with extended freshwater rearing periods (i.e. steelhead, coho, sockeye and stream-type Chinook) are predicted to experience large increases in hydrologic and thermal stress in summer due to diminishing streamflows and increasingly unfavorable stream temperatures. Salmon with an ocean-type life history (with relatively brief freshwater rearing periods) are predicted to experience the greatest freshwater productivity declines in transient runoff watersheds where future warming is predicted to increase the magnitude and frequency of winter flooding that reduces egg-to-fry survival rates.	http://cses.washington.edu/db/pubs/allpubs.shtml#Year2009	Climatic Change 102(1-2): 187-223, doi: 10.1007/s10584-010-9845-2
C0345	Terrestrial - Species & Food Webs	Climate Change	All	Potential responses to climate change in organisms with complex life histories: Evolution and plasticity in Pacific salmon	2008	Crozier, L.G., A.P. Hendry, P.W. Lawson, T.P. Quinn, N.J. Mantua, J. Battin, R.G. Shaw, and R.B. Huey	UW Climate Impacts Group	We present a conceptual model of how changing environmental conditions shift phenotypic optima and, through plastic responses, phenotype distributions, affecting the force of selection. Our predictions are tentative because we lack data on the strength of selection, heritability, and ecological and genetic linkages among many of the traits discussed here	We know little about ocean migration pathways, so cannot confidently suggest the potential changes in this life stage. Climate change might produce conflicting selection pressures in different life stages, which will interact with plastic (i.e. nongenetic) changes in various ways.	http://cses.washington.edu/db/pubs/allpubs.shtml#Year2008	Evolutionary Applications 1(2): 252–270, doi:10.1111/j.1752-4571.2008.00033.x.
C0346	Terrestrial - Water	Climate Change	All	Climate change impacts on water management in the Puget Sound region, Washington, USA	2009	Vano, J.A., N. Voisin, L. Cuo, A.F. Hamlet, M.M. Elsner, R.N. Palmer, A. Polebitski, and D.P. Lettenmaier	UW Climate Impacts Group	Chapter 3.2 in The Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate, Climate Impacts Group, University of Washington, Seattle, Washington	We extend ongoing efforts in the Puget Sound basin cities of Everett, Seattle, and Tacoma to characterize differences between historic and future streamflow and the ability of the region's water supply systems to meet future demands. Over the next century, under average conditions, all three water supply systems (Everett, Seattle, and Tacoma) are projected to experience a decline and eventual disappearance of the springtime snowmelt peak in their inflows. How these shifts impact water management depends on the specifics of the reservoir system and their operating objectives, site-specific variations in the influence that reductions in snowmelt have on reservoir inflows, and the adaptive capacity of each system. Without adaptations, average seasonal drawdown of reservoir storage is projected to increase in all of the systems throughout the 21st century. The reliability of the three water supply systems in the absence of demand increases is, however, generally robust to climate changes through the 2020s, and in the 2040s and 2080s reliability remains above 98% for the Seattle and Everett systems. With demand increases, however, system reliability is progressively reduced by climate change impacts.	http://cses.washington.edu/db/pubs/allpubs.shtml#Year2009	Climatic Change 102(1-2): 287-317, doi: 10.1007/s10584-010-9856-z
C0347	Terrestrial - Water	Climate Change	All	Precipitation extremes and the impacts of climate change on stormwater infrastructure in Washington State	2009	Rosenberg, E.A., P.W Keys, D.B. Booth, D. Hartley, J. Burkey, A.C. Steinemann, and D.P. Lettenmaier	UW Climate Impacts Group	Chapter 9 in The Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate, Climate Impacts Group, University of Washington, Seattle, Washington	We examined both historical precipitation records and simulations of future rainfall to evaluate past and prospective changes in the probability distributions of precipitation extremes across Washington State. Few statistically significant changes in extreme precipitation were observed in the historical records, with the possible exception of the Puget Sound. RCM simulations generally indicate increases in extreme rainfall magnitudes throughout the state, but the range of projections is too large to predicate engineering design, and actual changes could be difficult to distinguish from natural variability. Nonetheless, the evidence suggests that drainage infrastructure designed using mid-20th century rainfall records may be subject to a future rainfall regime that differs from current design standards.	http://cses.washington.edu/db/pubs/allpubs.shtml#Year2009	Climatic Change 102(1-2): 319-349, doi: 10.1007/s10584-010-9847-0.
C0348	Terrestrial - Habitats	Climate Change	All	Forest ecosystems, disturbance, and climatic change in Washington State, USA	2009	Littell, J.S., E.E. Oneil, D. McKenzie, J.A. Hicke, J.A. Lutz, R.A. Norheim, and M.M. Elsner	UW Climate Impacts Group	Chapter 7 in The Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate, Climate Impacts Group, University of Washington, Seattle, Washington	We address the role of climate in four forest ecosystem processes and project the effects of future climatic change on these processes: 1) In areas where Douglas-fir is not water-limited, future growth will continue to vary with interannual climate variability, but in places where Douglas-fir is water-limited, growth is likely to decline due to projected increase in summer potential evapotranspiration. 2) By the mid 21st century, some areas of the interior Columbia Basin and eastern Cascades are likely to have climates poorly suited to pine species that are susceptible to mountain pine beetle, and if these pines are climatically stressed, they may be more vulnerable to pine beetle attack. 3) Regional area burned is likely to double or even triple by the end of the 2040s, although Washington ecosystems have different sensitivities to climate and thus different responses to climatic change. 4) Host tree vulnerability is closely related to vapor pressure deficit (VPD), and future projections support the hypothesis that summer VPD will increase over a significant portion of the range of host tree species. Due to the increased host vulnerability, MPB populations are expected to become more viable at higher elevations leading to	http://cses.washington.edu/db/pubs/allpubs.shtml#Year2009	Climatic Change 102(1-2): 129-158, doi: 10.1007/s10584-010-9858-x.

Ref #	Ecosystem Component	Primary Pressure	Action Area	Study Title	Date	Author(s) or Study Contact	Supporting Agency	General Study Design/Methods	Study Results	Weblink	Journal Citation (if applicable)
C0349	Humans - Health	Climate Change	All	Public health impacts of climate change in Washington State: projected mortality risks due to heat events and air pollution	2009	Jackson, J.E., M.G. Yost, C. Karr, C. Fitzpatrick, B. Lamb, S.H. Chung, J. Chen, J. Avise, R.A. Rosenblatt, and R.A. Fenske	UW Climate Impacts Group	Chapter 10 in The Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate, Climate Impacts Group, University of Washington, Seattle, Washington	Study examined the historical relationship between age- and cause-specific mortality rates and heat events at the 99th percentile of humidex values in the greater Seattle area (King, Pierce and Snohomish counties), Spokane County, the Tri-Cities (Benton and Franklin counties) and Yakima County from 1980 through 2006; the relative risk of mortality during heat events compared with more temperate periods were then applied to population and climate projections for Washington State to calculate number of deaths above the baseline (1980-2006) expected to occur during projected heat events in 2025, 2045 and 2085. In the greater Seattle area, the largest number of excess deaths in all years and scenarios was predicted for persons aged 65 and above. Under the middle scenario, this age group is expected to have 96 excess deaths in 2025, 148 excess deaths in 2045 and 266 excess deaths in 2085 from all non-traumatic causes.	http://cses.washington.edu/db/pubs/allpubs.shtml#Year2009	Climatic Change 102(1-2): 159-186, doi: 10.1007/s10584-010-9852-3.
C0351	Terrestrial - Water	Climate Change	All	Assessing the impacts of global warming on snowpack in the Washington Cascades	2009	Casola, J.H., L. Cuo, B. Livneh, D.P. Lettenmaier, M. Stoelinga, P.W. Mote, and J.M. Wallace.	UW Climate Impacts Group	The decrease in mountain snowpack associated with global warming is difficult to estimate in the presence of the large year-to-year natural variability in observations of snow water equivalent. A more robust approach for inferring the impacts of global warming is to estimate temperature sensitivity λ of spring snowpack and multiply it by putative past and future temperature rises observed across the Northern Hemisphere.	Considering various rates of temperature rise over the Northern Hemisphere, it is estimated that spring snow water equivalent in the Cascades portion of the Puget Sound drainage basin should have declined by 8-16% over the past 30 years due to global warming and it can be expected to decline by another 11-21% by 2050.	http://cses.washington.edu/db/pubs/allpubs.shtml#Year2009	Journal of Climate 22:2758-2772
C0352	Terrestrial - Water	Climate Change	All	Has spring snowpack declined in the Washington Cascades?	2008	Mote, P.W., A.F. Hamlet, and E.P. Salathé	UW Climate Impacts Group	Analysis of long term records of 49 snow survey locations in Washington's Cascades and Olympics.	Our best estimates of 1 April snow water equivalent (SWE) in the Cascade Mountains of Washington State indicate a substantial (roughly 15–35%) decline from mid-century to 2006, with larger declines at low elevations and smaller declines or increases at high elevations.	http://cses.washington.edu/db/pubs/allpubs.shtml#Year2008	Hydrology and Earth System Sciences 12: 193-206
C0370	Humans - Health	Climate Change	All	Recent trends in paralytic shellfish toxins in Puget Sound, relationships to climate and capacity for prediction of toxic events	2009	S. K. Moore, N. Mantua, V. L. Trainer, B. M. Hickey	NOAA, Northwest Fisheries Science Center	Temporal and spatial trends in paralytic shellfish toxins (PSTs) in Puget Sound shellfish and their relationships with climate are investigated using long-term monitoring data since 1957. Data are selected for trend analyses based on the sensitivity of shellfish species to PSTs and their depuration rates, and the frequency of sample collection at individual sites.	Using blue mussel data only, there was no robust evidence to suggest that the frequency, magnitude, duration, or geographic scope of PST events in Puget Sound increased between 1993 and 2007. However, there is a significant basin-wide trend for closures to occur earlier in the year. There are no significant correlations between annual indices of mussel toxicity and aspects of the local and large-scale climate. Case studies of daily variations in local environmental factors leading up to exceptionally toxic events identify a combination of conditions that generally precedes most closures from 1993 to 2007. These results suggest that periods of warm air and water temperatures and low streamflow on sub-seasonal times cales may facilitate toxin accumulation in mussels. No relationships were found between water residence times in the surface layer and either streamflow or mussel toxicity. Recommendations are made for future monitoring to improve forecasting of PST risks in Puget Sound.	http://www.nwfsc.noaa.gov/publications/displayallinfo.cfm?docmetadataid=6857	Harmful Algae. 8: 463-477
C0433	Marine - Species & Food Webs	Climate Change	Whidbey	Multiscale influence of climate on estuarine populations of forage fish: the role of coastal upwelling, freshwater flow and temperature	2011	Reum, J.C.P.,T.E. Essington, C.M. Greene, C.A, Rice, K.L. Fresh	NOAA, Northwest Fisheries Science Center	Data collected during surface trawls examined how local- and regional-scale environmental drivers affect patterns of abundance and recruitment in 2 abundant and ecologically significant forage fishes (Pacific herring Clupea pallasi and surf smelt Hypomesus pretiosus) in the Skagit River estuary	Results suggest that age-0 recruitment in these populations is synchronized by regional upwelling as opposed to estuary-specific environmental forcing related to river flows. The present study isolates a potential key process governing age-0 forage fish abundance in this system and highlights the importance of simultaneously evaluating patterns of variability across multiple spatiotemporal scales in order to identify the primary pathways through which climate may impact estuarine populations.		Marine Ecology Progress Series (0171-8630), 425, p. 203.
C0440	Nearshore - Species & Food Webs	Climate Change	All	Anticipated effects of sea level rise in Puget Sound on two beach-spawning fishes, *in* Shipman et al 2010	2010	Krueger, K.L., Pierce, Jr., K.B., Quinn, Timothy, and Penttila, D.E.,	Washington Department of Fish and Wildlife	To describe the geographic and temporal distribution of surf smelt and sand lance spawning occurrence we analyzed survey data collected by the WDFW since 1972, which included visual observation of egg presence, and plotted spawning sample results onto Washington ShoreZone Inventory beaches. Also did surveys of Camano Island 2007-2008 and intertidal distributional surveys at 28 beaches in Central PS in 2004-2005.	Our analyses suggest that addressing shoreline armoring effects on beach morphology and surf smelt and sand lance spawning habitat is an important and urgent management concern. Loss of beach spawning habitat as a result of sea-level rise and shoreline armoring is likely to be widespread because much of the shoreline of Puget Sound is already armored and the desire to armor shorelines is expected to increase as additional shoreline is developed (Quinn, 2010) and as sea level rise speeds beach migration (Griggs and others, 1994; Johannessen and MacLennan, 2007). Further, the discontinuous geographic distribution of spawning occurrence and egg abundance suggest that loss of a relatively small number of spawning beaches might have a large detrimental effect on egg abundance.	http://pubs.usgs.gov/sir/2010/5254/	
C0444	Marine - Species & Food Webs	Climate Change	All	Unconfounding the effects of climate and density dependence using 60 years of data on spiny dogfish (Squalus acanthias)	2009	Taylor, I. G., and V. F. Gallucci	NOAA, Northwest Fisheries Science Center	The report compares demographic parameters for spiny dogfish in the Northeast Pacific and analyzed changes using Leslie matrix analysis.	Over a 60-year interval, growth parameters changed significantly, with faster growth to a smaller size. These changes could lead to an increase in population growth rate of about 1%. The greatest change in demographic parameters occurred between the 1940s and 1970s. The implications for fishing on long-lived populations during times of rapid environmental change are explored.	http://www.nrcresearchpress.com/doi/pdf/10.1139/F08-211	Canadian Journal of Fisheries and Aquatic Sciences 66:351-366
C0468	Humans - Health	Climate Change	All	Impacts of climate variability and future climate change on harmful algal blooms and human health	2008	Moore, S., V. Trainer, N. Mantua, M. Parker, E. Laws, L. Backer, and L. Fleming	NSF/NIEHS Centers for Oceans and Human Health, West Coast Center for Oceans and Human Health (WCCOHH)	This study reviews the interactions between selected patterns of large-scale climate variability and climate change, oceanic conditions, and harmful algae.	Evidence that climate change has influenced the frequency, duration, and geographical range of HABs is emerging as monitoring data temporally and spatially accumulates. Given the potential impact it is recommended that the influence of climate be considered and incorporated into future HAB research and monitoring efforts.	http://www.ehjournal.net/content/7/S2/S4	Environmental Health 7:S4
C0503	Marine - Species & Food Webs	Climate Change	All	Testing the Limits of Diet - Short-Term Climate Effects of Seabird-Forage Fish Linkages in Puget Sound	2011	Parrish, J.	SeaDoc Society (funding), University of Washington				
C0508	Marine - Species & Food Webs	Climate Change	All	Ocean Acidification: Developing Probes of Marine Ecosystem Health	2011	Pfister, C	SeaDoc Society (funding), University of Chicago				Aquatic Conservation: Marine and Freshwater Ecosystems
C0515	Nearshore - Species & Food Webs	Climate Change	Strait of Juan de Fuca	Rapid Environmental Change over the Past decade Revealed by Isotopic Analysis of the California Mussel in the Northeast Pacific	2011	Pfister et al.		The study analyzed stable carbon and oxygen isotopes (d13C, d18O) of decade-old California mussel shells (Mytilus californianus) in the context of an instrumental seawater record of the same length. The study further compared modern shells to shells from 1000 to 1340 years BP and from the 1960s to the present and show declines in the d13C of modern shells that have no historical precedent. The study's finding of decline in another shelled mollusk (limpet) and our extensive environmental data show that these d13C declines are unexplained by changes to the coastal food web, upwelling regime, or local circulation.	The study's observed decline in shell d13C parallels other signs of rapid changes to the nearshore carbon cycle in the Pacific, including a decline in pH that is an order of magnitude greater than predicted by an equilibrium response to rising atmospheric CO2, the presence of low pH water throughout the region, and a record of a similarly steep decline in d13C in algae in the Gulf of Alaska. These unprecedented changes and the lack of a clear causal variable underscores the need for better quantifying carbon dynamics in nearshore environments.		PLoS ONE Volume 6 Issue 10 1-8

Inventory of Recently Completed/Ongoing Scientific Studies

Ref #	Ecosystem Component	Primary Pressure	Action Area	Study Title	Date	Author(s) or Study Contact	Supporting Agency	General Study Design/Methods	Study Results	Weblink	Journal Citation (if applicable)
C0522	Marine - Species & Food Webs	Climate Change		Effects of ocean acidification on declining Puget Sound shellfish		Friedman, C.	Washington Sea Grant	The increasing level of carbon dioxide in the atmosphere is absorbed by seawater, causing a chemical change known as ocean acidification. Certain marine shell-builders like clams, oysters and other mollusks are particularly vulnerable to this change in seawater chemistry. The project will examine the relationship between changing environmental conditions and health of larval mollusks.			
C0559	Marine - Water	Climate Change	All	Climate forcing and the California Current.	2011	King JR, Agnostini VN, Harvey CJ, McFarlane GA, Foreman MG, Overland JE, Di Lorenzo E, Bond NA and Aydin KY	Washington Sea Grant	The Climate Forcing and Marine Ecosystem (CFAME) Task Team of the North Pacific Marine Science Organization (PICES) was formed to address climate forcing impacts on ecosystem structure and productivity of marine species. For the California Current system, the Task Team described the physical processes, built an overview of species across trophic levels, and described how the population dynamics of these species have changed over time. Based on the synthesis work, conceptual models were developed describing the potential pathways linking climate forcing, oceanography, and species' responses.	The resultant empirical data scenarios draw on ecosystem histories to provide a synopsis of expected change given global climate change. The multidisciplinary team faced challenges and limitations in their attempt to draw connections between the outputs from global climate models (GCMs), the physical processes, and the subsequent impacts on species via the identified pathways. To some degree, there was a mismatch of variables that fishery scientists identified as important in determining species' response to climate and physical forcing and the variables that current GCMs can now resolve at the regional level. These gaps will be important for researchers to consider as they begin to develop higher-resolution climate and regional oceanographic models for forecasting changes in species' productivity.	http://icesjms.oxfordjournals.org/content/68/6/1199.abstract	ICES J. Mar. Sci., 68(6):1199-1216
C0574	Marine - Species & Food Webs	Climate Change	All	Troubled Sediments: Heterosigma Cyst Formation and Longevity		Cattolico, Rose Ann	Washington Sea Grant	Climate change and human activities may contribute to increased occurrence of algal blooms. These toxic events impact the survival of salmon and other parts of the marine food chain and compromise the health of coastal ecosystems. This project will address the longstanding question of why blooms of an algal species differ in intensity, longevity and toxicity. It will also provide tools to commercial aquaculturists for monitoring Heterosigma akashiwo cells and cysts.			
C0581	Marine - Species & Food Webs	Climate Change	All	Effects of Ocean Acidification on Trophically Important Crustacean Zooplankton of Washington state		Keister, Julie	Washington Sea Grant	Over the next century, scientists predict that atmospheric carbon dioxide will significantly increase the acidity of global ocean surface water. Coastal upwelling and continued runoff into inland waters may exacerbate the changes in some regions. This shifting ocean chemistry could have broad-ranging effects on the development, growth and survival of organisms and thus on entire marine ecosystems. Yet due to lack of sufficient biological data to inform models, accurate predictions of ecosystem effects are not yet possible. This study will increase understanding of how coastal and inland marine ecosystems are likely to respond by testing the effects of ocean acidification on crustacean zooplankton under realistic current and future conditions.			
C0385	Marine - Water	Climate Change	All	Local and large-scale climate forcing of Puget Sound oceanographic properties on seasonal to interdecadal timescales	2008	Moore, S.K., N.J. Mantua, J.P. Kellogg, and J.A. Newton	UW Climate Impacts Group	The influence of climate on Puget Sound oceanographic properties is investigated on seasonal to interannual timescales using continuous profile data at 16 stations from 1993 to 2002 and records of sea surface temperature (SST) and sea surface salinity (SSS) from 1951 to 2002	The influence of climate on Puget Sound oceanographic properties is investigated on seasonal to interannual timescales using continuous profile data at 16 stations from 1993 to 2002 and records of sea surface temperature (SST) and sea surface salinity (SSS) from 1951 to 2002	http://cses.washington.edu/db/pubs/allpubs.shtml#Year2008	Limnology and Oceanography 53(5): 1746-1758
C0577	Nearshore - Species & Food Webs	Climate Change	All	Effects of Early Exposure of Pacific Oysters to Ocean Acidification on Subsequent Performance		Freidman, Carolyn	Washington Sea Grant	Ocean acidification is already impacting the Pacific Northwest and an increasing number of studies are documenting its negative effects on larval performance of marine shellfish. Poor hatchery performance and low natural recruitment in Pacific oysters may be a direct result of ocean acidification. This project will investigate the effects on later life stages of exposing broodstock and larvae to more corrosive waters. It will also estimate genetic parameters required to implement an effective breeding program for improved tolerance of acidic conditions.			
C0340	All	Climate Change	All	A high-resolution climate model for the U.S. Pacific Northwest: Mesoscale feedbacks and local responses to climate change	2008	Salathé, E.P., R. Steed, C.F. Mass, and P. Zahn	UW Climate Impacts Group	Present-day (1990-1999) and future (2020-2029, 2045-2054, and 2090-2099) conditions are simulated at high resolution (15-km grid spacing) using the MM5 model system and forced by ECHAM5 global simulations. Simulations use the IPCC Special Report on Emissions Scenarios (SRES) A2 emissions scenario, which assumes a rapid increase in greenhouse gas concentrations.	Simulations of future climate scenarios produced with a high-resolution climate model show markedly different trends in temperature and precipitation over the Pacific Northwest than in the global model in which it is nested, apparently due to mesoscale processes not resolved at coarse resolution. Simulations of future climate scenarios produced with a high-resolution climate model show markedly different trends in temperature and precipitation over the Pacific Northwest than in the global model in which it is nested, apparently due to mesoscale processes not resolved at coarse resolution	http://cses.washington.edu/db/pubs/allpubs.shtml#Year2008	Journal of Climate 21(21): 5708–5726,
C0412	Terrestrial - Species & Food Webs	Dams, Levees & Tidegates	South Central Puget Sound	Selection on breeding date and body size in colonizing coho salmon	2010	J. H. Anderson, P. Faulds, Will I. Atlas, G. R. Pess, T. P. Quinn	NOAA, Northwest Fisheries Science Center	We measured the form, direction, and strength of selection on body size and date of arrival to the breeding grounds over the first three cohorts (2003 2005) of a coho salmon (Oncorhynchus kisutch)population colonizing 33 km of habitat made accessible by modification of Landsburg Diversion Dam, on the Cedar River, Washington	Larger fish in both sexes produced more adult offspring, and the magnitude of the effect increased in subsequent years for males, suggesting that low densities attenuated traditional size-biased intrasexual competition. For both sexes, directional selection favoured early breeders in 2003, but stabilizing selection on breeding date was observed in 2004 and 2005. Adults that arrived, and presumably bred, early produced stream-rearing juvenile offspring that were larger at a common date than offspring from later parents, providing a possible mechanism linking breeding date to offspring viability. Comparison to studies employing similar methodology indicated selection during colonization was strong, particularly with respect to reproductive timing. Finally, female mean reproductive success exceeded that needed for replacement in all years so the population expanded in the first generation, demonstrating that salmon can proficiently exploit vacant habitat.	http://www.nwfsc.noaa.gov/publications/displayallinfo.cfm?docmetadataid=7071	Molecular Ecology, Volume: 19, Issue: 12, Pages: 2562-2573
C0413	Terrestrial - Species & Food Webs	Dams, Levees & Tidegates	South Central Puget sound	A genetic and phenetic baseline before the recolonization of steelhead above Howard Hanson Dam, Green River, Washington	2010	G. A. Winans, M. C. Baird, J. Baker	NOAA, Northwest Fisheries Science Center	Purpose of study was to provide data to help manage the stock of fish that are selected to recolonize the upper Green River and to track how resident rainbow trout above the dam respond genetically after 80 years of isolation. They characterized relevant gene pools in the upper Green River before fish transportation with 11 microsatellite loci to evaluate the genetic variability within and among collections.	Hatchery steelhead are clearly different from wild steelhead (FST = 0.037); genetic assignment tests correctly distinguished 91% of the steelhead. While there was no reduction in the amount of genetic variability in the resident rainbow trout above Howard Hanson Dam compared with that of wild steelhead collections below the dam, the two groups had low but statistically significant differences (FST = 0.03). The transport of juvenile and adult steelhead above the dam in the last 20 years may have affected these genetic results.	http://www.nwfsc.noaa.gov/publications/displayallinfo.cfm?docmetadataid=7052	North American Journal of Fisheries Management Volume: 30, Pages: 742-756
C0479	Nearshore - Habitats	Dams, Levees & Tidegates	Strait of Juan de Fuca	Beach morphology and change along the mixed grain-size delta of the dammed Elwha River, Washington	2009	Warrick, J.A., George, D.A., Gelfenbaum, G., Kaminsky, G., and Beirine, M.,	US Geological Survey	Examination of the effects of almost a century of sediment supply reduction from the damming of the Elwha River in Washington on shoreline position and beach morphology of its wave-dominated delta using erosion rate data 1939-2007	An armored layer of cobble clasts are not generally competent in the physical setting of the delta. Thus, the cobble low-tide terrace is very likely a geomorphological feature caused by coastal erosion of a coastal plain and delta, which in turn is related to the impacts of the dams on the Elwha River to sediment fluxes to the coast.	http://dx.doi.org/10.1016/j.geomorph.2009.04.012	Geomorphology, v. 111, p. 136–148

Ref #	Ecosystem Component	Primary Pressure	Action Area	Study Title	Date	Author(s) or Study Contact	Supporting Agency	General Study Design/Methods	Study Results	Weblink	Journal Citation (if applicable)
C0482	Nearshore - Habitats	Dams, Levees & Tidegates	All	Management Measures for Protection and Restoring the Puget Sound Nearshore	2009	Clancy, M., I. Logan, J. Lowe, J. Johannessen, A. MacLennan, F.B. Van Cleve, J. Dillon, B. Lyons, R. Carman, P. Cereghino, B. Barnard, C. Tanner, D. Myers, R. Clark, J. White, C. A. Simenstad, M. Gilmer, and N. Chin	Washington Department of Fish & Wildlife	The protection and restoration of nearshore habitats in Puget Sound requires the application of recovery actions or "management measures" that address nearshore ecosystem processes, functions, and structures. Management measures (MMs) are specific actions that can be implemented alone or in combination to restore the nearshore ecosystem. PSNERP has identified 21 management measures for implementing nearshore ecosystem restoration recognizing that (1) the measures can be capital projects, regulation, incentives, or education and outreach, and (2) the measures contribute to ecosystem recovery via protection, restoration, rehabilitation and substitution/creation. This technical report helps determine how to most effectively use the 21 management measures to accomplish process-based restoration in Puget Sound.	n/a	http://www.pugetsoundnearshore.org/technical_reports.htm	
C0502	Marine - Species & Food Webs	Dams, Levees & Tidegates	Whidbey	Can Intertidal Resources Alone Support Wintering Shorebirds? Stable Isotope Analyses of Dunlin Diet in the Skagit River Delta	2011	Lank, D.	SeaDoc Society (funding), Simon Fraser University				
C0563	Nearshore - Habitats	Dams, Levees & Tidegates	Strait of Juan de Fuca	Using Modern Processes to Understand Postglacial Delta Evolution: Elwha River Delta, EOS Trans. American Geophysical Union, 89(53), Fall Meeting 2008, Abstract OS53F-07	2008	Lee KM, Ogston AS, Nittrouer CA and Holmes M	Washington Sea Grant				
C0583	Marine - Species & Food Webs	Dams, Levees & Tidegates	All	Recovery of Elwha River Salmon and Trout after Dam Removal: Recolonization and the Awakening of Dormant Life-History Diversity		Quinn, Thomas	Washington Sea Grant	Pacific salmon and trout are among the most important fishes in the region and are keystone species for stream and riparian ecosystems. Impassable dams have been an important contributor to reductions in Pacific Northwest salmon populations. For this reason, the response of the Elwha River ecosystem to removal of two dams, which began in fall 2011, is a matter of great scientific and public interest. This study will explore the expansion of salmon and trout populations, their spatial use of the basin and the diversity of their life history traits in the Elwha River system as the dams are removed.			
C0585	Nearshore - Habitats	Dams, Levees & Tidegates	Strait of Juan de Fuca	Coastal Habitats of the Elwha River, Washington -- Biological and Physical Patterns and Processes Prior to Dam Removal	2011	Duda, Jeffrey, Jonathan Warrick, and Christopher Magirl (eds)	USGS	This report includes chapters that summarize the results of multidisciplinary studies to quantify and characterize the current (2011) status and baseline conditions of the lower Elwha River, its estuary, and the adjacent nearshore ecosystems prior to the historic removal of two long-standing dams that have strongly influenced river, estuary, and nearshore conditions. The studies were conducted as part of the U.S. Geological Survey Multi-disciplinary Coastal Habitats in Puget Sound (MD-CHIPS) project.	This report provides a scientific snapshot of the lower Elwha River, its estuary, and adjacent nearshore ecosystems prior to dam removal that can be used to evaluate the responses and dynamics of various system components following dam removal.		
C0472	Marine - Habitats	Derelict Gear & Vessels	All	Derelict Fishing Nets In Puget Sound And The Northwest Straits: Patterns And Threats To Marine Fauna	2010	T. P. Good, J. A. June, M. A. Etnier, G. Broadhurst	NOAA, Northwest Fisheries Science Center	Summary of analysis of 870 derelict fishing gillnets recovered since 2002 in Washington's inland waters.	most were recovered from northern Puget Sound and high-relief rocky habitats and were relatively small, of recent construction, in good condition, stretched open, and in relatively shallow water. Marine organisms documented in recovered gillnets included 31,278 invertebrates (76 species), 1036 fishes (22 species), 514 birds (16 species), and 23 mammals (4 species); 56% of invertebrates, 93% of fish, and 100% of birds and mammals were dead when recovered. For all taxa, mortality was generally associated with gillnet effectiveness (total area, age and condition, and suspension in the water). Mortality from derelict fishing gear is underestimated at recovery and may be important for species of economic and conservation concern.	http://www.nwfsc.noaa.gov/publications/displayallinfo.cfm?docmetadataid=7032	Marine Pollution Bulletin Volume: 60, Issue: 1, Pages: 39-50
C0521	Marine - Habitats	Derelict Gear & Vessels	All	Marine species mortality in derelict fishing nets in Puget Sound, WA and the cost/benefits of derelict net removal	2010	Gilardi et al.		Using data collected from repeated survey dives on derelict gillnets in Puget Sound, Washington, the study estimated the daily catch rate of a given derelict gillnet, and developed a model to predict expected total mortality caused by a given net based on entanglement data collected upon its removal. It also generated a cost:benefit ratio for derelict gear removal utilizing known true costs compared to known market values of the resources benefiting from derelict gear removal.	For one study net, the study calculated 4368 crab entangled during the impact lifetime of the net, at a loss of $19,656 of Dungeness crab to the commercial fishery, compared to $1358 in costs to remove a given gillnet, yielding a cost:benefit ratio of 1:14.5.		Marine Pollution Bulletin 60 (2010) 376-382
C0376	Terrestrial - Species & Food Webs	Invasives - Freshwater	All	Blue-Green Algae Toxins in Washington Lakes: Screening Fish Tissue for Microcystins and Anatoxin-a	2010	Johnson, A.	Washington Department of Ecology	The Washington State Department of Ecology conducted a screening survey to assess the presence of microcystins and anatoxin-a in muscle and liver tissue from fish in six Western Washington lakes that had blue-green blooms in 2008.	Microcystins were detected in all samples, with higher concentrations in liver than muscle. Anatoxin-a was not detected.	http://www.ecy.wa.gov/biblio/1003011.html	
C0343	Nearshore - Species & Food Webs	Invasives - Marine	All	Recent trends in paralytic shellfish toxins in Puget Sound, relationships to climate, and capacity for prediction of toxic events	2008	Moore, S.K., N.J. Mantua, B.M. Hickey, and V.L. Trainer	UW Climate Impacts Group	Temporal and spatial trends in paralytic shellfish toxins (PSTs) in Puget Sound shellfish and their relationships with climate are investigated using long-term monitoring data since 1957.Analyses were limited to the shellfish species Mytilus edulis at 20 sites from 1993 to 2007.	Using blue mussel data only, we find no robust evidence to suggest that the frequency, magnitude, duration, or geographic scope of PST events in Puget Sound increased between 1993 and 2007. However, there is a significant basin-wide trend for closures to occur earlier in the year. There are no significant correlations between annual indices of mussel toxicity and aspects of the local and large-scale climate.	http://cses.washington.edu/db/pubs/allpubs.shtml#Year2008	Harmful Algae Feb2009, Vol. 8 Issue 3, p463
C0456	Nearshore - Species & Food Webs	Invasives - Marine	All	Washington State 2009/10 Mussel Watch Pilot Project: A Collaboration Between National, State and Local Partners	2010	Jennifer Lanksbury, James West, Kathleen Herrmann, Andrea Hennings, Kate Litle and Amy Johnson	Washington Department of Fish & Wildlife	PSAMP staff coordinated with Snohomish County and Washington Sea Grant staff to identify which of the 26 core Mussel Watch locations would be sampled by volunteer teams, and which would be sampled by PSAMP staff, to identify appropriate local volunteer groups for volunteer sampling, and to develop volunteer materials based on the NOAA Mussel Watch protocol. All Mussel Watch locations were successfully sampled using adapted NOAA protocols by either PSAMP staff or a citizen scientist team.	Chemical analysis of mussel samples has been delayed, but the sampling process was successful. The report includes five recommendations and next steps for adapting Mussel Watch to Puget Sound needs. Successful adaptation of the National Mussel Watch program to the Puget Sound level will require sufficient and consistent funding to conduct adequate pilot studies, establish more sampling locations than currently exist, add seasonal sampling where necessary, and establish a well-tended wide-ranging network of committed volunteers and volunteer organizations.	http://wdfw.wa.gov/publications/pub.php?id=01127	
C0511	Marine - Species & Food Webs	Invasives - Marine	All	Evaluating Effects of Invasive Tunicates on Benthic and Epifaunal Communities in Puget Sound, Washington	2011	Herwig, R.	SeaDoc Society (funding), University of Washington				
C0561	Nearshore - Species & Food Webs	Invasives - Marine	All	Impacts of invasive drills on Olympia oysters in Puget Sound: implications for restoration. In: West coast native oyster restoration: 2006 workshop proceedings. US Department of Commerce, NOAA Restoration Center, p 31	2007	Buhle, ER and Ruesink JL	Washington Sea Grant				

Ref #	Ecosystem Component	Primary Pressure	Action Area	Study Title	Date	Author(s) or Study Contact	Supporting Agency	General Study Design/Methods	Study Results	Weblink	Journal Citation (if applicable)
C0562	Nearshore - Species & Food Webs	Invasives - Marine	All	Control strategies for Japanese oyster drill and implications for restoration and management of Olympia oyster (Ostrea conchaphila) in Liberty Bay, Washington. In: West Coast native oyster restoration: 2007 workshop proceedings. US Department of Commerce, NOAA Restoration Center, p 42	2008	Henson KD and Buhle ER	Washington Sea Grant				
C0579	Nearshore - Species & Food Webs	Invasives - Marine	All	Understanding Dormancy Requirements and Germination of Alexandrium Cysts and Evaluating Cyst Mapping as a Tool for Early Warning of Harmful Algal Blooms		Greengrove, Cheryl	Washington Sea Grant	Harmful algal blooms can contaminate shellfish and result in costly recalls of tainted product from the market, considerably reducing consumer confidence in seafood safety. To address this concern, health authorities in Washington dedicate significant resources to monitoring shellfish toxicity at more than 70 locations in the Sound at roughly two-week intervals. This project will enhance an early warning system for toxic blooms of one common culprit, Alexandrium catenella, in Puget Sound. Specifically, it will provide critical information on life-history characteristics of A. catenella that will inform a predictive model.			
C0489	n/a	Many	All	Using Existing Scientific Capacity to Set Targets for Ecosystem-based Management: A Puget Sound Case Study	2011	J. F. Samhouri, P. S. Levin, C. Andrew James, Jessi Kershner, Greg Williams	NOAA, Northwest Fisheries Science Center	Paper reviews five approaches, borrowed from a variety of disciplines, to establish target reference levels for EBM.	The approaches include the use of existing reference levels, reference directions, and reference levels based on nonlinear functional relationships, baselines, or social norms. Each approach is particularly suitable for EBM because it can be used alone or in combination with others to contextualize status for a diverse suite of ecosystem goals influenced by a wide variety of human activities.	http://www.nwfsc.noaa.gov/publications/displayallinfo.cfm?docmetadataid=7684	Marine Policy Volume: 35 Pages: 508-518
C0493	All	Many	All	Ecosystem Status and Trends	2009	Puget Sound Partnership	Puget Sound Partnership	The Puget Sound Partnership's report on the status of Puget Sound ecosystem provides a system level evaluation of human health and well-being, species and food webs and habitats, and water quantity and quality.	Within a human-biological-water framework, the Partnership's 2009 ecosystem status and trends reporting uses a number of ecosystem indicators to describe conditions related to the scope and span of interests described above. Ecosystem status and trends interpretations presented here reflect the Partnership's current understandings and judgments about system features most directly relevant to recovery of the Puget Sound ecosystem	http://www.psp.wa.gov/downloads/2009_tech_memos/Ecosystem_status_and_trends_tech_memo_2009_06_11_FINAL.pdf	
C0539	Marine - Species & Food Webs	Many	All	Changes in marine bird abundance in the Salish Sea: 1975 to 2007.	2009	Bower JL	Washington Sea Grant	Review of Salish Sea bird surveys including the 1978/79 Marine Ecosystems Analysis (MESA) Puget Sound Project, aerial surveys (1990–present) by the Puget Sound Ambient Monitoring Program (PSAMP), shore-based and ferry surveys by Western Washington University (WWU) of marine bird abundance (2003–present), and Christmas Bird Counts (CBCs, 1960s–present). The study uses these three surveys to evaluate changes in non-breeding-season marine bird abundance in the Salish Sea.	Data from the same locations shows significant declines in 14 of the 37 most common overwintering Salish Sea species, including 10 species that declined by more than 50%; seven species showed significant increases over that time period. Western Grebe Aechmophorus occidentalis, scaup (primarily Greater Scaup Aythya marila), and Marbled Murrelet Brachyramphus marmoratus showed significant declines. The Common Murre Uria aalge showed significant declines of more than 80%. Significant declines occurred in species of four of the five feeding guilds, including piscivores, benthivores, omnivores and planktivores, and significant increases were seen in species of three feeding guilds, demonstrating that the factors affecting species abundance are complex and may be unique to each species.	http://www.marineornithology.org/PDF/37_1/37_1_9-17.pdf	Marine Ornithology 37:9–17.
C0540	Marine - Species & Food Webs	Many	All	Changes in avifaunal abundance in a heavily used wintering and migration site in Puget Sound, Washington during 1966–2007.	2009	Anderson EM, Bower JL, Nysewander DR, Evenson JR and Lovvorn JR	Washington Sea Grant	A critical first step in guiding protection efforts for marine birds is comprehensive evaluation of monitoring results. To facilitate such a synthesis in Puget Sound, Washington, this study identified five survey programs that spanned large fractions of this region during 1966–2007. The study focused this initial review on Padilla Bay, one of the sites most heavily used by wintering and migrating birds on the Pacific Coast.	Comparisons suggest that the combined density of all marine birds in Padilla Bay declined between 1978/79 and 2003–2006. These overall declines occurred mainly during early winter (November) and especially during spring migration (mid-March to mid-May). During spring migration, species assemblages were highly dissimilar between 1978/79 and 2003–2006. Of 27 species and species groups we considered, six increased and 13 declined. These declines occurred across foraging guilds and were large for many formerly abundant species. For example, typical maximum densities declined by about 75% (400/km2 to 100/km2) for Brant Branta bernicla, 80% (75/km2 to 15/km2) for scaup (mainly Greater Scaup Aythya marila) and 98% (>50/km2 to <1/km2) for Western Grebes Aechmophorus occidentalis. Results of aerial surveys during 1992–2007 by the Washington Department of Fish and Wildlife were consistent with most of the identified changes. Causes of decline are unclear for most species, but appear to be widespread. Padilla Bay habitats and the many thousands of birds that depend on them face multiple threats.	http://www.marineornithology.org/PDF/37_1/37_1_19-27.pdf	Marine Ornithology, 37:19–27.
C0566	Marine - Species & Food Webs	Many	All	Non-invasive physiological monitoring of southern resident killer whales		Wasser, Samuel	Washington Sea Grant	Washington's endangered southern resident killer whale population experienced an unexplained 20 percent decline in the late 1990's. The study will use detection dogs aboard boats to locate fresh orca scat on the surface of the water. This noninvasive approach will analyze fecal hormone and toxin levels to test three potential population threats: declines in Chinook salmon as a major dietary component, disturbance by vessel traffic and the presence of persistent organic pollutants.			
C0391	Terrestrial - Water	n/a	South Puget Sound	Incorporation of Fine-Grained Sediment Erodibility Measurements into Sediment Transport Modeling, Capitol Lake, Washington	2008	Stevens, Andrew W.; Gelfenbaum, Guy; Elias, Edwin; Jones, Craig	US Geological Survey	Fifteen cores were collected at several sites throughout Capitol Lake and measured for erodibility using Sedflume.	n/a	http://pubs.usgs.gov/of/2008/1340/	
C0393	Terrestrial - Habitats	n/a	All	Baseline Characterization of Nine Proposed Freshwater Sediment Reference Sites, 2008	2009	Sloan, J. and N. Blakley	Washington Department of Ecology	The Department of Ecology collected and analyzed three sediment samples from nine proposed freshwater reference areas during the summer of 2008.	Target chemical analyses included total organic carbon, percent solids, grain size, sulfides, ammonia, semi-volatile organic compounds, polychlorinated biphenyls, polycyclic aromatic hydrocarbons, chlorinated pesticides, and metals. The bioassays suite included 20-day Midge (Chironomus tentans), 28-day Amphipod (Hyalella azteca), and Microtox.	http://www.ecy.wa.gov/biblio/0903032.html	

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C0397	Marine - Water	n/a	All	A descriptive analysis of temporal and spatial patterns of variability in Puget Sound oceanographic properties	2008	Moore, Stephanie; Mantua, Nathan J.; Newton, Jan A.; Kawase, Mitsuhiro; Warner, Mark J.; Kellogg, Jonathan P.	NOAA Climate Program Office	Temporal and spatial patterns of variability in Puget Sound's oceanographic properties are determined using continuous vertical profile data from two long-term monitoring programs; monthly observations at 16 stations from 1993 to 2002, and biannual observations at 40 stations from 1998 to 2003.	Climatological monthly means of temperature, salinity, and density reveal strong seasonal patterns. Water temperatures are generally warmest (coolest) in September (February), with stations in shallow finger inlets away from mixing zones displaying the largest temperature ranges. Salinities and densities are strongly influenced by freshwater inflows from major rivers during winter and spring from precipitation and snowmelt, respectively, and variations are greatest in the surface waters and at stations closest to river mouths. Vertical density gradients are primarily determined by salinity variations in the surface layer. Strong tidal stirring and reflux over sills at the entrance to Puget Sound generally removes vertical stratification. Mean summer and winter values of oceanographic properties reveal patterns of spatial connectivity in Puget Sound's three main basins; Whidbey Basin, Hood Canal, and Main Basin.	http://www.treesearch.fs.fed.us/pubs/35300	Estuarine, Coastal and Shelf Science 80: 545-554
C0400	Terrestrial - Water	n/a	All	Flow variability and the biophysical vitality of river systems	2008	Naiman, R. J., J. J. Latterell, N. E. Pettit, and J. D. Olden	Andrew W. Mellon Foundation, U.S. National Science Foundation, U.S. Forest Service Pacific Northwest Research Station, and Weyerhaeuser Company	Literature review.	We illustrate the fundamental importance of fluctuations in natural water flows to the long-term sustainability and productivity of riverine ecosystems and their riparian areas. Natural flows are characterized by temporal and spatial heterogeneity in the magnitude, frequency, duration, timing, rate of change, and predictability of discharge. These characteristics, for a specific river or a collection of rivers within a defined region, shape species life histories over evolutionary (millennial) time scales as well as structure the ecological processes and productivity of aquatic and riparian communities.	http://linkinghub.elsevier.com/retrieve/pii/S1631071308000266	Comptes Rendus Geoscience 340:629-643
C0405	All	n/a	All	Priority Habitats and Species List	2008	Washington Department of Fish & Wildlife	Washington Department of Fish & Wildlife	The PHS List is a catalog of habitats and species considered to be priorities for conservation and management. Priority species require protective measures for their survival due to their population status, sensitivity to habitat alteration, and/or recreational, commercial, or tribal importance.	There are 20 habitat types, 152 vertebrate species, 41 invertebrate species, and 10 species groups currently in the PHS List. These constitute about 17% of Washington's approximately 1000 vertebrate species and a fraction of the state's invertebrate fauna.	http://wdfw.wa.gov/publications/pub.php?id=00165	
C0408	Terrestrial - Species & Food Webs	n/a	All	Estimating Changes in Coho Salmon and Steelhead Abundance from Watershed Restoration: How Much Restoration is Needed to Measurably Increase Smolt Production?	2010	Philip Roni; George Pess; Tim Beechie; Sarah Morley	NOAA, Northwest Fisheries Science Center	Using existing data from evaluations of habitat restoration, we estimated the average change in coho salmon Oncorhynchus kisutch and steelhead O. mykiss parr and smolt densities for common in-channel (culvert removal, large wood placement, boulder placement, and constructed logjams) and floodplain restoration techniques (constructed side channels and reconnected floodplain habitats). We then used these numbers and a Monte Carlo simulation to predict changes in fish numbers in a model watershed for two restoration scenarios: (1) restoration of all accessible habitat within the watershed and (2) restoration of the average amount historically implemented in Puget Sound watersheds (8% of total restorable areas).	The percentage of floodplain and in-channel habitat that would have to be restored in the modeled watershed to detect a 25% increase in coho salmon and steelhead smolt production (the minimum level detectable by most monitoring programs) was 20%. However, given the large variability in fish response (changes in density or abundance) to restoration, 100% of the habitat would need to be restored to be 95% certain of achieving a 25% increase in smolt production for either species. Our study demonstrates that considerable restoration is needed to produce measurable changes in fish abundance at a watershed scale.		North American Journal of Fisheries Management Volume 30, Issue 6, 2010, Pages 1469 - 1484
C0420	Nearshore - Species & Food Webs	n/a	South Puget Sound	Pre-Restoration Habitat Use by Chinook Salmon in the Nisqually Estuary Using Otolith Analysis: An Additional Year	2009	Lind-Null, Angie, and Larsen, Kim	US Geological Survey	Otolith analysis was used to examine Chinook salmon life history, growth, and residence in the Nisqually Estuary. The purpose was to incorporate otolith microstructure analysis from 2005, to verify findings from 2004, and to evaluate between-year variation in otolith microstructure.	Results indicated no inter-annual variation in the appearance of the tidal delta check (TDCK) and delta-flats check (DFCK). A new life history type (fry migrant) was observed on samples collected in 2005. Fish caught in the tidal delta spent an average of 17 days in the tidal delta. There was a corresponding increase in growth rate as the fish migrated from freshwater (FW) to tidal delta to nearshore (NS) habitats. Fish grew 33 percent faster in the tidal delta than in FW habitat and slightly faster (14 percent) in the delta flats (DF) habitat compared to the tidal delta.	http://pubs.usgs.gov/of/2009/1106/	
C0421	Nearshore - Species & Food Webs	n/a	South Puget Sound	Otolith Analysis of Pre-Restoration Habitat Use by Chinook Salmon in the Delta-Flats and Nearshore Regions of the Nisqually River Estuary	2010	Lind-Null, Angie, and Larsen, Kim	US Geological Survey	Otolith analysis was used to examine Chinook salmon life history, growth, and residence in the Nisqually River estuary.	Generally, freshwater mean increment width of unmarked fish, on average, was smaller compared to marked Chinook followed by tidal delta and DF/NS portions respectively. On average, the complete tidal delta growth rate was higher for marked Chinook compared to unmarked Chinook. The average DF/NS growth rate on unmarked Chinook was consistently lower than marked Chinook during all years; however, sample sizes were small during some years. Unmarked Chinook, on average, spent longer in the tidal delta compared to marked Chinook. Otolith microstructural analysis can be a valuable tool in establishing baseline information on the utilization of Nisqually River estuary habitats by juvenile Chinook salmon prior to the newly funded restoration efforts.	http://pubs.usgs.gov/of/2010/1238/	
C0428	Terrestrial - Species & Food Webs	n/a	All	Land Use Planning for Salmon, Steelhead and Trout: A land use planner's guide to salmonid habitat protection and recovery	2009	Katie Knight	Washington Department of Fish & Wildlife	This planner's guide to salmonid recovery is intended for local governments and includes information on state salmonid recovery efforts, sources of best available science, and model policies and development regulations for implementing salmonid recovery.	n/a	http://wdfw.wa.gov/publications/pub.php?id=00033	
C0431	Marine - Species & Food Webs	n/a	All	Species composition and relative abundance of large medusae in Puget Sound, WA	2010	Reum, J., M. Hunsicker, and C. Paulsen	UW - Fisheries	We assessed species composition and relative biomass densities of large medusae (bell diameters larger than 4 cm) at four locations in Puget Sound, Washington, over two sampling periods (June and September). We specifically sampled sites in southern Hood Canal (near Hoodsport), northern Hood Canal (Hazel Point), southern Admiralty Inlet (Useless Bay) and Possession Sound using a bottom trawl as part of a larger survey of demersal fish and invertebrate community structure.	Our results indicate that jellyfish biomass changed markedly within and among locations, which has implications for modeling energy flows in Puget Sound and developing monitoring schemes that are able to capture interannual variability in jellyfish biomass. Given the abundance of jellyfish in our survey and their potential as sentinels of change in the marine environment we recommend that jellyfish populations be routinely monitored in Puget Sound.	http://www.bioone.org/doi/abs/10.3955/046.084.0202	Northwest Science.84(2):131-140. doi: 10.3955/046.084.0202
C0432	Marine - Species & Food Webs	n/a	All	Quantitative evaluation of marine ecosystem indicator performance using food web models	2009	Samhouri, J., P. Levin, and C. Harvey	NOAA, Northwest Fisheries Science Center	The study analyzed seven marine food web models to evaluate the performance of candidate indicators of ecosystem structure and function. The basic approach involved simulating fishing perturbations to each model, measuring the response of ecosystem attributes and candidate indicators to the perturbations, and testing the ability of the indicators to track changes in the values of the attributes.	Our analysis suggests that no single indicator is sufficient to describe all of the ecosystem attributes, but at the same time highlights broad, catch-all indicators (for example, detritivores, jellyfish) and distinguishes the strongest attribute– indicator relationships. Ecosystem indicators consisting of lower-trophic level, higher-productivity functional groups tended to perform particularly well. We also identified indicators that showed strong or weak associations with different attributes, but together captured changes in nearly all of them. Examples of such complementary indicators include phytoplankton, zooplanktivorous fish, piscivorous fish, and trophic level of the catch. Quantitative approaches such as this one will enable managers to make informed decisions about ecosystem-scale monitoring in the oceans.	http://www.springerlink.com/content/k3k81124v4x70p37/	Ecosystems 12:1283-1298
C0434	Marine - Species & Food Webs	n/a	Whidbey	Prevalence of Viral Erthrocytic Necrosis in Pacific Herring and Epizootics in Skagit Bay, Puget Sound, Washington	2009	P. K. Hershberger, N. Elder, C. A. Grady, J. L. Gregg, C. A. Pacheco, C. Greene, C. Rice, T. R. Meyers	USGS	Measured epizootics of viral erythrocytic necrosis (VEN)in juvenile Pacific herring (Clupea pallasii) in Skagit Bay, Puget Sound, Washington, during 2005 2007	The persistence and recurrence of VEN epizootics indicate that the disease is probably common among juvenile Pacific herring throughout the eastern North Pacific Ocean, and although population-level impacts probably occur they are typically covert and not easily detected.	http://www.nwfsc.noaa.gov/publications/displayallinfo.cfm?docmetadataid=6954	Journal of Aquatic Animal Health Volume: 21 Pages: 1-7

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C0437	Marine - Species & Food Webs	n/a	All	2008 Washington State Herring Stock Status Report	2009	Kurt C. Stick and Adam Lindquist	Washington Department of Fish & Wildlife	This is the fourth edition of the Washington Department of Fish and Wildlife herring stock status report. Similar to previous editions, this document uses localized documented herring spawning grounds in Washington waters to represent discrete stocks.	The cumulative abundance of south and central Puget Sound herring stocks in recent years is comparable to that observed in the 1970's and 1980's, while the Cherry Point stock, and cumulative north Puget Sound (excluding the Cherry Point stock) and Strait of Juan de Fuca regional spawning biomasses are at low levels of abundance. For the 2007-08 period, less than half (47%) of Puget Sound herring stocks are classified as healthy or moderately healthy. This is the lowest percentage of individual stocks meeting these criteria since development of the stock status summary in 1994, although very similar to the status breakdown for the previous two-year periods (2003-04 and 2005-06).	http://wdfw.wa.gov/publications/pub.php?id=00928	
C0438	Marine - Species & Food Webs	n/a	San Juan/Whatcom	Estimating Acoustic Abundance of Forage Fish in Rosario Strait, Washington	2009	Darcy A. Wildermuth	Washington Department of Fish & Wildlife	Hydroacoustic-trawl surveys were conducted in June of 2008 to assess pelagic forage abundance and composition in Rosario Strait and Burrows Bay, Washington.	Pelagic forage species composition varied by area and survey date, but was dominated by juvenile Walleye Pollock (Theragra chalcogramma), (TL=60.9 mm) and pre-metamorphosed Pacific Herring (Clupea pallasii), (TL= 45.0 mm). From these results, 1,369 metric tons of pelagic forage, including 505 metric tons of juvenile pollock and 169 metric tons of pre-metamorphosed herring were estimated.	http://wdfw.wa.gov/publications/pub.php?id=00929	
C0443	Marine - Species & Food Webs	n/a	All	Seasonal variation in guild structure of the Puget Sound demersal fish community	2008	Reum, J., and T. Essington	UW - Fisheries	The study analyzed guild structure of the demersal fish assemblage in Puget Sound, WA, a temperate estuarine system on the US west coast. Using diet information from 2,401 stomachs collected across three seasons (fall, winter, and summer), we identified guild membership for 21 fish species, examined seasonal guild switching, and tested for seasonal shifts in predation and for differences in the degree of diet overlap at the assemblage level.	Using cluster analysis and a permutation approach, we identified seven significant guilds that were typified by predation on benthic invertebrates, pelagic invertebrates, and piscivory. Of the 18 species with more than one season of diet information, six switched guilds (Pacific sanddab L, sturgeon poacher, Pacific tomcod S, speckled sanddab, rex sole, and rock sole S). At the assemblage level, we tested for seasonal differences in prey use between seasons by performing an analysis of similarities based on Bray–Curtis diet similarities and found no significant difference. However, diet overlap was significantly higher in the summer than the fall and winter (with summer>fall>winter) indicating that diets within the assemblage converged in the summer. These results indicate that analyses of guild structure and diet overlap can reveal seasonal variation in community trophic structure and highlight intra-annual food web variation in the Puget Sound demersal fish community.	http://www.springerlink.com/content/tlju0r8238337pg8/	Estuaries and Coasts 31:790-801
C0447	Marine - Species & Food Webs	n/a	San Juan/Whatcom	Tidal influence on the haul-out behavior of harbor seals (Phoca vitulina) at a site available at all tide levels	2008	Patterson, J., and A. Acevedo-Gutierrez	Western Washington University	The study counted hauled-out Harbor Seals from sunrise to sunset on floatingwater-breakers at Semiahmoo Marina, Washington, to examine the effect of tides on haul-out behavior. Because haul-out behavior is affected by several factors, we conducted mixed-factor analyses that included tide level, tidal current, time of season, and time of day as fixed factors, and several meteorological variables as random factors.	The number of hauled-out Harbor Seals was significantly associated with tide level, time of season, and time of day. Results suggest that seal counts in Semiahmoo Marina should be made late in the pupping season and early in the afternoon at moderately positive tide levels to achieve the highest counts. They also indicate that tide was associated with seal numbers unrelated to site availability because seal numbers were positively related to tide height, a finding opposite to studies at tidal haul-out sites.	http://www.biol.wwu.edu/mbel/media/pdfs/NWNat2008_89.pdf	Northwestern Naturalist 89:17-23
C0449	Nearshore - Habitats	n/a	South, South Central	Restricted ranges in physical factors may constitute subtle stressors for estuarine biota	2010	Dethier, M.N., Ruesink, J., Berry, H., Sprenger, A.G., and Reeves, B.	University of Washington	Analysis of physical parameters of beaches to look for correlations with shallow gradients in nearshore wave energy, temperature, and salinity.	Variation in physical parameters on estuarine shorelines in Puget Sound is quite low compared to many other estuaries, but particular parameters nonetheless correlate with strong gradients in species richness and biomass.		Marine Environmental Research, v. 69, p. 240–247.
C0450	Nearshore - Habitats	n/a	All	Puget Sound intertidal biotic community monitoring—2008 monitoring report	2009	Dethier, M.N., and Berry, H.D.	Washington Department of Natural Resources	DNR has monitored biotic communities and assessed the condition of nearshore habitats since 1997 (in collaboration with UW). Monitoring methods characterize epibiota and infauna using quadrat and core samples.	Report addresses three research questions for Puget Sound through status and trends in intertidal biota at Admiralty Inlet, Possession Sound, and San Juan embayments.	http://www.dnr.wa.gov/ResearchScience/Topics/AquaticHabitats/Pages/aqr_nrsh_publications.aspx	
C0453	Marine - Species & Food Webs	n/a	San Juan/Whatcom, Strait of Juan de Fuca, Whidbey	Reevaluating Marine Diets of Surf and White-Winged Scoters: Interspecific Differences and the Importance of Soft-Bodied Prey.	2008	Anderson, E. M., J. R. Lovvorn, and M. T. Wilson	USFWS and others	Analyzed diets of Surf Scoters collected in northern Puget Sound, Washington during 2005–2006 using following alternative methods: collecting birds that are feeding, immediately preserving gut contents, excluding gizzard contents, averaging food-item percentages across birds versus pooling gut contents for all birds, and using energy or ash-free dry mass versus wet mass values of foods.	Found that the bivalve component of diet declining by over half and a near doubling of soft-bodied prey (i.e., crustaceans, polychaetes) compared to previous diet analysis methods. Also, relative to White-winged Scoters, Surf Scoters consume smaller bivalves, a smaller and more variable percentage of mollusk prey (including bivalves and gastropods), and a declining percentage of bivalves as winter progresses. Past diet studies for scoters may provide misleading guidelines to conservation efforts by implying that only standing stocks of bivalves require consideration when prioritizing critical foraging sites.		The Condor 110:285-295
C0454	Marine - Species & Food Webs	n/a	San Juan/Whatcom, Strait of Juan de Fuca, Whidbey	Changes in marine bird abundance in the Salish Sea: 1975 to 2007	2009	Bower, J. L.	Washington Sea Grant, Western Washington University	Compared results of four marine bird surveys to evaluate non-breeding bird abundance: The 1978/79 Marine Ecosystems Analysis (MESA), PSAMP aerial surveys (1990–present) and shore-based and ferry surveys by WesternWashington University (WWU) of marine bird abundance (2003–present), and Christmas Bird Counts (CBCs, 1960s–present).	Significant declines occurred in species of four of the five feeding guilds, including piscivores, benthivores, omnivores and planktivores, and significant increases were seen in species of three feeding guilds, demonstrating that the factors affecting species abundance are complex and may be unique to each species. The WWU study largely corroborates declines documented by the PSAMP study, and analysis of 11 Salish Sea CBCs found the fewest species with significant declines.		Marine Ornithology 37:9-17
C0455	Marine - Species & Food Webs	n/a	All	Marine Bird and Mammal Component of the Puget Sound Ambient Monitoring Program web reports.	2010	Evenson, J.R, D.R. Nysewander, B.L. Murphie, and T.A. Cyra	Washington Department of Fish & Wildlife	The density atlas displays distributions and density indices of a selected subset of the major groups of marine birds and diving waterfowl species seen by aerial surveys conducted since 1992 by Washington Department of Fish and Wildlife on the inner marine waters of Washington State. The area of main focus extends from the western end of the Strait of Juan de Fuca eastwards, and from the Canadian borders near Point Roberts south to the southern end of Puget Sound.	n/a	http://wdfw.wa.gov/mapping/psamp/index.html	
C0463	Nearshore - Habitats	n/a	All	Area of Eelgrass Depth Bands in Greater Puget Sound	2011	Dowty, P.	Washington Department of Natural Resources	DNR has found that there is a need for more information on both the historical and potential distribution of eelgrass in greater Puget Sound to support target setting. The purpose of this report is to contribute in this area by presenting new estimates of the area within the eelgrass depth range in greater Puget Sound. The approach utilized available gridded bathymetry datasets and existing information on the distribution of eelgrass by depth.	The estimated area of the eelgrass depth band in greater Puget Sound was 53,785 ± 12,580 ha (95% confidence interval). This is a wider confidence interval than expected. Based on this estimate, the current regional percent cover of eelgrass is 40%. Note that depth is only one of many environmental factors that constrain the distribution of eelgrass.	http://www.dnr.wa.gov/ResearchScience/Topics/AquaticHabitats/Pages/aqr_nrsh_publications.aspx	
C0464	Nearshore - Habitats	n/a	San Juan/Whatcom	Eelgrass (Zostera marina L.) Abundance and Depth Distribution Along Selected San Juan Archipelago Shallow Embayments	2010	Berry, H.D. and L. Ferrier	Washington Department of Natural Resources	Work specific to San Juan Archipelago follows protocols of DNRs Submerged Vegetation Monitoring Program	Report summarizes the findings of collaborative work to document current abundance and depth distribution of Z. marina in the Westcott Bay Complex (inclusive of Westcott Bay proper and five other sites) as well as several other shallow embayments in the San Juan Archipelago. No recovery of previous losses as well as new declines were recorded.	http://www.dnr.wa.gov/ResearchScience/Topics/AquaticHabitats/Pages/aqr_nrsh_publications.aspx	

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C0465	Nearshore - Habitats	n/a	All	Puget Sound Submerged Vegetation Monitoring Project-2009 Report	2011	Gaeckel, J., P. Dowty, H. Berry, L.Ferrier	Washington Department of Natural Resources	In 2000, DNR established the Submerged Vegetation Monitoring Project (SVMP) to track this valuable resource. The SVMP uses a statistically robust sampling design and underwater videography to monitor Z. marina on an annual basis. This report presents the soundwide and San Juan County-Cypress Island focus area monitoring results from the 2009 field season	The results in 2009 continue to indicate a pattern of Z. marina decline throughout Puget Sound. Although there is a marginally significant increasing trend in Z. marina area, the pattern of site level decline throughout Puget Sound suggests losses are prevalent at individual sites. There is consistently greater prevalence of year-to-year and long-term declines in Z. marina area and depth distribution throughout the study area. There is also strong evidence of Z. marina decline in the Hood Canal region. The occurrence and soundwide distribution of sites with significant declines is of concern for habitat connectivity and ecological functions.	http://www.dnr.wa.gov/ResearchScience/Topics/AquaticHabitats/Pages/aqr_nrsh_publications.aspx	
C0466	Nearshore - Habitats	n/a	San Juan/Whatcom	Eelgrass Stressor-Response Report 2007-2008: Zostera marina L. (eelgrass) transplant growth and survival along a spatial and tidal gradient in Westcott Bay	2011	Schanz, A., H. Julich, L. Ferrier, H. Berry	Washington Department of Natural Resources	The study combined Z. marina transplant experiments and continuous environmental monitoring to assess habitat suitability. Hypothesizing that unfavorable physical conditions prevent Z. marina growth at sites in the inner and head of Westcott Bay, we transplanted Z. marina in currently and formerly vegetated areas along a spatial gradient of decreasing eelgrass abundance from the mouth to the bay head at three different tidal elevations, and related transplant performance to environmental parameters	The study demonstrates that current environmental conditions do not support Z. marina survival at three tested tidal elevations at the head of Westcott Bay and in the intertidal at the site of the inner bay. This suggests that the current observed Z. marina distribution in Westcott Bay most likely represents the extent of suitable habitat.	http://www.dnr.wa.gov/ResearchScience/Topics/AquaticHabitats/Pages/aqr_nrsh_publications.aspx	
C0467	Nearshore - Habitats	n/a	All	Puget Sound Submerged Vegetation Monitoring Project: 2008 Monitoring Report, Nearshore Habitat Program	2009	Gaeckle, J. L., P.Dowty, H. Berry, and L. Ferrier	Washington State Department of Natural Resources	Zostera marina, a marine flowering plant, is recognized globally as an indicator of ecosystem health and provides valuable nearshore habitat to ecologically and economically important species. In 2000, DNR recognized the important functions and values Z. marina provides to nearshore systems and established the Submerged Vegetation Monitoring Project (SVMP) to track this valuable resource. The SVMP uses a statistically robust sampling design and underwater videography to monitor Z. marina on an annual basis. This report presents the monitoring results from the 2008 field season.	Multiple indications suggest a pattern of slight Z. marina decline throughout Puget Sound, however, the magnitude of the observed changes were not sufficient to cause a significant year-to-year or long-term decrease in the total sound-wide Z. marina area estimate. The current Z. marina area estimate in Puget Sound is 22,800 ± 4,500 hectares. The Focus Area effort in the North Puget Sound Region completed the project's initial sampling of all 5 regions in the study area. There are 9,859 ± 2,603 ha of Z. marina in the North Puget Sound Region and nearly 91% of this resource is located in large, shallow embayments.	http://www.dnr.wa.gov/Publications/aqr_nrsh_2008_svmp_report_final.pdf	
C0469	All	n/a	Whidbey, South Central Puget Sound	King County Biodiversity Report	2008	King County	King County	n/a	The report describes the ecology of biodiversity in King County, describes threats to biodiversity, exames biodiversity management in county governance, and recommends public participation programs.	http://www.kingcounty.gov/environment/animalsAndPlants/biodiversity/king-county-biodiversity-report.aspx	
C0473	Marine - Habitats	n/a	All	Marine Protected Areas in Washington: Recommendations of the Marine Protected Areas Work Group to the Washington State Legislature	2009	F. Brie Van Cleve, Greg Bargmann, Michele Culver	Washington Department of Fish & Wildlife	The MPA Work Group was established by the Washington State Legislature in 2008 and tasked to inventory MPAs in Washington's state waters, assess current MPA management, and provide a series of recommendations to the Legislature on how to improve the use and effectiveness of MPAs in the future. The MPA Work Group was chaired by WDFW and populated with governmental representatives, including tribal representatives, and agencies that manage MPAs in Washington's state waters.	The group agreed that the current terminology used to describe various types of MPAs complicates and even frustrates efforts to improve coordination and consistency among MPAs and MPA managers. The group identified the need for a Puget Sound and coast-wide coordinating entity to oversee the implementation of the recommendations in this report, review new MPA proposals, convene MPA managers, and lead coordination efforts. The MPA Work Group developed 17 recommendations for improving the use of MPAs as a management tool		
C0475	Terrestrial - Water	n/a	All	An Assessment of Washington Lakes: National Lake Assessment Results	2010	Bell-McKinnon, M.	Washington Department of Ecology	In 2007, the Washington Department of Ecology collected biological, chemical, and physical data at 30 randomly selected lakes in Washington State. This study was part of EPA's National Lake Assessment which encompassed monitoring at 1,028 lakes in the lower 48 U.S. States. Measurements of environmental stress were evaluated using the reference site approach. This approach involves setting a reasonable expectation, or reference condition, for each measured parameter.	This study showed over 80% of the lake sample population in Washington is in fair or good condition with regard to physical habitat. The results also showed nutrients and chlorophyll-a were the parameters of highest concern.	http://www.ecy.wa.gov/biblio/1003029.html	
C0476	Nearshore - Habitats	n/a	North Central	Seasonal patterns of coarse sediment transport on a mixed sand and gravel beach due to vessel wakes, wind waves, and tidal currents:	2009	Curtiss, G.M., Osborne, P.D., and Horner-Devine, A.R.	Federal Transportation Adminstration	Used direct measurements of coarse sediment (gravel) transport from a mixed sand and gravel beach on Bainbridge Island, Puget Sound, WA that is exposed to wind waves, vessel wakes, and tidal currents in order to quantify the relative role of different forcing mechanisms and the corresponding time scales of morphological response. Also used Radio Frequency Identification (RFID) Passive Integrated Transponder (PIT) technology for tracking studies of sediment particles.	These results, which are unique in their duration, suggest that mixed sand and gravel beaches experience different modes of behavior over the range of forcing conditions observed during a typical year. They point to the need for including grain composition in modeling mixed sand and gravel beach response and the need for long term observations of both forcing and response.		Marine Geology, v. 259, p. 73–85
C0477	Nearshore - Habitats	n/a	All	Principles for Strategic Conservation and Restoration	2010	Courtney M. Grenier	Puget Sound Nearshore Partnership (U.S. Army Corps of Engineers & Washington Department of Fish and Wildlife)	The purpose of this document is to summarize principles of landscape ecology and conservation biology that are applicable to the conservation and restoration of nearshore ecosystems in the Puget Sound. The principles in this report were drawn from a scientific literature review of landscape ecology and conservation biology. The review focused on literature related to the selection of sites for the conservation and restoration of ecosystems.	Eleven principles were derived from the literature and have been organized into three hierarchical scales to provide context. They are listed by relative importance in landscape ecology and conservation biology but their application is flexible. The principles are tailored towards PSNERP's goals and objectives, and are therefore restoration focused; however they are also applicable to conservation actions. While a few of the principles can be applied explicitly, most are conceptual and require further evaluation to ensure appropriate application.	http://www.pugetsoundnearshore.org/technical_papers/conservation_and_restoration_principles.pdf	
C0478	Nearshore - Habitats	n/a	All	A geomorphic classification of Puget Sound nearshore landforms	2008	Shipman, H.	Puget Sound Nearshore Partnership (U.S. Army Corps of Engineers & Washington Department of Fish and Wildlife)	This report proposes a conceptual classification of nearshore landforms that is hierarchical, reflects the primary role of geomorphic processes in shaping the landscape and is relevant to the unique setting of Puget Sound. This framework is based on the concept that ecosystems are shaped by physical processes and are uniquely associated with particular coastal landforms. The report identifies the factors that influence the primary shoreline types observed on Puget Sound and discusses the close relationship between geomorphic processes and landforms.		http://www.pugetsoundnearshore.org/technical_reports.htm	
C0484	Humans - Social Conditions	n/a	All	Social and Economic Considerations for Coastal and Watershed Restoration in the Puget Sound, Washington: A Literature Review	2009	Stinchfield, H.M., Koontz, L., and Sexton, N.R.,	US Geological Survey	Summarize and synthesize information regarding the impacts of socioeconomic factors on coastal and watershed restoration in Puget Sound.	Socioeconomic factors play an important role in determining the designation, process, and success of restoration projects. Specific findings are reported for various topic areas.	http://pubs.usgs.gov/of/2009/1079/	
C0485	Terrestrial - Habitats	n/a	All	Description of Existing Data for Integrated Landscape Monitoring in the Puget Sound Basin, Washington	2008	Danielle P. Aiello, Alicia Torregrosa, Allyson L. Jason, Tracy L. Fuentes and Edward G. Josberger	US Geological Survey	The report summarizes existing geospatial data and monitoring programs for the Puget Sound as part of the USGS Puget Sound Integrated Landscape Monitoring pilot project.	The data and monitoring efforts cataloged here are intended to be used to discover what knowledge and data are available between ecosystems and at different spatial scales across the Puget Sound Basin. The data sources included can be used to answer questions on conditions, impacts, and changes to the marine and terrestrial systems of the Puget Sound Basin. The data can also be evaluated collectively to gain an understanding for the time and location of monitoring efforts within the Puget Sound Basin and PSILM study area.	http://pubs.usgs.gov/of/2008/1308/	

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C0488	Marine - Species & Food Webs	n/a	All	Incorporating catastrophic risk assessments into setting conservation goals for Pacific salmon	2008	T. P. Good, J. R. Davies, B. J. Burke, M. H. Ruckelshaus	NOAA, Northwest Fisheries Science Center	Explored the likelihood of Puget Sound chinook salmon ESU persistence by examining spatial patterns of catastrophic risk and testing ESU viability recommendations for 22 populations of the threatened Puget Sound chinook salmon ESU.	Recovery strategies that called for two viable populations in each of five geographic regions had lower risk than random strategies; strategies that included life-history diversity had even lower risks. Geographically distributed populations have varying catastrophic-risks profiles, thus identifying and reinforcing the spatial and life-history diversity critical for populations to respond to environmental change or needed to rescue severely depleted or extirpated populations. Recovery planning can promote viability of Pacific salmon ESUs across the landscape by incorporating catastrophic risk assessments	http://www.nwfsc.noaa.gov/publications/displayallinfo.cfm?docmetadataid=6609	Ecological Applications Volume 18, Issue 1, Pages 246-257
C0496	Marine - Species & Food Webs	n/a	San Juan/Whatcom	One Species or Two? Gentic Analysis of the Taxonomic Status of Pinto Abalone *Haliotis kamtschatkana* in Northern Puget Sound-Georgia Basin	2011	Naish, K.	SeaDoc Society (funding), University of Washington				
C0497	Marine - Species & Food Webs	n/a	All	Linking Marine Birds to Forage Fish - Is Diet a Limiting Factor in Puget Sound?	2011	Parish, J.	SeaDoc Society (funding), University of Washington				
C0498	Terrestrial - Species & Food Webs	n/a		The Role of Bald Eagles in Declines of Waterbirds in Puget Sound/Strait of Georgia	2011	Butler, R.	Pacific Wildlife Foundation				
C0499	All	n/a		What is Natural in the Puget Sound Ecosystem? Establishing Baseline Conditions and Identifying Ecological Indicators	2011	Essington, T.	SeaDoc Society (funding), University of Washington				
C0500	Marine - Species & Food Webs	n/a	San Juan/Whatcom	Investigation of Outplant Strategies in the Recovery of Pinto Abalone Populations in Washington State	2011	Friedman, C.	SeaDoc Society (funding), University of Washington				
C0501	Marine - Species & Food Webs	n/a	All	Development of Genetic Markers for Evaluating Fine-Scale Population Structure of Western Grebes (*Aechmophorus occidentalis*)	2011	Girman, D.	SeaDoc Society (funding), Sonoma State University				
C0505	Marine - Species & Food Webs	n/a	San Juan/Whatcom	The efficacy of aggregation as an in-situ restoration technique for the recovery of pinto abalone (*Haliotis kamtschatkana*) in the San Juan Archipelago	2011	Friedman, C.	SeaDoc Society (funding), University of Washington				
C0506	Marine - Species & Food Webs	n/a	San Juan/Whatcom	Evaluating adult aggregations of Northern abalone (*Haliotis kamtschatkana*) for restoration in the Puget Sound, Washington	2011	Bennett, W.	SeaDoc Society (funding), University of California, Davis				
C0507	Marine - Species & Food Webs	n/a	All	Assembling and Assessing Seabird Diet Information in the Salish Sea	2011	Pearson, S.	SeaDoc Society (funding), Washington Department of Fish and Wildlife				
C0513	Marine - Species & Food Webs	n/a	All	Pacific white-sided dolphin Photo ID study	2011	Ashe, E.	SeaDoc Society (funding), Tides Canada				
C0518	Nearshore - Species & Food Webs	n/a	All	Birds and Mammals that Dependo nt he Salish Sea: A Compilation	2011	Gaydos and Pearson		The study compiled information from varied sources and identified 172 bird and 37 mammal species that depend on the Salish Sea marine ecosystem.	Of these species, 72 bird and 29 mammal species are both highly dependent on intertidal or marine habitat as well as on marine derived food. One hundred bird species and 8 mammal species that use the Salish Sea marine ecosystem have varying degrees of dependence on the marine and terrestrial ecosystems to meet significant life history needs. These interactions between the marine and terrestrial ecosystems indicate the need to integrate marine and terrestrial restoration efforts to achieve long-term conservation of the suite of birds and mammals that use and depend on the marine ecosystem.		Northwestern Naturalist 92:79-94 (2011)
C0525	Marine - Species & Food Webs	n/a	All	Bridging the gap between the phenotype and the genotype: linking genetic variation, selection, and adaptation in fishes.	2008	Naish KA and Hard JJ	Washington Sea Grant	The study discusses two major genetic approaches to studying the evolution of complex traits, multivariate quantitative genetics and molecular genetics, and examines the increasing interaction between the two fields. These interactions include using pedigree-based methods to study the evolution of multivariate traits in natural populations, comparing neutral and quantitative measures of population structure, and examining the contribution that the two approaches have made to each other. The study then explores the major role that quantitative genetics is playing in two key issues in the conservation and management of fish populations: the evolutionary effects of fishing and adaptation to climate change. Throughout, it emphasizes that it is important to anticipate the availability of improvements in molecular technology and statistical analyses by creating research populations such as inbred lines and families segregating at fitness traits, developing approaches to measuring the full range of phenotypes related to fitness, and collecting biological material and ecological data in natural populations. These steps will facilitate studies of the evolution of complex traits over informative temporal and spatial scales.		http://onlinelibrary.wiley.com/doi/10.1111/j.1467-2979.2008.00302.x/abstract {abstract}	Fish and Fisheries, 9:396-422

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C0526	Terrestrial - Species & Food Webs	n/a	South Central Puget Sound	Summer distribution and growth of juvenile coho salmon during colonization of newly accessible habitat.	2008	Anderson JH, Kiffney PM, Pess GR and Quinn TP	Washington Sea Grant	Pacific salmon Oncorhynchus spp. are capable of exploiting vacant habitat, but most research has focused on straying and colonization by adults. However, dispersal of juveniles of stream-rearing species, such as coho salmon O. kisutch, may also be an important component of colonization. Installation of fish passage structures on the Cedar River, Washington, and subsequent adult migration into the newly accessible habitat provided a rare opportunity to investigate colonization as coho salmon regained access to 33 km of habitat from which they had been excluded for more than a century. This study describes the spatial distribution and growth patterns of the first two generations of juvenile coho salmon produced in the new habitat.	Snorkel surveys in the Cedar River revealed patchy distributions of juvenile coho salmon that largely matched the distribution of adults spawning the previous fall, and higher densities occurred in lower reaches (i.e., those not far upstream from the dam). However, sequential surveys indicated that juveniles entered and moved upstream within a Cedar River tributary, Rock Creek, where few, if any, adults spawned. Juveniles captured in the Cedar River were similar in size to those in Rock Creek, but sizes differed between years and larger fish tended to occur farther upriver. The study found no evidence for density-dependent growth; there was no relationship between fish size and local density in either main-stem or tributary habitat. Abundance estimates suggest that relatively few juvenile coho salmon dispersed long distances into reaches neglected by spawning adults. The study was unable to find any clear evidence that juvenile dispersal would increase the number of adults returning in the next generation, but such movements could accelerate the spatial expansion of the colonizing population in philopatric species like coho salmon.	http://water.washington.edu/research/Articles/Anderson.juvenile.coho2008.pdf	Transactions of the American Fisheries Society, 137:772-781
C0527	Marine - Species & Food Webs	n/a	All	Paradigm shifts in marine fisheries genetics: ugly hypotheses slain by beautiful facts.	2008	Hauser L and Carvalho GR	Washington Sea Grant	By providing new approaches to the investigation of demographic and evolutionary dynamics of wild populations, molecular genetics has led to fundamental changes in our understanding of marine ecology. In particular, genetic approaches have revolutionized our understanding in three areas: (i) most importantly, they have contributed to the discovery of extensive genetic population structure in many marine species, overturning the notion of large, essentially homogenous marine populations limiting local adaptation and speciation. (ii) Concomitant differences in ecologically important traits now indicate extensive adaptive differentiation and biocomplexity, potentially increasing the resilience to exploitation and disturbance. Evidence for rapid adaptive change in many populations underlies recent concerns about fisheries-induced evolution affecting life-history traits. (iii)	A compilation of recent published research shows estimated effective population sizes that are 2-6 orders of magnitude smaller than census sizes, suggesting more complex recruitment dynamics in marine species than previously assumed. Studies on Atlantic cod are used to illustrate these paradigm shifts. In the synthesis, the study emphasizes the implications of these discoveries for marine ecology and evolution as well as the management and conservation of exploited marine fish populations. An important implication of genetic structuring and the potential for adaptive divergence is that locally adapted populations are unlikely to be replaced through immigration, with potentially detrimental consequences for the resilience to environmental change - a key consideration for sustainable fisheries management.	http://www.fish.washington.edu/research/alaska/publications/ASP_Papers/Hauser%20%26%20Carvalho%2008%20Paradigm%20shifts.pdf	Fish and Fisheries, 9:333-362.
C0528	Marine - Species & Food Webs	n/a	All	Advances in molecular technology and their impact on fisheries genetics.	2008	Hauser L and Seeb JE	Washington Sea Grant	Although genetic approaches to questions in fisheries management have been very useful in the past, they have encountered consistent hurdles despite the development of new marker systems. However, recent technological advances in molecular genetics will help to overcome many of these hurdles and are likely to revolutionize fish and fisheries biology. DNA-sequencing costs have been decreasing exponentially, and recent breakthroughs have led to rapid increase in throughput that allows sequencing the entire expressed genome of a non-model organism with standard project budgets. Increase in screening throughput and number of available markers, reduction in costs and improved insights into gene function and control of gene expression will allow applications that were impossible until recently. The study briefly recounts the recent history of fisheries genetics, provide an outlook on near-term and long-term developments in genetic technology and consider their applications and implications for fisheries science and education.		http://onlinelibrary.wiley.com/doi/10.1111/j.1467-2979.2008.00306.x/abstract [abstract]	Fish and Fisheries, 9:473-486
C0530	Marine - Species & Food Webs	n/a	All	Spatial and temporal characteristics of plankton-rich layers in a shallow, temperate fjord.	2008	Menden-Deuer S	Washington Sea Grant	Between June and October 2005, a CTD profiler with mounted fluorometer identified the presence and extent of plankton-rich layers (PRLs), i.e. horizontal patches of high plankton concentrations bordered by steep gradients, in East Sound, a shallow fjord in Washington, USA. The suitability of this profiling approach for identifying the meter-scale plankton layers was verified through correlation analysis, which showed that in situ fluorescence was significantly correlated with all subsequent proxy measurements of phytoplankton abundance, including extracted chlorophyll a concentration and plankton biomass. Species abundance and community composition within and outside the layers were analyzed during peak layer occurrence in July 2005. Layers contained up to an order of magnitude more phytoplankton biomass than surrounding waters.	This analysis showed that (1) plankton layers were horizontally coherent, because the species composition of samples from within PRLs from up to 5 stations collected on any given day were statistically indistinguishable; (2) layers were not continuous in time, since species composition changed significantly between sampling days; and (3) layers could have formed within East Sound, since no differences were observed in species composition among samples collected at any depth. Phytoplankton biomass was dominated by the diatom genus Chaetoceros (up to 95%), whereas heterotrophic protists (5 to 200 μm) were dominated by thecate dinoflagellates (up to 80% of biomass), with oligotrich ciliates and athecate dinoflagellates at times abundant (up to 40% of biomass). Motile heterotrophic protists were significantly aggregated within phytoplankton prey layers, which confirmed predictions from prior laboratory and modeling work. Biomass of phytoplankton prey species within PRLs uniformly exceeded the dominant predator's survival threshold, whereas prey concentrations outside PRLs would not support growth in all but 3 samples. These observations suggest that PRLs may be		Marine Ecology Progress Series, 355:21-30
C0531	Nearshore - Species & Food Webs	n/a		The effects of intertidal air exposure on the respiratory physiology and the killing activity of hemocytes in the pacific oyster, Crassostrea gigas (Thunberg).	2008	Allen SM and Burnett L	Washington Sea Grant	The focus of this study is to determine the respiratory (pH, Po2, Pco2 and total CO2) and immune responses of oysters exposed to air at normal seasonal temperatures, and to determine whether these stresses associated with emersion inhibit the immune system of the oyster and contribute to summer mortalities.	There was no significant difference in the killing index between pH treatment groups. Temperature was the only factor to significantly affect the killing indices among temperature and oxygen treatment groups. The killing index was lowest (29.3% ± 3.25 S.E.M.) at 30 °C and 7% oxygen, simulating in vivo oxygen pressure in well-aerated conditions and 30 °C and 3% oxygen, simulating in vivo oxygen pressure in hypoxia (30.5% ± 3.25 S.E.M.), compared with the index in 7% oxygen at low temperature (18 °C) (44.4% ± 4.50 S.E.M.) or compared with low oxygen (3%) at low temperature (18 °C) (39.7% ± 2.51 S.E.M.). The seasonal and diurnal rise in temperature may, therefore, be an important factor contributing to summer mortalities of C. gigas.	http://www.sciencedirect.com/science/article/pii/S0022098108000348	Journal of Experimental Marine Biology and Ecology, 357:165–171
C0532	Marine - Species & Food Webs	n/a	All	A genetic linkage map for coho salmon (Oncorhynchus kisutch).	2008	McClelland EK and Naish KA	Washington Sea Grant	Construction of genetic linkage maps is an important first step for a variety of genomic applications, such as selective breeding in aquaculture, comparative studies of chromosomal evolution and identification of loci that have played key roles in the evolution of a species. The study presents a sex-specific linkage map for coho salmon. The map was constructed using 148 AFLP markers, 133 microsatellite loci and the phenotypic locus SEX. Twenty-four linkage groups spanning 287.4 cM were mapped in males, and 33 linkage groups spanning 429.7 cM were mapped in females.	Several male linkage groups corresponded to two female linkage groups. The combination of linkage groups across both sexes appeared to characterize regions of 26 chromosomes. Two homeologous chromosomes were identified based on information from duplicated loci. Homologies between the coho and rainbow trout maps were examined. Eighty-six loci were found to form common linkage relationships between the two maps; these relationships provided evidence for whole-arm fissions, fusions and conservation of chromosomal regions in the evolution of these two species.	http://www.ncbi.nlm.nih.gov/pubmed/18318791	Animal Genetics, 39:169-179

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C0533	Marine - Species & Food Webs	n/a	All	Genetic isolation by distance and localized fjord population structure in Pacific cod (Gadus macrocephalus): limited effective dispersal in the northeastern Pacific Ocean.	2009	Cunningham KM, Canino MF, Spies IB, Hauser L	Washington Sea Grant	Genetic population structure of Pacific cod was examined across much of its northeastern Pacific range by screening variation at 11 microsatellite DNA loci.	Samples suggested that effective dispersal is limited among populations. Genetic divergence was highly correlated with geographic distance in an isolation-by-distance (IBD) pattern along the entire coastal continuum in the northeastern Pacific Ocean, extending from Washington State to the Aleutian Islands, and over smaller geographic distances for three locations in Alaska. Slopes of IBD regressions suggested average dispersal distance between birth and reproduction of less than 30 km. Exceptions to this pattern were found in samples taken from fjord environments in the Georgia Basin, where populations were differentiated from coastal cod. Our results showed population structure at spatial scales relevant to fisheries management, both caused by limited dispersal along the coast and by sharp barriers to migration isolating smaller stocks in coastal fjord environments.	http://www.pmel.noaa.gov/foci/publications/2009/cunn0670.pdf	Can J Fish Aquat Sci, 66:153-166
C0534	Nearshore - Species & Food Webs	n/a	All	Development and optimization of quantitative PCR assaysto aid Ostrea lurida carpenter 1864 restoraion efforts.	2009	Wight NA, Suzuki J, Vadopalas B, Friedman CS	Washington Sea Grant	The Olympia oyster (Ostrea lurida)† is a prime candidate for the development of a rapid, high throughput, species-specific larval identification and quantification assay. We developed O. lurida specific DNA primers and a fluorescently labeled probe that amplify a mitochondrial DNA region cytochrome oxidase 1 subunit (COI) to use in quantitative polymerase chain reaction (qPCR).			Journal of Shellfish Research, 28(1):33-41
C0535	Nearshore - Species & Food Webs	n/a	All	Temperature Effects on the Depuration of Vibrio parahaemolyticus and Vibrio vulnificus from the American Oyster (Crassostrea virginica).	2009	Chae MJ, Cheney D, and Su Y-C	Washington Sea Grant	This study investigated temperature effects on depuration for reducing Vibrio parahaemolyticus and Vibrio vulnificus in American oyster (Crassostrea virginica). Raw oysters were inoculated with 5-strain cocktail of V. parahaemolyticus or V. vulnificus to levels of 10(4) to 10(5) MPN (most probable number)/g and depurated in artificial seawater (ASW) at 22, 15, 10, and 5 degrees C.	Depuration of oysters at 22 degrees C had limited effects on reducing V. parahaemolyticus or V. vulnificus in the oysters. Populations of V. parahaemolyticus and V. vulnificus were reduced by 1.2 and 2.0 log MPN/g, respectively, after 48 h of depuration at 22 degrees C. Decreasing water temperature to 15 degrees C increased the efficacy of depuration in reducing V. parahaemolyticus and V. vulnificus in oysters. Reductions of V. parahaemolyticus and V. vulnificus in oysters increased to 2.1 and 2.9 log MPN/g, respectively, after 48 h of depuration at 15 degrees C. However, depurations at 10 and 5 degrees C were less effective than at 15 degrees C in reducing the Vibrio spp. in oysters. Extended depuration at 15 degrees C for 96 h increased reductions of V. parahaemolyticus and V. vulnificus in oysters to 2.6 and 3.3 log MPN/g, respectively		J Food Sci, 74(2):M62-M66
C0537	Marine - Species & Food Webs	n/a	All	The strain concept in phytoplankton ecology.	2009	Lakeman M, Von Dassow, P, Cattolico RA	Washington Sea Grant		The study presents a review of the processes of evolution as they pertain to microalgal culture, and illustrates this discussion with examples of in-culture evolution from both within and outside the field of phycology. Recommendations are made for experimental practice focusing on comparative physiology, for which the effects of in-culture evolution are particularly confounding. Finally the study argues that, although problematic in some contexts, the evolutionary propensities of phytoplankton cultures actually present an important opportunity for experimental evolutionary research with direct environmental significance.	http://www.jlakes.org/web/Strain-concept-phytoplankton-ecology-HA2009.pdf	Harmful Algae, 8:746-758
C0542	Terrestrial - Species & Food Webs	n/a	South Central Puget Sound	Changes in fish communities following recolonization of the Cedar River, WA, USA by Pacific salmon after 103 years of local extirpation.	2009	Kiffney PM, Pess GR, Anderson JH, Faulds P, Burton K and Riley SC	Washington Sea Grant	Installation of a fish passage facility at the Landsburg Dam, WA, USA provided migratory fish access to habitat from which they had been excluded for over 100 years. Relying on voluntary recruitment, the study examined the effectiveness of this facility in restoring coho (Oncorhynchus kisutch) salmon populations above the diversion, and whether reintroduction of native anadromous species affected the distribution and abundance of resident trout (O. mykiss and O. clarki).	Before the ladder, late summer total salmonid (trout only) density increased with distance from the dam. This pattern was reversed after the ladder was opened, as total salmonid density (salmon + trout) approximately doubled in the three reaches closest to the dam. These changes were primarily due to the addition of coho, but small trout density also increased in lower reaches and decreased in upper reaches. A nearby source population, dispersal by adults and juveniles, low density of resident trout and high quality habitat above the barrier likely promoted rapid colonization of targeted species. The results suggest that barrier removal creates an opportunity for migratory species to re-establish populations leading to range expansion and potentially to increased population size.	http://water.washington.edu/research/Articles/Kiffney.etal.2009.pdf	River Research and Applications, 25(4):438-452
C0543	Nearshore - Species & Food Webs	n/a	All	The proper name for the geoduck: resurrection of Panopea generosa Gould, 1850, from the synonymy of Panopea abrupta (Conrad, 1849) (Bivalvia: Myoida: Hiatellidae).	2010	Vadopalas B, Pietsch TW and Friedman CS	Washington Sea Grant	Literature review and review of specimens at the Burke Museum of Natural History and Culture and more than 4,000 specimens collected from Puget Sound, Washington.	The study establishes that the Pacific geoduck should properly be named *Panopea generosa* as named by Gould in 1850. The synonymy of *Panopea abrupta* is an error perpetuated since 1984.	http://www11.cac.washington.edu/burkemuseum/collections/ichthyology/documents/pietsch/Geoduck.pdf	Malacologia 52(1):169-173
C0544	Nearshore - Species & Food Webs	n/a	All	Restricted ranges in physical factors may constitute subtle stressors for estuarine biota.	2010	Dethier MN, J Ruesink, H Berry, AG Sprenger, B Reeves	Washington Sea Grant	Biotic trends along estuarine gradients can be affected by co-varying processes ranging from large-scale oceanographic to local-scale physico-chemical effects. As a baseline for future process studies, the study investigated the distinct gradients in species richness and biomass in pebble-sand shorelines along the estuarine axis of Puget Sound, and the scales of variation of some of their physical correlates.	Higher richness and biomass at beaches at the more marine end of the Sound are temporally consistent and seen in all trophic groups. Variables that correlate with biotic patterns include relatively subtle increases in beach surface and sediment temperatures and decreases in nearshore salinity near the head of the estuary, but not more localized parameters such as sediment grain size or porewater salinity.	http://www.ncbi.nlm.nih.gov/pubmed/19913906	Marine Environmental Research, 69:240-247
C0545	Marine - Species & Food Webs	n/a	All	Ontogenetic Diet Shifts of Juvenile Chinook Salmon in Nearshore and Offshore Habitats of Puget Sound.	2010	Duffy EJ, Beauchamp DA, Sweeting RM, Beamish RJ, and Brennan JS	Washington Sea Grant	The study examined the recent (2001–2007) dietary habits of Puget Sound, Washington, Chinook salmon (listed as threatened under the U.S. Endangered Species Act) during their first marine growing season (April–September). Juvenile Chinook salmon initially fed in nearshore marine habitats and then shifted to feed primarily offshore during July–September.	Diet composition varied significantly among sampling regions (northern, central, and southern), habitats (nearshore, offshore), years, months, and fish size-classes. Annual variation in the composition of offshore prey appeared to be determined early in the growing season, suggesting that environmental factors (e.g., climate) affecting marine productivity might produce strong interannual trends in marine survival of Puget Sound Chinook salmon. In addition, the importance of insects as high-quality prey highlighted the terrestrial link to the marine feeding of Chinook salmon and suggests that shoreline development and land use changes will affect feeding opportunities for these fish in Puget Sound.	http://nisquallydeltarestoration.org/pdf/Duffy%20et%20al.%202010.%20ontogenetic%20diet%20shifts%20J%20Chinook%20PS.pdf	Transactions of the American Fisheries Society, 139:803–823
C0546	Marine - Species & Food Webs	n/a	All	Validation and efficacy of transgenerational mass marking of otoliths in viviparous fish larvae.	2010	Kuroki M, Buckley RM, LeClair LL and Hauser L	Washington Sea Grant		Transgenerational mass marking of viviparous fish larvae in vivo was validated by intra-muscular injection of elemental strontium chloride ($SrCl_2$) in gestating females and detection of the Sr in the otoliths of developing larvae. All otoliths of brown rockfish Sebastes auriculatus larvae produced from $SrCl_2$-injected females showed enriched Sr:Ca ratios near the otolith edges, and the signatures did not appear to be affected by the anterior, centre and posterior positions of larvae within the ovary. Results from the present study indicate that transgenerational marking is a highly reliable technique for marking large numbers of extremely small viviparous fish larvae.	http://onlinelibrary.wiley.com/doi/10.1111/j.1095-8649.2010.02681.x/abstract	Journal of Fish Biology, 77:292–298

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C0547	Marine - Species & Food Webs	n/a	All	Selection on breeding date and body size in colonizing coho salmon.	2010	Anderson JH, Faulds PL, Atlas WI, Pess GR, Quinn TP	Washington Sea Grant	The study measured the form, direction, and strength of selection on body size and date of arrival to the breeding grounds over the first three cohorts (2003–2005) of a coho salmon (Oncorhynchus kisutch) population colonizing 33 km of habitat made accessible by modification of Landsburg Diversion Dam, on the Cedar River, Washington, USA. Salmon were sampled as they bypassed the dam, parentage was assigned based on genotypes from 10 microsatellite loci, and standardized selection gradients were calculated using the number of returning adult offspring as the fitness metric.	Larger fish in both sexes produced more adult offspring, and the magnitude of the effect increased in subsequent years for males, suggesting that low densities attenuated traditional size-biased intrasexual competition. For both sexes, directional selection favoured early breeders in 2003, but stabilizing selection on breeding date was observed in 2004 and 2005. Adults that arrived, and presumably bred, early produced stream-rearing juvenile offspring that were larger at a common date than offspring from later parents, providing a possible mechanism linking breeding date to offspring viability. Comparison to studies employing similar methodology indicated selection during colonization was strong, particularly with respect to reproductive timing. Finally, female mean reproductive success exceeded that needed for replacement in all years so the population expanded in the first generation, demonstrating that salmon can proficiently exploit vacant habitat.	http://www.cityofseattle.org/util/groups/public/@spu/@ssw/documents/webcontent/01_009971.pdf	Molecular Ecology 19:2562-2573
C0548	Marine - Species & Food Webs	n/a	All	Multiple ice-age refugia in Pacific cod, Gadus macrocephalus.	2010	Canino MF, Spies IB, Cunningham KM, Hauser L, Grant WA	Washington Sea Grant	This study surveyed genetic variation at 11 microsatellite loci and mitochondrial (mt) DNA in samples from twelve locations from the Sea of Japan to Washington State.	Both microsatellite (mean H = 0.868) and mtDNA haplotype (mean h = 0.958) diversities were large and did not show any geographical trends. Both marker classes showed a strong genetic discontinuity between northwestern and northeastern Pacific populations that likely represents groups previously isolated during glaciations that are now in secondary contact. The presence of two major coastal mtDNA lineages on either side of the Pacific Ocean basin implies at least two ice-age refugia and separate postglacial population expansions facilitated by different glacial histories. Northward expansions into the Gulf of Alaska were possible 14-15 kyr ago, but deglaciation and colonization of the Georgia Basin probably occurred somewhat later. Population expansions were evident in mtDNA mismatch distributions and in Bayesian skyline plots of the three major lineages, but the start of expansions appeared to pre-date the last glacial maximum.	http://www.pmel.noaa.gov/foci/publications/2010/cani0750.pdf	Mol. Ecol, 19:4339-4351
C0549	Marine - Species & Food Webs	n/a	All	Variation in recruitment does not drive the cline in diversity along an estuarine gradient.	2010	Dethier, MN	Washington Sea Grant	The study investigated whether spatial patterns of infaunal recruitment along an estuarine gradient could account for the observed cline in adult diversity. On 9 occasions spread over 13 mo, cores of sterile sediment from 2 different sources were embedded in beaches along the estuarine axis of Puget Sound, Washington, and sampled 6 wk later for new recruits.	Identities and abundances of recruits (mostly polychaetes and bivalves) varied among seasons, but differed little between sediments from different sources. Contrary to expectations, neither recruit richness nor abundance was lower at the southern (more estuarine) end of the gradient, where adult taxonomic diversity is low. For a number of taxa and time periods, recruitment was actually stronger at the southern beaches. Multivariate differences between assemblages of recruits and adults were much greater at the southern sites, indicating that post-recruitment processes at these sites modify diversity and abundance patterns initially established by recruitment. These processes could include predation on juveniles, adult–juvenile competition, or physiologically stressful abiotic conditions.	http://www.int-res.com/abstracts/meps/v410/p43-54/	Marine Ecology Progress Series, 410:43-54
C0550	Marine - Species & Food Webs	n/a	All	Temperature and diet modified swimming behaviors of larval sand dollar.	2010	Chan KKY, Grunbaum D	Washington Sea Grant	The study used non-invasive video-tracking techniques to quantify swimming in larvae of the sand dollar Dendraster excentricus, raised on 4 algal diets differing in their fatty acid profiles and then exposed to an ecologically relevant temperature decrease from 20 to 12°C.	Differences in diet quality led to significant morphological differences by the 8-arm larval stage, and there were significant diet-temperature interaction effects on swimming patterns. While larval swimming speeds decreased as temperature decreased across all diet treatments, net vertical velocities of larvae did not decrease. Changes in helical geometries of larval swimming trajectories suggest that larvae compensate for reduced swimming speeds by reducing horizontal movement, thus preserving their ability to regulate depth. The observed compensatory mechanism effectively circumvents constraints on swimming due to lowered temperatures. More generally, video-tracking of free-swimming larvae can yield quantitative data to inform biophysically coupled models that better predict consequences of larval dispersal for adult population dynamics under current and future environmental conditions.	http://www.int-res.com/abstracts/meps/v415/p49-59/	Marine Ecology Progress Series, 415:49-59
C0551	Marine - Species & Food Webs	n/a	All	Visualizing "green oil" in live algal cells.	2010	Cooper M, Hardin W, Petersen T, and Cattolico RA	Washington Sea Grant		The study reports that BODIPY 505/515, a green lipophilic fluorescent dye, serves as an excellent vital stain for the oil-containing lipid bodies of live algal cells. BODIPY 505/515 vital staining can be used in combination with fluorescent activated cell sorting to detect and isolate algal cells possessing high lipid content.	http://algalbiofuels.pbworks.com/f/Cooper_2010.pdf	J. of Bioscience and Bioengineering, 109:2 198-201.
C0553	Marine - Species & Food Webs	n/a	All	Quantitative trait locus analysis of hatch timing, weight, length and growth rate in coho salmon, Oncorhynchus kisutch.	2010	McClelland EK and Naish KA	Washington Sea Grant	In this study, a quantitative trait locus (QTL) analysis using an outbred cross was initiated to determine the molecular basis of phenotypic correlations between such growth traits in coho salmon (Oncorhynchus kisutch), an important fish species distributed throughout the North Pacific Ocean.	Fifty-three QTL for growth rate, length and weight at eight time periods were located on seven linkage groups (OKI03, OKI06, OKI18, OKI19, OKI23, OKI24 and an unnamed linkage group) or associated with five unlinked markers (Omm1159, Omm1367/i, Omy325UoG, OmyRGT55TUF and OtsG422UCD). One QTL for hatch timing was associated with the marker, Omm1241. All QTL were of minor effect, explaining no more than 20% of the observed variation in phenotypic value. Several instances of colocalization of QTL weight, length and growth rate were observed, suggesting a genetic basis for phenotypic correlations observed between these traits. This study lays the foundation for future QTL mapping efforts, for detailed examinations of the genetic basis of phenotypic correlations between growth traits, and for exploring the adaptive significance of growth traits in natural populations.	http://www.nature.com/hdy/journal/v105/n6/full/hdy201022a.html	Heredity, 105:562-573
C0554	Marine - Species & Food Webs	n/a	All	The trophic fingerprint of marine fisheries.	2010	Branch TA, Watson R, Fulton EA, Jennings S, McGilliard CR, Pablico GT, Ricard D, and Tracey SR	Washington Sea Grant		The study combines model predictions with global assessments of mean trophic level (MTL) from catches, trawl surveys and fisheries stock assessments and find that catch MTL does not reliably predict changes in marine ecosystems. Instead, catch MTL trends often diverge from ecosystem MTL trends obtained from surveys and assessments. In contrast to previous findings of rapid declines in catch MTL, we observe recent increases in catch, survey and assessment MTL. However, catches from most trophic levels are rising, which can intensify fishery collapses even when MTL trends are stable or increasing. To detect fishing impacts on marine biodiversity, the study recommends greater efforts to measure true abundance trends for marine species, especially those most vulnerable to fishing.	http://www.nature.com/nature/journal/v468/n7322/full/nature09528.html	Nature. 468:431-435.

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C0555	Marine - Species & Food Webs	n/a	All	Reconstructing Juvenile Chinook Salmon Life History in the Salmon River Estuary, Oregon, Using Otolith Microchemistry and Microstructure.	2010	Volk EC, Bottom DL, Jones KK and Simenstad CA	Washington Sea Grant	The study quantified the juvenile rearing and migratory patterns of individuals from a population of fall-spawning Chinook salmon Oncorhynchus tshawytscha in Oregon's Salmon River estuary using otolith microchemistry and microstructure.	The study confirmed the daily periodicity of otolith growth increments in a natural fish population under field conditions and validated fundamental assumptions about increased otolith strontium : calcium values during entry into saline waters. The otolith results indicated that more than 75% of the subyearling Chinook salmon captured near the mouth of the Salmon River had entered the estuary during the summer and that two-thirds of these fish had spent more than a month in the estuary before capture. Rather than revealing a series of discrete "types" defined by the predominant rearing patterns in the population, the individual otolith results depict a continuum of freshwater and estuarine life histories that is consistent with reports of considerable phenotypic plasticity in Chinook salmon. Otolith analysis offers the potential to quantify the relative contributions of different juvenile rearing patterns to adult returns.	http://oregonstate.edu/dept/ODFW/freshwater/inventory/pdffiles/Volk%20et%20al.pdf	Transactions of the American Fisheries Society, 139(2):535-549
C0557	Marine - Species & Food Webs	n/a	All	Rapid growth in the early marine period improves the marine survival of Chinook salmon (Oncorhynchus tshawytscha) in Puget Sound, Washington.	2011	Duffy EJ and Beauchamp DA	Washington Sea Grant	The study examined the effect of early marine entry timing and body size on the marine (smolt-to-adult) survival of Puget Sound Chinook salmon (Oncorhynchus tshawytscha). It used data from coded wire tag release groups of hatchery Chinook salmon to test whether hatchery release date, release size, and size in offshore waters in July and September influenced marine survival.	Marine survival was most strongly related to the average body size in July, with larger sizes associated with higher survivals. This relationship was consistent over multiple years (1997–2002), suggesting that mortality after July is strongly size-dependent. Release size and date only slightly improved this relationship, whereas size in September showed little relationship to marine survival. The findings highlight the importance of local conditions in Puget Sound during the spring and summer, and suggest that declines in marine survival since the 1980s may have been caused by reductions in the quality of feeding and growing conditions during early marine life.	http://www.nrcresearchpress.com/doi/abs/10.1139/F10-144	Canadian Journal of Fisheries and Aquatic Sciences, 68(2):232-240
C0558	Marine - Habitats	n/a	All	Can information from marine protected areas be used to inform control-rule-based management of small-scale, data-poor stocks?.	2011	McGilliard CR, Hilborn R, MacCall A, Punt AE and Field J	Washington Sea Grant	The potential use of the ratio of the density of fish outside a marine protected area to that inside it each year (the density ratio, DR) in a control rule is evaluated to determine the direction and magnitude of change in fishing effort in the next year. Management strategy evaluation was used to evaluate the performance of this DR control rule (DRCR) for a range of movement rates of larvae and adults and other biological scenarios, and the parameters of the control rule that maximized cumulative catch (over 95 years) for each scenario were found.	The cumulative catch under the optimal DRCR was 90% of the cumulative catch from an optimal constant effort rule (CER). A small range of parameter values for the DRCR produced 75% or more of the cumulative catch produced from optimal CERs for a variety of assumptions about biology and initial stock status. The optimal DRCR was most sensitive to the movement patterns of larvae and adults and survey variability.	http://icesjms.oxfordjournals.org/content/early/2010/10/20/icesjms.fsq151.abstract	ICES Journal of Marine Science, 68(1):201–211
C0560	Marine - Habitats	n/a	All	Spatial structure induced by no-take marine reserves shapes population responses to catastrophes in simple mathematical models.	2011	McGilliard C, Punt AE and Hilborn R	Washington Sea Grant	The study investigate the effects of local and global catastrophic events on populations managed with and without no-take marine reserves and with fishing mortality rates that are optimized accounting for reserves. A spatial population dynamics model is used to explore effects of large, catastrophic natural mortality events. The effects of the spatial spread, magnitude, probability of catastrophe, and persistence of a catastrophic event through time are explored.	Catastrophic events affecting large spatial areas and those that persist through time have the greatest effects on population dynamics because they affect natural mortality nonlinearly, whereas the probability and magnitude of catastrophic events result in only linear increases in natural mortality. The probability of falling below 10% or 20% of unfished abundance was greatest when a no-take marine reserve was implemented with no additional fishing regulations and least when a no-take marine reserve was implemented in addition to the maintenance of optimal fishing mortality in fished areas. In the absence of implementation error, maintaining abundance across space using restrictions on fishing mortality rates, regardless of the existence of a no-take marine reserve, decreased the probability of falling below 10% or 20% of unfished abundance.	http://www.esajournals.org/doi/abs/10.1890/10-0001.1	Ecological Applications, 21(4):1399–1409
C0564	Marine - Species & Food Webs	n/a	All	Ocean distribution and habitat of North American steelhead trout. Summary of the Eleventh Pacific Coast Steelhead Management Meeting, Boise, March 4-6 2008. Pacific States Marine Fisheries Commission and US Fish and Wildlife Service, p 32	2008	Davis ND, Myers KW, Walker RV, Atcheson M, Fukuwaka M	Washington Sea Grant				
C0570	Marine - Species & Food Webs	n/a	All	Linking genetic variation, selection and adaptation in Chinook salmon: next generation genome sequencing		Naish, Kerry	Washington Sea Grant	One of the key challenges remaining in the conservation and management of fish populations is the ability to anticipate their adaptive response to human activities. Understanding this response will allow researchers to track the impact of these activities, explore alternative management strategies and assess the success of any remedial actions taken. This project will develop powerful tools, based on recent innovations in DNA sequencing, that can be used to evaluate variation across the Chinook salmon genome, measure changes in population fitness and improve forecasting efforts in species management.			
C0571	Marine - Species & Food Webs	n/a	All	Optical detection and characterization of the fish-killing alga Heterosigma akashiwo		Grunbaum, Daniel	Washington Sea Grant	Heterosigma akashiwo forms massive slicks that can be lethal to fish, particularly penned salmon, and other marine organisms. Models that predict Heterosigma blooms can give fish farms time to protect stocks, but current monitoring methods cannot supply needed data in a timely, cost-effective way. Optical instruments are available to quantify Heterosigma cell distributions and swimming behaviors to inform spatially-explicit models that predict timing and location of toxic slick formation. This proposal will integrate these elements into a prototype of a functional, low-cost remote sensing platform for detection of Heterosigma cells.			
C0576	Humans - Social Conditions	n/a	All	Governing Complex Environmental Commons: Stakeholder Partnerships in Salmon Recovery in Washington, Oregon and California		Dolsak, Nives	Washington Sea Grant	Using decision-making processes for salmon recovery, this project will assess governmental conservation efforts that seek stakeholder collaboration and maximum local involvement. It will examine challenges for such efforts that might leave participants less trusting, less cooperative and less convinced of the need to sacrifice in order to save endangered species. The goal is to improve understanding of governance across complex coastal and marine issues and collaborative governance across different resource management and stakeholder groups.			
C0580	Marine - Species & Food Webs	n/a	All	Local Adaptation in Puget Sound Pacific Cod		Hauser, Lorenz	Washington Sea Grant	The abundance of Pacific cod in Puget Sound has been declining for several decades, but the causes of this decline, especially in relation to the relatively abundant northern stocks, are uncertain. Recently the Puget Sound cod population was listed as a species of concern by the National Marine Fisheries Service, in part based on genetic evidence from a previous Sea Grant project demonstrating its long-term isolation from ocean populations. This project will investigate the level of local adaption of Pacific cod stocks in Puget Sound by examining its genetic makeup in combination with captive selection experiments.			

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C0582	Marine - Species & Food Webs	n/a	All	Using Microbiota for the Evaluation and Monitoring of Puget Sound Ecosystems		Nesbitt, Elizabeth	Washington Sea Grant	The Puget Sound ecosystem is a complex stew of natural and human-produced ingredients. This study will assess the effects of the transfer of these ingredients into the system by monitoring foraminifera — tiny mineralizing organisms that are a vital link in the food web. Analyses of foraminiferal populations, including species composition, density, diversity and species richness, correlated with sediment parameters, will yield a picture of the effects of inputs such as tides, currents, rivers, stormwater and sewage effluent. The project will develop a new, cost-effective tool for monitoring Puget Sound ecosystems and their response to environmental stresses.			
C0354	Marine - Water	Non-Point Source Loading & Runoff	All	Control of Toxic Chemicals in Puget Sound, Phase 2: Pollutant Loading Estimates for Surface Runoff and Roadways	Nov-08	Enviro Vision, Herrera, Ecology	Washington Department of Ecology	Literature Review, GIS analyses, Computation of loading estimates for 17 toxic chemicals of concern	For the entire Puget Sound Basin, total loading estimates were generally greatest for residential land use, which was the largest source for 14 of the 17 toxic chemicals of concern. Forest/field/other areas were the largest source for three toxic chemicals of concern (arsenic, mercury, and DDT and metabolites). For 10 of the toxic chemicals considered, highways had the lowest total loading estimates of all the land use categories. The total contribution of toxic chemical loadings from highways was between less than 1 percent to 14 percent of the total loading from surface runoff to Puget Sound, depending on the specific chemical.	http://www.ecy.wa.gov/biblio/0810084.html	
C0355	Terrestrial - Water	Non-Point Source Loading & Runoff	King County	Vashon-Maury Island 2009 Water Resources Data Report	2010	King County	King County	This study is evaluating the role of nitrogen in the risk of low oxygen events in Quartermaster Harbor, to recommend policy changes in the 2012 King County Comprehensive Plan update for nitrogen management on Vashon-Maury Island, and to assess management options for implementing the recommended policy changes. This report summarizes the monitoring activities completed during the water year 2009 for the Water Resource Evaluation (WRE) Project.	The difference in total precipitation between water year 2008 and 2009 varied across the island from a 4.8 inch to 3.8 inch decrease. Stream gauging activities recorded decreases in stream flow at four out of the five sites when comparing water year 2009 to water year 2008. Bacteria data show two large spikes not seen in previous water years. Overall, the water quality of the groundwater on VMI is very good as compared to drinking water standards.	http://www.kingcounty.gov/environment/waterandland/groundwater/management-areas/vashon-maury-island-gwma/vashon-island/WRE-data-report.aspx	
C0360	Terrestrial - Water	Non-Point Source Loading & Runoff	San Juan/Whatcom	Lake Whatcom Watershed Total Phosphorus and Bacteria Total Maximum Daily Loads: Water Quality Study Findings	2008	Pickett, P. and S. Hood	Washington Department of Ecology	Ecology conducted this technical study to set Total Maximum Daily Loads (cleanup plans) for these pollutants. Based on 2002 and 2003 data, a CE-QUAL-W2 lake model and an HSPF watershed model were developed. Land uses in the watershed model were adjusted to evaluate Lake Whatcom's response to phosphorus. Loading capacities for total phosphorus and for developed acres were calculated to protect dissolved oxygen in the lake.	Bacteria levels in 11 tributaries did not meet standards. Bacteria concentration and reduction targets were calculated.	http://www.ecy.wa.gov/biblio/0803024.html	
C0365	Terrestrial - Water	Non-Point Source Loading & Runoff	All	Quality Assurance Project Plan for Phase 3: Characterization of Toxic Chemicals in Puget Sound and Selected Major Tributaries	2009	Randy Coots and David Osterberg	Washington Department of Ecology	Existing data were used to estimate chemical loadings during Phase 1 of the PSTLA. Phase 2 efforts included development of the Puget Sound Toxics Box Model to simulate chemical fate, transport, and bioaccumulation. For the present study, the Washington State Department of Ecology (Ecology) will collect seasonal water samples (June, September, and December of 2009) at three oceanic boundary sites, in four Puget Sound basins, and at the mouths of the five largest rivers discharging to the Sound.	The Puget Sound Partnership identified the control and reduction of toxic chemicals entering Puget Sound as vital to the ecosystem's recovery and maintenance. In a multi-phase effort to develop source-control strategies for toxic contaminants, the Puget Sound Toxics Loading Analysis (PSTLA) will quantify concentrations within, and loadings to, Puget Sound, ultimately guiding management decisions.	http://www.ecy.wa.gov/pubs/0903118.pdf	
C0372	Terrestrial - Water	Non-Point Source Loading & Runoff	All	Control of Toxic Chemicals in Puget Sound: Characterization of Toxic Chemicals in Puget Sound and Major Tributaries, 2009-10	2011	Gries, T. and D. Osterberg	Washington Department of Ecology	Ecology conducted this 2009-2010 study to address data gaps identified by the Puget Sound Toxics Box Model. Samples were collected from the marine water column and 5 major rivers discharging to Puget Sound and analyzed for various toxic chemicals. Many were present in low concentrations but others were seldom if ever detected.	Marine water concentrations were used to evaluate exchange of toxic chemicals between Puget Sound and the ocean. Most chemicals, except for cadmium, appeared to be exported from Puget Sound. River water concentrations and flows were used to calculate daily loads of toxic chemicals. Additional monitoring for fewer target chemicals, especially in suspended particulate matter, was recommended	http://www.ecy.wa.gov/biblio/1103008.html	
C0377	Marine - Water	Non-Point Source Loading & Runoff	All	A Toxics-Focused Biological Observing System for Puget Sound	2010	Lyndal Johnson, Sandie O'Neill, Mark S. Myers, Gina Ylitalo, Nathaniel Scholz, Tracy Collier, NOAA Fisheries Northwest Fisheries Science Center; Claudio Bravo, University of California at Davis; James West, WA Department of Fish and Wildlife	Washington Department of Fish & Wildlife	The report explores the background of and need for toxics-focused biological monitoring and recommends approaches.	The report recommends a biologically-based ecosystem-wide monitoring program for toxics called a toxics-focused biological observing system (TBiOS).	http://wdfw.wa.gov/publications/pub.php?id=01129	
C0387	Marine - Species & Food Webs	Non-Point Source Loading & Runoff	Hood Canal	The Effects of Hypoxia on Marine Fish Populations in Southern Hood Canal, Washington	2008	Palsson, W. A., R. E. Pacunski, T. R. Parra, and Beam.J.	Washington Department of Fish & Wildlife	By correlating ambient oxygen concentrations with fish abundance and by relating fish kills to oxygen concentrations, we are developing a model for predicting when fish will avoid or be killed by low oxygen events.	Copper rockfish Sebastes caurinus avoid oxygen concentrations below 2 mg/L but can tolerate concentrations to 1 mg/L. Other marine fish species show similar responses, but smaller fish and species appear to be affected more than larger ones. Fish kill events are not consistent between years, affecting rockfish in one instance and lingcod in another. Differences in behavior and lethality during hypoxic conditions may relate to the magnitude and duration of exposure, temperature, past experience, and physiology. Recent and past fish kill events have resulted in long-term impacts reducing populations of rockfish and lingcod at Sund Rocks by one-third. Based on our results, continued efforts to minimize other population stressors are warranted.	http://md1.csa.com/partners/viewrecord.php?requester=gs&collection=ENV&recid=8452668&q=The+effects+of+hypoxia+on+marine+fish+populations+in+Southern+Hood+Canal%2C+Washington&uid=790718227&setcookie=yes	American Fisheries Society Symposium [Am. Fish. Soc. Symp.]. no. 64, pp. 255-280. 2008
C0388	Marine - Species & Food Webs	Non-Point Source Loading & Runoff	Hood Canal	Nekton distribution and midwater hypoxia: a seasonal, diel prey refuge?	2009	Parker-Stetter, J. L. and J. K. Horne	Hood Canal Dissolved Oxygen Program through a Naval Sea Systems Command contract	Using acoustics, we quantified vertical distribution of nekton at two sites (Hoodsport and Duckabush) before (July) and after (September) OML development.	Both Hoodsport and Duckabush had strong OML between 10 and 35 m in September, with lower (minimum 0.63 mg L_1) oxygen levels at Hoodsport compared to Duckabush (1.58 mg L_1). The OML did not affect daytime distribution of fish or invertebrates, with both occupying depths >60 m. At night in July, with no OML, invertebrates migrated into waters <20 m and fish dispersed to within 15 m of the surface at both sites. In the presence of the September OML, invertebrates migrated into waters <20 m, but the upper limit of fish vertical distribution stopped at the base of the OML (35 m) at Hoodsport. Fish vertical distribution at Duckabush was less pronounced within and above the OML (10–35 m) than it had been in July. Our results suggest that the OML did not affect invertebrate vertical distribution, but did affect fish vertical migration, and may provide a seasonal, diel prey refuge.	http://www.acoustics.washington.edu/pubs/2008%20parker-stetter%20horne%20and%20langness%20ECSS.pdf	Estuaries and Coasts 81:13-18

Ref #	Ecosystem Component	Primary Pressure	Action Area	Study Title	Date	Author(s) or Study Contact	Supporting Agency	General Study Design/Methods	Study Results	Weblink	Journal Citation (if applicable)
C0389	Marine - Species & Food Webs	Non-Point Source Loading & Runoff	Hood Canal	The influence of midwater hypoxia on nekton vertical migration	2009	Parker-Stetter, S. L., J. K. Horne, and M. M. Langness	Hood Canal Dissolved Oxygen Program through a Naval Sea Systems Command contract	Using acoustics (38 and 120 kHz), the 2007 night DVM patterns of nekton were quantified before (June, August) and during (September) an OML.	All months had similar precrepuscular distributions (>50-m depth) of fish and invertebrates. During the September evening crepuscular period, a zooplankton layer migrated upwards (>1.5 m min−1), but the layer's rate of ascent slowed to <0.5 m min−1 when it reached the lower edge of the OML. The bottom edge of the layer then moved below the OML and remained there for 13 minutes before moving through the OML at >1.0 m min−1. As in June and August, fish in September followed the upward migration of the zooplankton layer to the surface, crossing through the OML. Our results suggest that the 2007 OML did not affect zooplankton or fish vertical distributions.	http://icesjms.oxfordjournals.org/content/66/6/1296.full	ICES Journal of Marine Science 66:1296-1302
C0390	Marine - Species & Food Webs	Non-Point Source Loading & Runoff	Hood Canal	Quantifying hypoxia impacts on an estuarine demersal community using a hierarchical ensemble approach	2010	Essington, TE and Paulsen, CE	UW - Fisheries	Applied conventional and hierarchical ensemble analyses to evaluate the weight of evidence in support of hypoxia impacts on local densities of individual and groups of demersal fish and invertebrate species in Hood Canal, WA, which is subject to seasonal hypoxia in its southern reaches. Central to approach was a sample design and analysis scheme that was designed specifically to consider multiple alternative hypotheses regarding factors that dictate local species' densities.	The hierarchical ensemble analysis improved the precision of species-specific effect sizes, and also allowed us to make inferences about the response of aggregated groups of species. The estimated mean density reductions during hypoxic events (dissolved oxygen ~2 mg/l) ranged from 73 to 98% among mobile invertebrates, benthic, and benthopelagic fishes. The large reduction in benthic and benthopelagic species suggests substantial effects of hypoxia in Hood Canal even at oxygen levels that were marginally hypoxic.		Ecosystems Volume 13, Number 7, 1035-1048
C0394	Nearshore - Habitats	Non-Point Source Loading & Runoff	San Juan/Whatcom, Strait of Juan de Fuca	Sediment Quality Assessment of the Bays and Inlets of the San Juan Islands, Eastern Strait of Juan de Fuca, and Admiralty Inlet, 2002-2003	2008	Long, E., S. Aasen, M. Dutch, K. Welch, and V. Partridge	Washington Department of Ecology	During 2002 and 2003, a sediment quality survey was conducted in the bays and inlets of the San Juan Islands, Eastern Strait of Juan de Fuca, and Admiralty Inlet as part of the Puget Sound Assessment and Monitoring Program. Sediment chemistry, toxicity, and invertebrate community structure were measured.	Measurement of sediment chemistry, toxicity, and invertebrate community structure indicated that: Highest sediment quality was measured in Admiralty Inlet (67% of area); The majority of the sediments measured in the San Juan Islands and the Eastern Strait of Juan de Fuca (70 and 71% of each area, respectively) were of intermediate quality; No sediments were of degraded quality in any of the three regions.	http://www.ecy.wa.gov/biblio/0803030.html	
C0446	Marine - Species & Food Webs	Non-Point Source Loading & Runoff	All	Effects of age, sex and reproductive status on persistent organic pollutant concentrations in "Southern Resident" killer whales	2009	Krahn, M. M., M. B. Hanson, G. S. Schorr, C. K. Emmons, D. G. Burrows, J. L. Bolton, R. W. Baird, and G. M. Ylitalo	NOAA, Northwest Fisheries Science Center, Cascadia Research Collective	Twelve Southern Resident killer whales (two from J-pod, five from K-pod and five from L-pod) were biopsied in 2007. Each sample was analyzed for POPs, carbon and nitrogen stable isotopes and lipids in order to assess possible changes in the Southern Residents POP levels and diet.	Blubber biopsy samples from Southern Resident juveniles had statistically higher concentrations of certain persistent organic pollutants than were found for adults. Most Southern Resident killer whales, including the four juveniles, exceeded the health-effects threshold for total PCBs in marine mammal blubber. Maternal transfer of contaminants to the juveniles during rapid development of their biological systems may put these young whales at greater risk than adults for adverse health effects (e.g., immune and endocrine system dysfunction). Pollutant ratios and field observations established that two of the pods (K- and L-pod) travel to California to forage. Nitrogen stable isotope values, supported by field observations, indicated possible changes in the diet of L-pod over the last decade.		Marine Pollution Bulletin 58:1522-1529
C0451	Nearshore - Habitats	Non-Point Source Loading & Runoff	San Juan/Whatcom	Decadal Changes in Shoreline Biota in Westcott and Garrison Bays, San Juan County	2008	Dethier, M.N. and H.D. Berry	Washington Department of Natural Resources	Intertidal biotic communities were censused at multiple tidal heights using quadrat and core sampling techniques, and compared current data to historical records ranging from 1974-1998	The purpose of the study was to determine whether there has been a similar radical change in intertidal biotic communities over 2001 and 2003 when virtually of the eelgrass (Zostera marina) disappeared for unknown reasons. The presence or absence of change in these communities, which are largely ecologically independent of eelgrass communities, could provide a key piece of data on the causes of the eelgrass decline. Virtually all of the species found in the 1990s were also found in 2007 suggesting that eelgrass loss in the early part of the decade was not indicative of a broader ecosystem-wide change in Westcott and Garrison Bays.	http://www.dnr.wa.gov/ResearchScience/Topics/AquaticHabitats/Pages/aqr_nrsh_publications.aspx	
C0569	Marine - Species & Food Webs	Non-Point Source Loading & Runoff	Hood Canal	How does hypoxia impact marine food webs and fisheries? Evaluating distributional shifts in Hood Canal		Essington, Tim	Washington Sea Grant	Hypoxia has emerged as a widespread threat to estuaries, coasts and semi-enclosed seas worldwide. Regionally, hypoxia has been identified as a key threat to the Puget Sound ecosystem. The intensity and extent of hypoxia have been increasing in southern Hood Canal over the past two decades, causing widespread distributional shifts in mobile fish populations that may be more ecologically significant than more visible impacts, such as fish kills.			
C0572	Marine - Water	Non-Point Source Loading & Runoff	All	SoundCitizen: Students and Citizens Working Together to Evaluate Sources and Fates of Emerging Pollutants in Puget Sound		Keil, Richard	Washington Sea Grant	Persistent exposure to low levels of mixed pollutants can result in a variety of impacts on human and environmental health. While current research focuses primarily on sources and effects of known pollutants, SoundCitizen will examine emerging pollutants that are common in urban households, have multiple sources and pathways into the aquatic environment and are likely to increase in the future because they are found in 'green' products of growing popularity. SoundCitizen uses school groups and volunteers to collect water samples for toxin analyses and educates participants about ecosystem health and sustainability.			
C0584	Marine - Water	Non-Point Source Loading & Runoff	All	Effects of Waterfront Stormwater Solution Prototypes on Water Quality Runoff in Penn Cove, Town of Coupeville		Rottle, Nancy	Washington Sea Grant	Untreated runoff is one of the leading causes of degradation to Puget Sound and carries toxic chemicals that threaten aquatic natural resources. Stormwater outfall sites may provide the final opportunity to improve stormwater quality before it enters the Sound. This project will assess the effectiveness of green stormwater infrastructure in reducing the harmful effects of runoff on aquatic resources, including contamination, habitat loss and environmental degradation. The prototype will help coastal communities find ways to address local and regional planning decisions and capture the economic, aesthetic and ecological benefits of alternative stormwater solutions.			
C0442	Nearshore - Species & Food Webs	Oil & Hazardous Spills	All	Cardiac Arrhythmia Is the Primary Response of Embryonic Pacific Herring (Clupea pallasi) Exposed to Crude Oil during Weathering	2009	Incardona, J.P., Carls, M.G., Day, H.L., Sloan, C.A., Bolton, J.L., Collier, T.K., and Scholz, N.L.	NOAA—Fisheries	Teleost embryos develop a syndrome characterized by edema when exposed to water that weathers substrates contaminated with crude oil. Previous studies using zebrafish demonstrated that crude oil exposure causes cardiogenic edema, and that the most abundant polycyclic aromatic hydrocarbons (PAHs) in weathered crude oils (tricyclic fluorenes, dibenzothiophenes, and phenanthrenes) are cardiotoxic, causing arrhythmia through a pathway that does not require activation of the aryl hydrocarbon receptor (AHR).	The study demonstrates for Pacific herring, a species impacted by the Exxon Valdez oil spill, that the developing heart is the primary target of crude oil exposure. Herring embryos exposed to the effluent of oiled gravel columns developed dose-dependent edema and irregular cardiac arrhythmia soon after the heartbeat was established. At a dose that produced cardiac dysfunction in 100% of exposed embryos, tissue levels of tricyclic PAHs were below 1 μmol/kg, suggesting a specific, high affinity target in the heart. These findings have implications for understanding the mechanism of tricyclic PAH cardiotoxicity, the development of biomarkers for the effects of PAH exposure in fish, and understanding the long-term impacts of oil spills and other sources of PAH pollution in aquatic environments.	http://pubs.acs.org/doi/abs/10.1021/es802270t	Environmental Science & Technology 43(1): 201-207
C0361	Marine - Water	Onsite Sewage Systems	San Juan/Whatcom	Addendum to Quality Assurance Project Plan: Drayton Harbor Watershed Fecal Coliform Total Maximum Daily Load	2008	Mathieu, Nuri	Washington Department of Ecology	Quality Assurance Project Plan: sets protocol for monitoring Fecal Coliform Total Maximum Daily Load.	This is the addendum to Quality Assurance Project Plan: Drayton Harbor Watershed Fecal Coliform Total Maximum Daily Load.	http://www.ecy.wa.gov/biblio/0803105add1.html	

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C0362	Marine - Water	Onsite Sewage Systems	San Juan/Whatcom	Quality Assurance Project Plan: Drayton Harbor Watershed Fecal Coliform Total Maximum Daily Load: Phase 1 Water Quality Study Design	2008	Mathieu, N., and D. Sargeant	Washington Department of Ecology	This Quality Assurance (QA) Project Plan describes Phase 1 of the technical study that will monitor levels of fecal coliform bacteria in Drayton Harbor, as well as California and Dakota Creeks. It forms the basis for a bacteria TMDL.	Each study conducted by Ecology must have an approved QA Project Plan. The plan describes the objectives of the study and the procedures to be followed to achieve those objectives. The Phase 2 plan will be presented in an addendum. After completion of the study, a final report describing the study results from both phases will be published.	http://www.ecy.wa.gov/biblio/0803105.html	
C0364	Marine - Water	Onsite Sewage Systems	Whidbey	Quality Assurance Project Plan: Skagit Bay Fecal Coliform Bacteria Loading Assessment	2010	Kardouni, J.	Washington Department of Ecology	This is the quality assurance project plan for the study, Skagit Bay Fecal Coliform Bacteria Loading Assessment. The goal of this study is to help reduce FC contamination to the bay. The objective of this study is to evaluate FC concentrations, surface water discharge, and general water quality parameters within the watershed during 2010-2011.	Data collected will form the basis for calculating FC contaminant loads to the bay. After completion of the study, a final report describing the results will be posted to the Internet.	http://www.ecy.wa.gov/biblio/1003121.html	
C0487	Humans - Health	Onsite Sewage Systems	All	Status and Trends in Fecal Coliform Pollution in Shellfish Growing Areas of Puget Sound: Year 2009	2010	Determan, T.	Washington Department of Health	Detailed methods of sampling in report	Over 92% of stations (1317 stations) showed negligible impact. Just over 2% of stations had very high impact.	http://www.doh.wa.gov/ehp/sf/Pubs/fecalreport.pdf	
C0520	Marine - Species	Pathogen Pollution	All	Novel and Canine Genotypes of *Giardia Duodenalis* in Harbor Seals (*Phoca Vitulina Richardsi*)	2008	Gaydos et al.		Feces of harbor seals (*Phoca vitulina richardsi*) and hybrid Glaucous-winged/Western gulls (*Larus glaucescens/ occidentalis*) from Washington State's inland marine waters were examined for *Giardia* spp. and *Cryptosporidium* spp. to determine whether genotypes carried by these wildlife species were the same as those that commonly infect humans and domestic animals.	Using immunomagnetic separation followed by direct fluorescent antibody detection, *Giardia* spp. cysts were detected in 42% (41/97) of seal fecal samples. *Giardia* spp.–positive samples came from 90% (9/10) of the sites, and the prevalence of positive seal fecal samples differed significantly among study sites. Fecal samples collected from seal haulout sites with >400 animals were 4.7 times more likely to have *Giardia* spp. cysts than were samples collected at smaller haulout sites. In gulls, a single *Giardia* sp. cyst was detected in 4% (3/78) of fecal samples. *Cryptosporidium* spp. oocysts were not detected in any of the seals or gulls tested.		Journal of Parasitology 94(6) 1264-1268 (2008)
C0369	Nearshore - Species & Food Webs	Point Source Pollution	All	Polybrominated Diphenyl Ethers In Outmigrant Juvenile Chinook Salmon From The Lower Columbia River And Estuary And Puget Sound, WA	2010	C. A. Sloan, B. F. Anulacion, J. L. Bolton, D. Boyd, O. P. Olson, S. Y. Sol, G. M. Ylitalo, L. L. Johnson	NOAA, Northwest Fisheries Science Center	We present the concentrations of PBDEs measured in gutted bodies and stomach contents of outmigrant juvenile Chinook salmon collected at six sites in the LCR&E and four sites in Puget Sound. For comparison, we also analyzed gutted bodies of juvenile Chinook salmon from eight hatcheries in the LCR&E as well as samples of the hatchery fish feeds.	The mean PBDE concentrations measured in bodies of juvenile Chinook salmon from the different sites ranged from 350 to 2800 ng/g lipid weight, whereas those in stomach contents ranged from less than the quantitation limit (<2 ng/g wet weight) to 39 ng/g wet weight. The levels of PBDEs in the hatchery fish were significantly lower than those measured in the salmon samples collected from the LCR&E and Puget Sound. These results show that outmigrant juvenile Chinook salmon in the LCR&E and Puget Sound have been exposed to PBDEs in the environment and that these chemicals are bioaccumulating in their tissues; thus, the potential effects of PBDEs on these salmon should be further investigated.	http://www.nwfsc.noaa.gov/publications/displayallinfo.cfm?docmetadataid=6970	Archives of Environmental Contamination and Toxicology, Volume 58, Issue 2, Pages 403-414
C0371	Terrestrial - Water	Point Source Pollution	All	Perflourinated Compounds in Washington Rivers and Lakes	2010	C. Fuir and C. Meredith	Washington Department of Ecology	The study represents an exploratory effort seeking information on 13 perfluorinated compounds (PFCs) statewide in surface waters, wastewater treatment plant effluents, and fish tissues. Surface water and effluent samples were collected during periods of low and high flows.	Generally speaking, total PFC concentrations in all matrices recorded as part of the study were within or below the range of values recorded at other United States locations.	http://www.ecy.wa.gov/biblio/1003034.html	
C0373	Terrestrial - Species & Food Webs	Point Source Pollution	All	An Assessment of the PCB and Dioxin Background in Washington Freshwater Fish, with Recommendations for Prioritizing 303(d) Listings	2010	Johnson, A., K. Seiders, and D. Norton	Washington Department of Ecology	In order to prioritize the state's TMDL resources, a study was conducted to measure PCB and dioxin levels in fish from freshwater background areas. The results are used to recommend approaches for prioritizing 303(d) listings for these compounds.	The results are used to recommend approaches for prioritizing 303(d) listings for these chemicals, with the intent of accelerating cleanup actions across the state.	http://www.ecy.wa.gov/biblio/1003007.html	
C0378	Nearshore - Species & Food Webs	Point Source Pollution	All	Marine distribution, life history traits, and the accumulation of polychlorinated biphenyls in chinook salmon from Puget Sound, Washington	2009	O'Neill, S. M., and J. E. West	Washington Department of Fish & Wildlife	Polychlorinated biphenyl (PCB) levels and the factors affecting PCB accumulation in subadult and maturing Chinook salmon Oncorhynchus tshawytscha from Puget Sound were characterized. Specifically, the study (1) determined PCB levels in Chinook salmon from Puget Sound and compared them with levels in Chinook salmon from other West Coast populations, (2) determined whether PCB accumulation mainly occurred in the freshwater or marine habitats, and (3) quantified the relative importance of fish age, fish size (fork length), lipid content, and saltwater age (the number of winters spent in saltwater) on PCB concentration.	The average PCB concentration measured in skinless muscle tissue samples of subadult and maturing Chinook salmon collected from Puget Sound was 53 ng/g (wet weight), which was 3–5 times higher than those measured in six other populations of Chinook salmon on the West Coast of North America. We hypothesized that residency in the contaminated Puget Sound environment was a major factor contributing to the higher and more variable PCB concentrations in these fish. This hypothesis was supported with an independent data set from a fishery assessment model, which estimated that 29% of subyearling Chinook salmon and 45% of yearling out-migrants from Puget Sound displayed resident behavior.	http://depts.washington.edu/tribalws/Resources/O'Neill_and_West_2009.pdf	Transactions of the American Fisheries Society 138:616-632
C0379	Marine - Species & Food Webs	Point Source Pollution	South Central Puget Sound	Dioxins, furans, and other contaminants in surface sediment and English sole collected from greater Elliott Bay (Seattle)	2008	Sloan, J., and Gries, T	Washington Department of Ecology	For this 2007 study, contaminants were measured in surface sediments and tissues of English sole from greater Elliott Bay.	Median levels of dioxins/furans in sediments of 2 depths were 7.7 and 5.9 ng/kg Toxic Equivalents (TEQ). English sole whole-body tissue and skinless fillet samples had 0.99-1.71 and 0.26-0.57 ng/kg (wet weight) TEQ dioxins/furans, respectively. Tissue preparation influenced levels more than where fish were collected. Levels of most organic contaminants in 0-2 and 0-10 cm sediment samples did not differ, but most trace metals and PCBs were significantly lower in 0-2 cm samples. Sediment contaminant levels at 5 of 30 stations may represent area background conditions.	http://www.ecy.wa.gov/biblio/0803017.html	
C0380	Marine - Species & Food Webs	Point Source Pollution	All	Control of Toxic Chemicals in Puget Sound - Phase 2: Sediment Flux/Puget Sound Sediments, Bioaccumulation Model - Derived Concentrations for Toxics - Final Summary Technical Report	May-09	Ecology and Environment Inc. Contact: Chance Asher	Washington Department of Ecology	The model used in this study is based on a bioaccumulation model developed by Condon in 2007. Condon's model evaluates PCB accumulation in biota of the Strait of Georgia, which is adjacent to Puget Sound and within the same major watershed. Modified to evaluate Puget Sound toxics, the model showed how several toxic compounds move (flux) from sediment to biota.	The model identified some instances where toxics concentrations at the SQS level exceeded criteria derived to protect both human and wildlife receptors. While the model's predictions appear to be reasonable based on available verification, caution should be exercised when interpreting these results and applying them to regulatory issues because of the uncertainty associated with the model's assumptions.	http://www.ecy.wa.gov/biblio/0909069.html	
C0381	Marine - Species & Food Webs	Point Source Pollution	South Puget Sound	Mercury in Sediment, Water, and Biota of Sinclair Inlet, Puget Sound, Washington, 1989-2007	2010	Anthony J. Paulson, Morgan E. Keys, and Kelly L. Scholting	US Geological Survey	Total mercury concentratoins in various biota species were compared among geographical locations and included data of composite samples, individual speciments, and caged mussels.	Mercury concentrations in muscle and liver of English sole from Sinclair Inlet ranked in the upper quarter and third respectively of Puget Sound locations. For other species, concentrations from Sinclair Inlet were within the mid-range of locations. Total mercury concentrations in rockfish from Sinclair Inlet were highest in Puget Sound.	http://pubs.usgs.gov/of/2009/1285/pdf/ofr20091285.pdf	
C0382	Nearshore - Species & Food Webs	Point Source Pollution	South Puget Sound	More than 100 Years of Background-Level Sedimentary Metals, Nisqually River Delta, South Puget Sound, Washington	2011	Takesue, Renee K.; Swarzenski, Peter W.	US Geological Survey	The goal of this study was to determine whether there were historical trends in contaminant metals in Nisqually Delta sediment.	Five shallow sediment cores were collected at low tide from the Nisqually tidal flats in August 2009 (fig. 1; table 1). Total metal contents of sediment were examined in the core that had the best-preserved sediment record, as derived from downcore excess 210Pb profiles.	http://pubs.er.usgs.gov/publication/ofr20101329	
C0383	Terrestrial - Species & Food Webs	Point Source Pollution	All	Measuring Mercury Trends in Freshwater Fish in Washington State, 2009 Sampling Results	2010	Meredith, C., C. Furl, and M. Friese	Washington Department of Ecology	Mercury levels were measured in 50 individual bass and 25 fish composites during the fifth year of a long-term monitoring program to assess mercury levels in fish tissues across Washington State. Previous Department of Ecology studies identified elevated mercury levels which led to fish consumption advisories.	Mercury concentrations in individual bass ranged from 40 - 907 ppb, with a median of 163 ppb. Four percent of bass (2 of 50 samples) exceeded Washington's water quality standard of 770 ppb. Seven individual bass and one composite sample were above the EPA recommended criterion guidance of 300 ppb.	http://www.ecy.wa.gov/biblio/1003058.html	

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C0384	Terrestrial - Species & Food Webs	Point Source Pollution	All	Measuring Mercury Trends in Freshwater Fish in Washington State: 2007 Sampling Results	2008	Furl, C. and C. Meredith	Washington Department of Ecology	Mercury concentrations were measured in 60 individual fish and 32 composite samples as part of the third year of long-term monitoring of mercury in fish tissues across Washington State.	A total of 73% of individuals and 28% of composites sampled had mercury concentrations higher than the EPA's recommended water quality criterion of 300 ppb. A single four-year-old female bass from Lake Ozette contained a concentration of 1800 ppb. This sample was the highest mercury concentration recorded in a largemouth bass during the first three years of this long-term study.	http://www.ecy.wa.gov/biblio/0803027.html	
C0392	Nearshore - Habitats	Point Source Pollution	San Juan/Whatcom	Assessment of Sediment Toxicity near Post Point (Bellingham Bay)	2008	Gries, T.	Washington Department of Ecology	Sediments were collected from 8 locations in September 2007 and tested using 4 bioassays. Sulfide levels in sediment, porewater, and during bioassays were also measured.	Only 2 samples had minor toxicity, but they were among the highest sulfide levels measured, and a dose-response relationship was suggested. Sulfides levels near Post Point were not different from levels in other inner Bellingham Bay areas.	http://www.ecy.wa.gov/biblio/0803016.html	
C0395	Nearshore - Habitats	Point Source Pollution	South Central Puget Sound	Urban Waters Initiative, 2007; Sediment Quality in Elliott Bay	2007	Partridge, V., Weakland, S., Long, E., Welch, K., Dutch, M., and Jones, M	Washington Department of Ecology	As part of the Urban Waters Initiative, the Department of Ecology's Environmental Assessment Program is assessing sediment quality throughout urban bays in Puget Sound, beginning with Elliott Bay and adjoining waterways of the lower Duwamish River in 2007. These bay-scale assessments assist environmental managers in determining whether collective localized cleanups and source control improve conditions over a wider area.	Comparisons of the 2007 survey results with similar data collected in 1998 show bay-wide decreases in sediment contamination by numerous toxics, especially PAHs and PCBs. Spatial extent of toxicity decreased significantly from 1998 to 2007, and some measures of benthic infaunal community health improved.	http://www.ecy.wa.gov/biblio/0903014.html	
C0402	Terrestrial - Water	Point Source Pollution	North Central Puget Sound	Selected Natural Attenuation Monitoring Data, Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 2007 and 2008	2009	Dinicola, R.S., and Huffman, R.L.,	US Geological Survey	Report contains results of long-term monitoring for natural attenuation by two hybrid poplar plantations on the landfill (planted in spring 1999) to remove and to control the migration of chlorinated VOCs in shallow groundwater.	Multiple results listed in report	http://pubs.usgs.gov/of/2009/1141/	
C0480	Nearshore - Habitats	Point Source Pollution	San Juan/Whatcom	Thatcher Bay, Washington, Nearshore Restoration Assessment	2009	Breems, Joel, Wylie-Echeverria, Sandy, Grossman, Eric, and Elliot, Joel	US Geological Survey	The distribution and thickness of residual wood-waste at Thatcher Bay was determined using sediment coring and GIS-based interpolation techniques. Additionally, pilot studies were conducted to characterize in place sediment redox, organic composition, and sulfide impacts to nearshore flora and fauna. Three restoration alternatives were considered, and a ranking matrix was developed to score each alternative against site-specific and regional criteria.	The process identified the removal of wood-waste from a water-based platform as the preferred alternative. The investigation identified the location, thickness, and potential impacts of wood-waste that has persisted in the nearshore environment of Thatcher Bay since at least 1942. It also provided a process to efficiently evaluate alternatives to remediate the impact of this historical disturbance and to potentially contribute to an increase of nearshore diversity and productivity at this site.	http://pubs.usgs.gov/of/2008/1369/	

APPENDIX C: INVENTORY OF RECOMMENDED RESEARCH

Inventory of Scientific Study Recommendations

Ref #	Ecosystem Component	Primary Pressure	Recommended Study	Source Document	Study Details (if provided)	Weblink
R0473	All	n/a	Establish a new coordinated multi-party structure to collect, analyze, and disseminate credible and useful information about the Puget Sound Basin's freshwater, marine environments and aquatic habitat to strengthen policy and management decisions that affect the Basin.	Surface Water and Aquatic Habitat Monitoring Advisory Committee: The Committee's Report and Recommendations	Representatives of twenty-four public and private organizations met between September and December 2006 to discuss the need for and components of a regional monitoring program for surface waters and aquatic habitat. The Surface Water and Aquatic Habitat Advisory Committee members quickly reached agreement that there is a need for and interest in coordinated regional monitoring throughout Washington State. The Committee also reached consensus that initially the joint monitoring program needs to focus on the Puget Sound Basin before being extended throughout or replicated elsewhere in the State.	http://www.ecy.wa.gov/programs/wq/psmonitoring/ps_monitoring_docs/16Mar2007FinalReporttemp.pdf
R0474	All	n/a	What is the status and trends of surface waters and aquatic habitat monitoring in the Puget Sound Basin?	Surface Water and Aquatic Habitat Monitoring Advisory Committee: The Committee's Report and Recommendations (3/9/07)	What monitoring is currently being done to determine status and trends? Who is doing it? Is the monitoring the result of regulatory directives or is it being done voluntarily? Does that have any impact on the direction of studies (i.e., are the study designs inherently creating bias)?	http://www.ecy.wa.gov/programs/wq/psmonitoring/ps_monitoring_docs/16Mar2007FinalReporttemp.pdf
R0475	All	Non-Point Source Loading & Runoff	Do surface waters and aquatic habitat meet water quality goals?	Surface Water and Aquatic Habitat Monitoring Advisory Committee: The Committee's Report and Recommendations (3/9/07)	Are scientifically appropriate performance standards available to help determine success in achieving the goals and standards?	http://www.ecy.wa.gov/programs/wq/psmonitoring/ps_monitoring_docs/16Mar2007FinalReporttemp.pdf
R0476	All	Non-Point Source Loading & Runoff	If the goals are not being met, what are the reasons for that and what would it take to achieve them?	Surface Water and Aquatic Habitat Monitoring Advisory Committee: The Committee's Report and Recommendations (3/9/07)	Are we doing appropriate compliance, effectiveness or performance monitoring? Temporal, Spatial, Gaps in our knowledge	http://www.ecy.wa.gov/programs/wq/psmonitoring/ps_monitoring_docs/16Mar2007FinalReporttemp.pdf
R0477	All	Non-Point Source Loading & Runoff	How do we ensure monitoring is applicable and useful?	Surface Water and Aquatic Habitat Monitoring Advisory Committee: The Committee's Report and Recommendations (3/9/07)	How do we consistently perform and apply effective, defensible and scientifically powerful monitoring regionally? And how can we most effectively and efficiently share the information that results from monitoring so that it is accessible and understandable to everyone in the region who needs it?	http://www.ecy.wa.gov/programs/wq/psmonitoring/ps_monitoring_docs/16Mar2007FinalReporttemp.pdf
R0478	All	n/a	Provide information that improves decision-making for public policy and aquatic resource management through more direct communication and connection between policy-makers and the scientific and technical community.	Surface Water and Aquatic Habitat Monitoring Advisory Committee: The Committee's Report and Recommendations (3/9/07)		http://www.ecy.wa.gov/programs/wq/psmonitoring/ps_monitoring_docs/16Mar2007FinalReporttemp.pdf
R0479	All	n/a	Assist regulators and the regulated to work collaboratively to ensure that monitoring-related regulatory requirements are consistent with the monitoring priorities identified by the regional monitoring program.	Surface Water and Aquatic Habitat Monitoring Advisory Committee: The Committee's Report and Recommendations (3/9/07)		http://www.ecy.wa.gov/programs/wq/psmonitoring/ps_monitoring_docs/16Mar2007FinalReporttemp.pdf
R0480	Marine - Water	Non-Point Source Loading & Runoff	Create a comprehensive conceptual model for pollutants of the Puget Sound Basin,	Control of Toxic Chemicals in Puget Sound, Phase 2: Pollutant Loading Estimates for Surface Runoff and Roadways (11/2008)	Model should fit Ecology's Toxics Box Model and allow other scientists can compare their assumptions, input data, and analytical methods.	http://www.ecy.wa.gov/biblio/0810084.html
R0481	Marine - Water	Non-Point Source Loading & Runoff	Improve its estimates of the relative contribution of toxic chemicals from land use and roadway areas with additional data collected through studies of relatively small catchments.	Control of Toxic Chemicals in Puget Sound, Phase 2: Pollutant Loading Estimates for Surface Runoff and Roadways (11/2008)	The contribution of toxic chemical loadings from highways was a small fraction (less than 1 percent to 14 percent, depending on the chemical) of the total loading from surface runoff into Puget Sound.	http://www.ecy.wa.gov/biblio/0810084.html
R0482	Marine - Water	Non-Point Source Loading & Runoff	Differentiate the loading contributions from potential pollutant sources within each land use category.	Control of Toxic Chemicals in Puget Sound, Phase 2: Pollutant Loading Estimates for Surface Runoff and Roadways (11/2008)	Distinguishing the loading contributions of the various land use areas from the roadway areas was difficult because most of the data that existed for the non-highway roadwaytypes reflected commingled runoff (a mixture of runoff from the road and parking lot surfaces and from the general non-road land surfaces).	http://www.ecy.wa.gov/biblio/0810084.html
R0483	Marine - Water	Non-Point Source Loading & Runoff	d) Increase the priority of monitoring organic toxic chemicals in surface runoff.	Control of Toxic Chemicals in Puget Sound, Phase 2: Pollutant Loading Estimates for Surface Runoff and Roadways (11/2008)	Particularly for compounds that are a growing concern in urban stormwater runoff such as PAHs, PBDEs, phthalates, and TPH.	http://www.ecy.wa.gov/biblio/0810084.html
R0484	Marine - Water	Non-Point Source Loading & Runoff	e) Require laboratory-reporting limits that are as low as analytically feasible for all monitoring of stormwater runoff.	Control of Toxic Chemicals in Puget Sound, Phase 2: Pollutant Loading Estimates for Surface Runoff and Roadways (11/2008)	Facilitate the detection of trace amounts of toxic chemicals.	http://www.ecy.wa.gov/biblio/0810084.html
R0485	Marine - Water	Non-Point Source Loading & Runoff	f) Consolidate efforts to further assess toxic chemicals with the assessment of other contaminants, such as nutrients.	Control of Toxic Chemicals in Puget Sound, Phase 2: Pollutant Loading Estimates for Surface Runoff and Roadways (11/2008)		http://www.ecy.wa.gov/biblio/0810084.html
R0486	Nearshore - Habitats	Shoreline Armoring	Synthesize existing inventories of armoring trends; identify field sites for monitoring, field experiments, and modeling efforts; quantify the percentage of Puget Sound shoreline suffering from passive erosion; attempt to quantify rates (volume) of sediment source reduction as a result of shoreline armoring.	Impacts of shoreline armoring on sediment dynamics by P. Ruggerio, *in* Shipman et al 2010	Desk studies	http://pubs.usgs.gov/sir/2010/5254/
R0487	Nearshore - Habitats	Shoreline Armoring	Develop a nearshore morphology monitoring program along walled/no-walled sections of coast. Separate short‑term morphodynamic variability (active) from interannual or longer-term shoreline change trends (passive).	Impacts of shoreline armoring on sediment dynamics by P. Ruggerio, *in* Shipman et al 2011	Field studies	http://pubs.usgs.gov/sir/2010/5254/
R0488	Nearshore - Habitats	Shoreline Armoring	Investigate the interactions between seawalls and active nearshore processes via detailed examination of the following: random high frequency fetch limited waves, complicated beach morphology and mixed sediment environment, and variable water levels changing position of seawall relative to surf zone.	Impacts of shoreline armoring on sediment dynamics by P. Ruggerio, *in* Shipman et al 2012	Field studies and numerical modeling	http://pubs.usgs.gov/sir/2010/5254/
R0489	Nearshore - Habitats	n/a	Complete analysis of Z. marina monitoring data recorded in Westcott Bay and other shallow embayments in the San Juan Archipelago in 2008 and 2009 to assess changes in Z. marina distribution in other related areas of concern.	Eelgrass Stressor-Response Report 2007-2008: Zostera marina L. (eelgrass) transplant growth and survival along a spatial and tidal gradient in Westcott Bay		http://www.dnr.wa.gov/ResearchScience/Topics/AquaticHabitats/Pages/aqr_nrsh_publications.aspx
R0490	Nearshore - Habitats	n/a	Assess the carbohydrate reserves in root and rhizome tissue of Z. marina transplants from Westcott Bay in order to identify the potential early depletion of the carbohydrate reserve and to better understand causes of Z. marina losses.	Eelgrass Stressor-Response Report 2007-2008: Zostera marina L. (eelgrass) transplant growth and survival along a spatial and tidal gradient in Westcott Bay		http://www.dnr.wa.gov/ResearchScience/Topics/AquaticHabitats/Pages/aqr_nrsh_publications.aspx
R0491	Nearshore - Habitats	n/a	Analyze existing water column nutrient data in Westcott Bay in order to characterize nutrient variability along a spatial scale from the entrance to the head of the bay.	Eelgrass Stressor-Response Report 2007-2008: Zostera marina L. (eelgrass) transplant growth and survival along a spatial and tidal gradient in Westcott Bay		http://www.dnr.wa.gov/ResearchScience/Topics/AquaticHabitats/Pages/aqr_nrsh_publications.aspx
R0492	Nearshore - Habitats	Non-Point Source Loading & Runoff	Assess the combined effect of elevated water temperature and sediment sulfides on Z. marina survival in Westcott Bay.	Eelgrass Stressor-Response Report 2007-2008: Zostera marina L. (eelgrass) transplant growth and survival along a spatial and tidal gradient in Westcott Bay		http://www.dnr.wa.gov/ResearchScience/Topics/AquaticHabitats/Pages/aqr_nrsh_publications.aspx
R0493	Nearshore - Habitats	Non-Point Source Loading & Runoff	Analyze water column oxygen in Westcott Bay in order to identify hypoxic or anoxic events.	Eelgrass Stressor-Response Report 2007-2008: Zostera marina L. (eelgrass) transplant growth and survival along a spatial and tidal gradient in Westcott Bay		http://www.dnr.wa.gov/ResearchScience/Topics/AquaticHabitats/Pages/aqr_nrsh_publications.aspx
R0494	Nearshore - Habitats	n/a	Analyze 2009 PAR data (recorded at different tidal elevations) to evaluate light availability in late summer and fall. Reduced light levels in late summer and fall may prove to be critical to plant survival, e.g., during high plant respiration due to stress.	Eelgrass Stressor-Response Report 2007-2008: Zostera marina L. (eelgrass) transplant growth and survival along a spatial and tidal gradient in Westcott Bay		http://www.dnr.wa.gov/ResearchScience/Topics/AquaticHabitats/Pages/aqr_nrsh_publications.aspx
R0495	Marine - Habitats	n/a	Promote coordination between tribes, state and federal agencies, and local jurisdictions in Puget Sound and on the coast relative to existing MPAs and future MPA planning efforts with dedicated support for coordination.	Marine Protected Areas in Washington: Recommendations of the Marine Protected Areas Work Group to the Washington State Legislature (Van Cleve et al. 2009)	Requires Legislative Action; Implementation Lead: PSP, DNR, WDFW, ECY	http://wdfw.wa.gov/publications/pub.php?id=00038
R0496	Marine - Habitats	n/a	MPAs should address a documented conservation concern through clear goals and objectives and performance evaluation	Marine Protected Areas in Washington: Recommendations of the Marine Protected Areas Work Group to the Washington State Legislature (Van Cleve et al. 2009)	Does not require Legislative Action; Implementation Lead: Managing agencies	http://wdfw.wa.gov/publications/pub.php?id=00038
R0497	Marine - Habitats	n/a	Agencies should link their respective processes for consideration of new MPAs and should use one or more existing MPA authorities to address conservation needs.	Marine Protected Areas in Washington: Recommendations of the Marine Protected Areas Work Group to the Washington State Legislature (Van Cleve et al. 2009)	Does not require Legislative Action; Implementation Lead: WDFW, DNR	http://wdfw.wa.gov/publications/pub.php?id=00038
R0498	Marine - Habitats	n/a	Coordinated by the MPA Work Group, MPA managing agencies should develop common criteria and a process for evaluating MPAs.	Marine Protected Areas in Washington: Recommendations of the Marine Protected Areas Work Group to the Washington State Legislature (Van Cleve et al. 2009)	Does not require Legislative Action; Implementation Lead: MPAWG	http://wdfw.wa.gov/publications/pub.php?id=00038
R0499	Marine - Habitats	n/a	Provide adequate funding for MPA designation, management, and monitoring.	Marine Protected Areas in Washington: Recommendations of the Marine Protected Areas Work Group to the Washington State Legislature (Van Cleve et al. 2009)	Requires Legislative Action; Implementation Lead: Legislature	http://wdfw.wa.gov/publications/pub.php?id=00038
R0500	Marine - Habitats	n/a	Promote consistent use of MPA-related terms among state MPAs and between state and federal MPAs where possible. Where necessary, change state laws and regulations to reflect a consistent set of terms across multiple agencies.	Marine Protected Areas in Washington: Recommendations of the Marine Protected Areas Work Group to the Washington State Legislature (Van Cleve et al. 2009)	Requires Legislative Action; Implementation Lead: Legislature	http://wdfw.wa.gov/publications/pub.php?id=00038
R0501	Marine - Habitats	n/a	Inventory and evaluate current monitoring activities and identify overlaps and critical gaps. Key monitoring activities should address a range of necessary management targets, including socioeconomic targets, where appropriate.	Marine Protected Areas in Washington: Recommendations of the Marine Protected Areas Work Group to the Washington State Legislature (Van Cleve et al. 2009)	Does not require Legislative Action; Implementation Lead: Managing agencies	http://wdfw.wa.gov/publications/pub.php?id=00038
R0502	Marine - Habitats	n/a	Promote consistent management and sharing of monitoring data and maximize benefits of monitoring efforts by leveraging funding through formal agency partnerships.	Marine Protected Areas in Washington: Recommendations of the Marine Protected Areas Work Group to the Washington State Legislature (Van Cleve et al. 2009)	Does not require Legislative Action; Implementation Lead: Managing agencies A consistent data management and sharing system of monitoring efforts and outcomes could be developed and utilized by MPA managing agencies. This should include baseline data. Use of centralized databases would facilitate data availability and sharing of research results and metadata from Washington and other states.	http://wdfw.wa.gov/publications/pub.php?id=00038

Inventory of Scientific Study Recommendations

Ref #	Ecosystem Component	Primary Pressure	Recommended Study	Source Document	Study Details (if provided)	Weblink
R0503	Marine - Habitats	n/a	Target monitoring towards identified management goals, objectives, and threats in an ecosystem context and, where possible, coordinate monitoring of common threats across MPAs.	Marine Protected Areas in Washington: Recommendations of the Marine Protected Areas Work Group to the Washington State Legislature (Van Cleve et al. 2009)	Does not require Legislative Action; Implementation Lead: Managing agencies	http://wdfw.wa.gov/publications/pub.php?id=00038
R0504	Marine - Habitats	n/a	Conduct a Puget Sound and coast-wide marine conservation needs assessment and gap analysis of existing MPAs and provide recommendations for action	Marine Protected Areas in Washington: Recommendations of the Marine Protected Areas Work Group to the Washington State Legislature (Van Cleve et al. 2009)	Requires Legislative Action; Implementation Lead: MPAWG	http://wdfw.wa.gov/publications/pub.php?id=00038
R0505	Marine - Habitats	n/a	Use other ecosystem-based management tools to inform MPA management and establishment	Marine Protected Areas in Washington: Recommendations of the Marine Protected Areas Work Group to the Washington State Legislature (Van Cleve et al. 2009)	Does not require Legislative Action; Implementation Lead: Managing agencies	http://wdfw.wa.gov/publications/pub.php?id=00038
R0506	Marine - Habitats	n/a	Consider using Marine Stewardship Areas to engage local governments and NGOs in developing MPA proposals	Marine Protected Areas in Washington: Recommendations of the Marine Protected Areas Work Group to the Washington State Legislature (Van Cleve et al. 2009)	Does not require Legislative Action; Implementation Lead: Managing agencies	http://wdfw.wa.gov/publications/pub.php?id=00038
R0507	Marine - Habitats	n/a	Use the tribal MPA policy developed by the tribes of the Northwest Indian Fisheries Commission in 2003 as a starting point from which to evaluate the effectiveness of MPAs.	Marine Protected Areas in Washington: Recommendations of the Marine Protected Areas Work Group to the Washington State Legislature (Van Cleve et al. 2009)	Does not require Legislative Action; Implementation Lead: PSP	http://wdfw.wa.gov/publications/pub.php?id=00038
R0508	Marine - Habitats	n/a	Implement a comprehensive process to evaluate the effectiveness of existing MPAs using the tribal MPA policy statement to determine what would be required to create networks of MPAs	Marine Protected Areas in Washington: Recommendations of the Marine Protected Areas Work Group to the Washington State Legislature (Van Cleve et al. 2009)	Does not require Legislative Action; Implementation Lead: PSP	http://wdfw.wa.gov/publications/pub.php?id=00038
R0509	Marine - Habitats	n/a	Use adaptive management to optimize efficiency and effectiveness of individual MPAs and MPA networks.	Marine Protected Areas in Washington: Recommendations of the Marine Protected Areas Work Group to the Washington State Legislature (Van Cleve et al. 2009)	Does not require Legislative Action; Implementation Lead: Managing agencies	http://wdfw.wa.gov/publications/pub.php?id=00038
R0510	Marine - Habitats	n/a	Identify and monitor reference sites in order to evaluate MPA effectiveness	Marine Protected Areas in Washington: Recommendations of the Marine Protected Areas Work Group to the Washington State Legislature (Van Cleve et al. 2009)	Requires Leglislative Action; Implementation Lead: Managing agencies	http://wdfw.wa.gov/publications/pub.php?id=00038
R0511	Marine - Habitats	n/a	Promote consistent area-based marine conservation through alternatives to MPAs	Marine Protected Areas in Washington: Recommendations of the Marine Protected Areas Work Group to the Washington State Legislature (Van Cleve et al. 2009)	Does not require Legislative Action; Implementation Lead: Managing agencies	http://wdfw.wa.gov/publications/pub.php?id=00038
R0512	Marine - Species & Food Webs	n/a	Support partners in identifying special habitat conditions and actions necessary to reach wild fish population goals	21st Century Salmon and Steelhead Initiative (WDFW, 2008)	Big challenges for wild salmon and steelhead require that management and recovery efforts be more strategic than ever. WDFW must: support the work of our partners to restore and protect habitat; ensure fisheries protect wild populations; and reform hatchery programs. WDFW formed a planning team−with expertise in science, habitat protection and recovery, hatchery management, fisheries, enforcement, and outreach−to build a new framework for 21st century salmon and steelhead management. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be judged. The framework is organized around six key outcome areas: Wild Fish Populations, Habitat, Fisheries, Co-Management, Internal Alignment, and External	http://hccc.wa.gov/Integrated+Watershed+Management+Plan/WatershedDocumentsInventory/regional-plans/Downloads_GetFile.aspx?id=363200&fd=0
R0513	Marine - Species & Food Webs	n/a	Protect habitat by providing additional technical assistance to effectively implement the Growth Management Act, Forest and Fish Act, Shorelines Management Act and other state statutes	21st Century Salmon and Steelhead Initiative (WDFW, 2008)	Big challenges for wild salmon and steelhead require that management and recovery efforts be more strategic than ever. WDFW must: support the work of our partners to restore and protect habitat; ensure fisheries protect wild populations; and reform hatchery programs. WDFW formed a planning team−with expertise in science, habitat protection and recovery, hatchery management, fisheries, enforcement, and outreach−to build a new framework for 21st century salmon and steelhead management. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be judged. The framework is organized around six key outcome areas: Wild Fish Populations, Habitat, Fisheries, Co-Management, Internal Alignment, and External	http://hccc.wa.gov/Integrated+Watershed+Management+Plan/WatershedDocumentsInventory/regional-plans/Downloads_GetFile.aspx?id=363200&fd=0
R0514	Marine - Species & Food Webs	n/a	Support habitat restoration by providing engineering and technical assistance needed to implement salmon recovery projects.	21st Century Salmon and Steelhead Initiative (WDFW, 2008)	Big challenges for wild salmon and steelhead require that management and recovery efforts be more strategic than ever. WDFW must: support the work of our partners to restore and protect habitat; ensure fisheries protect wild populations; and reform hatchery programs. WDFW formed a planning team−with expertise in science, habitat protection and recovery, hatchery management, fisheries, enforcement, and outreach−to build a new framework for 21st century salmon and steelhead management. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be judged. The framework is organized around six key outcome areas: Wild Fish Populations, Habitat, Fisheries, Co-Management, Internal Alignment, and External Support.	http://hccc.wa.gov/Integrated+Watershed+Management+Plan/WatershedDocumentsInventory/regional-plans/Downloads_GetFile.aspx?id=363200&fd=0
R0515	Marine - Species & Food Webs	n/a	Develop and implement management plans for WDFW lands with additional emphasis on habitat needs for salmon and steelhead.	21st Century Salmon and Steelhead Initiative (WDFW, 2008)	Big challenges for wild salmon and steelhead require that management and recovery efforts be more strategic than ever. WDFW must: support the work of our partners to restore and protect habitat; ensure fisheries protect wild populations; and reform hatchery programs. WDFW formed a planning team−with expertise in science, habitat protection and recovery, hatchery management, fisheries, enforcement, and outreach−to build a new framework for 21st century salmon and steelhead management. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be judged. The framework is organized around six key outcome areas: Wild Fish Populations, Habitat, Fisheries, Co-Management, Internal Alignment, and External Support.	http://hccc.wa.gov/Integrated+Watershed+Management+Plan/WatershedDocumentsInventory/regional-plans/Downloads_GetFile.aspx?id=363200&fd=1
R0516	Marine - Species & Food Webs	Dams, Levees & Tidegates	Identify, prioritize, and correct barriers to fish passage on WDFW lands.	21st Century Salmon and Steelhead Initiative (WDFW, 2008)	Big challenges for wild salmon and steelhead require that management and recovery efforts be more strategic than ever. WDFW must: support the work of our partners to restore and protect habitat; ensure fisheries protect wild populations; and reform hatchery programs. WDFW formed a planning team−with expertise in science, habitat protection and recovery, hatchery management, fisheries, enforcement, and outreach−to build a new framework for 21st century salmon and steelhead management. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be judged. The framework is organized around six key outcome areas: Wild Fish Populations, Habitat, Fisheries, Co-Management, Internal Alignment, and External Support.	http://hccc.wa.gov/Integrated+Watershed+Management+Plan/WatershedDocumentsInventory/regional-plans/Downloads_GetFile.aspx?id=363200&fd=2
R0517	Marine - Species & Food Webs	Water Withdrawals & Diversions	Develop and implement policies to manage WDFW water rights consistent with salmon recovery.	21st Century Salmon and Steelhead Initiative (WDFW, 2008)	Big challenges for wild salmon and steelhead require that management and recovery efforts be more strategic than ever. WDFW must: support the work of our partners to restore and protect habitat; ensure fisheries protect wild populations; and reform hatchery programs. WDFW formed a planning team−with expertise in science, habitat protection and recovery, hatchery management, fisheries, enforcement, and outreach−to build a new framework for 21st century salmon and steelhead management. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be judged. The framework is organized around six key outcome areas: Wild Fish Populations, Habitat, Fisheries, Co-Management, Internal Alignment, and External Support.	http://hccc.wa.gov/Integrated+Watershed+Management+Plan/WatershedDocumentsInventory/regional-plans/Downloads_GetFile.aspx?id=363200&fd=3
R0518	Marine - Species & Food Webs	Unsustainable Fishing / Harvesting	Reduce the number of hatchery fish spawning in rivers and as appropriate, use wild salmon and steelhead as broodstock to increase the productivity and diversity of wild populations.	21st Century Salmon and Steelhead Initiative (WDFW, 2008)	Big challenges for wild salmon and steelhead require that management and recovery efforts be more strategic than ever. WDFW must: support the work of our partners to restore and protect habitat; ensure fisheries protect wild populations; and reform hatchery programs. WDFW formed a planning team−with expertise in science, habitat protection and recovery, hatchery management, fisheries, enforcement, and outreach−to build a new framework for 21st century salmon and steelhead management. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be judged. The framework is organized around six key outcome areas: Wild Fish Populations, Habitat, Fisheries, Co-Management, Internal Alignment, and External Support.	http://hccc.wa.gov/Integrated+Watershed+Management+Plan/WatershedDocumentsInventory/regional-plans/Downloads_GetFile.aspx?id=363200&fd=4
R0519	Terrestrial - Species & Food Webs	Aquaculture	Ensure that hatchery facilities are "wild salmon friendly" with passage facilities, intake screening, and pollutant control systems that comply with environmental regulations.	21st Century Salmon and Steelhead Initiative (WDFW, 2008)	Big challenges for wild salmon and steelhead require that management and recovery efforts be more strategic than ever. WDFW must: support the work of our partners to restore and protect habitat; ensure fisheries protect wild populations; and reform hatchery programs. WDFW formed a planning team−with expertise in science, habitat protection and recovery, hatchery management, fisheries, enforcement, and outreach−to build a new framework for 21st century salmon and steelhead management. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be judged. The framework is organized around six key outcome areas: Wild Fish Populations, Habitat, Fisheries, Co-Management, Internal Alignment, and External Support.	http://hccc.wa.gov/Integrated+Watershed+Management+Plan/WatershedDocumentsInventory/regional-plans/Downloads_GetFile.aspx?id=363200&fd=5
R0520	Terrestrial - Species & Food Webs	Unsustainable Fishing / Harvesting	Eliminate programs that cannot be modified to meet conservation and fishery objectives in a cost-effective manner.	21st Century Salmon and Steelhead Initiative (WDFW, 2008)	Big challenges for wild salmon and steelhead require that management and recovery efforts be more strategic than ever. WDFW must: support the work of our partners to restore and protect habitat; ensure fisheries protect wild populations; and reform hatchery programs. WDFW formed a planning team−with expertise in science, habitat protection and recovery, hatchery management, fisheries, enforcement, and outreach−to build a new framework for 21st century salmon and steelhead management. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be judged. The framework is organized around six key outcome areas: Wild Fish Populations, Habitat, Fisheries, Co-Management, Internal Alignment, and External Support.	http://hccc.wa.gov/Integrated+Watershed+Management+Plan/WatershedDocumentsInventory/regional-plans/Downloads_GetFile.aspx?id=363200&fd=6
R0521	Marine - Species & Food Webs	Unsustainable Fishing / Harvesting	Expand selective fisheries to increase opportunities for recreational and commercial fishing on hatchery fish and reduce the harvest of wild salmon.	21st Century Salmon and Steelhead Initiative (WDFW, 2008)	Big challenges for wild salmon and steelhead require that management and recovery efforts be more strategic than ever. WDFW must: support the work of our partners to restore and protect habitat; ensure fisheries protect wild populations; and reform hatchery programs. WDFW formed a planning team−with expertise in science, habitat protection and recovery, hatchery management, fisheries, enforcement, and outreach−to build a new framework for 21st century salmon and steelhead management. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be judged. The framework is organized around six key outcome areas: Wild Fish Populations, Habitat, Fisheries, Co-Management, Internal Alignment, and External Support.	http://hccc.wa.gov/Integrated+Watershed+Management+Plan/WatershedDocumentsInventory/regional-plans/Downloads_GetFile.aspx?id=363200&fd=7

Ref #	Ecosystem Component	Primary Pressure	Recommended Study	Source Document	Study Details (if provided)	Weblink
R0522	Marine - Species & Food Webs	Unsustainable Fishing / Harvesting	Implement in-season DNA stock identification to direct fishing to areas with low impacts on wild salmon.	21st Century Salmon and Steelhead Initiative (WDFW, 2008)	Big challenges for wild salmon and steelhead require that management and recovery efforts be more strategic than ever. WDFW must: support the work of our partners to restore and protect habitat; ensure fisheries protect wild populations; and reform hatchery programs. WDFW formed a planning team−with expertise in science, habitat protection and recovery, hatchery management, fisheries, enforcement, and outreach−to build a new framework for 21st century salmon and steelhead management. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be judged. The framework is organized around six key outcome areas: Wild Fish Populations, Habitat, Fisheries, Co-Management, Internal Alignment, and External Support.	http://hccc.wa.gov/Integrated+Watershed+Management+Plan/WatershedDocumentsInventory/regional-plans/Downloads_GetFile.aspx?id=363200&fd=8
R0523	Marine - Species & Food Webs	Unsustainable Fishing / Harvesting	Improve fishery monitoring to assure that impacts to wild fish are accurately assessed.	21st Century Salmon and Steelhead Initiative (WDFW, 2008)	Big challenges for wild salmon and steelhead require that management and recovery efforts be more strategic than ever. WDFW must: support the work of our partners to restore and protect habitat; ensure fisheries protect wild populations; and reform hatchery programs. WDFW formed a planning team−with expertise in science, habitat protection and recovery, hatchery management, fisheries, enforcement, and outreach−to build a new framework for 21st century salmon and steelhead management. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be judged. The framework is organized around six key outcome areas: Wild Fish Populations, Habitat, Fisheries, Co-Management, Internal Alignment, and External Support.	http://hccc.wa.gov/Integrated+Watershed+Management+Plan/WatershedDocumentsInventory/regional-plans/Downloads_GetFile.aspx?id=363200&fd=9
R0524	Marine - Species & Food Webs	Unsustainable Fishing / Harvesting	Ensure compliance with fishing regulations.	21st Century Salmon and Steelhead Initiative (WDFW, 2008)	Big challenges for wild salmon and steelhead require that management and recovery efforts be more strategic than ever. WDFW must: support the work of our partners to restore and protect habitat; ensure fisheries protect wild populations; and reform hatchery programs. WDFW formed a planning team−with expertise in science, habitat protection and recovery, hatchery management, fisheries, enforcement, and outreach−to build a new framework for 21st century salmon and steelhead management. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be judged. The framework is organized around six key outcome areas: Wild Fish Populations, Habitat, Fisheries, Co-Management, Internal Alignment, and External Support.	http://hccc.wa.gov/Integrated+Watershed+Management+Plan/WatershedDocumentsInventory/regional-plans/Downloads_GetFile.aspx?id=363200&fd=10
R0525	Marine - Species & Food Webs	Unsustainable Fishing / Harvesting	Clearly identify fishery management objectives, review the status of wild salmon and steelhead, and adjust harvest rates to better protect at-risk stocks.	21st Century Salmon and Steelhead Initiative (WDFW, 2008)	Big challenges for wild salmon and steelhead require that management and recovery efforts be more strategic than ever. WDFW must: support the work of our partners to restore and protect habitat; ensure fisheries protect wild populations; and reform hatchery programs. WDFW formed a planning team−with expertise in science, habitat protection and recovery, hatchery management, fisheries, enforcement, and outreach−to build a new framework for 21st century salmon and steelhead management. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be judged. The framework is organized around six key outcome areas: Wild Fish Populations, Habitat, Fisheries, Co-Management, Internal Alignment, and External Support.	http://hccc.wa.gov/Integrated+Watershed+Management+Plan/WatershedDocumentsInventory/regional-plans/Downloads_GetFile.aspx?id=363200&fd=11
R0526	Marine - Species & Food Webs	Unsustainable Fishing / Harvesting	Identify status of all primary populations of salmon and steelhead.	21st Century Salmon and Steelhead Initiative (WDFW, 2008)	Big challenges for wild salmon and steelhead require that management and recovery efforts be more strategic than ever. WDFW must: support the work of our partners to restore and protect habitat; ensure fisheries protect wild populations; and reform hatchery programs. WDFW formed a planning team−with expertise in science, habitat protection and recovery, hatchery management, fisheries, enforcement, and outreach−to build a new framework for 21st century salmon and steelhead management. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be judged. The framework is organized around six key outcome areas: Wild Fish Populations, Habitat, Fisheries, Co-Management, Internal Alignment, and External Support.	http://hccc.wa.gov/Integrated+Watershed+Management+Plan/WatershedDocumentsInventory/regional-plans/Downloads_GetFile.aspx?id=363200&fd=12
R0527	Marine - Species & Food Webs	Residential, Commercial, Port & Shipyard	Track changes in critical habitat using satellite imagery and aerial photography.	21st Century Salmon and Steelhead Initiative (WDFW, 2008)	Big challenges for wild salmon and steelhead require that management and recovery efforts be more strategic than ever. WDFW must: support the work of our partners to restore and protect habitat; ensure fisheries protect wild populations; and reform hatchery programs. WDFW formed a planning team−with expertise in science, habitat protection and recovery, hatchery management, fisheries, enforcement, and outreach−to build a new framework for 21st century salmon and steelhead management. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be judged. The framework is organized around six key outcome areas: Wild Fish Populations, Habitat, Fisheries, Co-Management, Internal Alignment, and External Support.	http://hccc.wa.gov/Integrated+Watershed+Management+Plan/WatershedDocumentsInventory/regional-plans/Downloads_GetFile.aspx?id=363200&fd=13
R0528	Marine - Species & Food Webs	Unsustainable Fishing / Harvesting	Monitor numbers of juvenile fish that migrate to marine areas and adult fish that return to fresh water to spawn to determine effectiveness of conservation and recovery actions.	21st Century Salmon and Steelhead Initiative (WDFW, 2008)	Big challenges for wild salmon and steelhead require that management and recovery efforts be more strategic than ever. WDFW must: support the work of our partners to restore and protect habitat; ensure fisheries protect wild populations; and reform hatchery programs. WDFW formed a planning team−with expertise in science, habitat protection and recovery, hatchery management, fisheries, enforcement, and outreach−to build a new framework for 21st century salmon and steelhead management. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be judged. The framework is organized around six key outcome areas: Wild Fish Populations, Habitat, Fisheries, Co-Management, Internal Alignment, and External Support.	http://hccc.wa.gov/Integrated+Watershed+Management+Plan/WatershedDocumentsInventory/regional-plans/Downloads_GetFile.aspx?id=363200&fd=14
R0529	Marine - Habitats	Residential, Commercial, Port & Shipyard	Assess the compliance WDFW's Hydraulic Permit Approvals (HPAs) and the effectiveness of HPAs in protecting habitat.	21st Century Salmon and Steelhead Initiative (WDFW, 2008)	Big challenges for wild salmon and steelhead require that management and recovery efforts be more strategic than ever. WDFW must: support the work of our partners to restore and protect habitat; ensure fisheries protect wild populations; and reform hatchery programs. WDFW formed a planning team−with expertise in science, habitat protection and recovery, hatchery management, fisheries, enforcement, and outreach−to build a new framework for 21st century salmon and steelhead management. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be judged. The framework is organized around six key outcome areas: Wild Fish Populations, Habitat, Fisheries, Co-Management, Internal Alignment, and External Support.	http://hccc.wa.gov/Integrated+Watershed+Management+Plan/WatershedDocumentsInventory/regional-plans/Downloads_GetFile.aspx?id=363200&fd=15
R0530	Marine - Species & Food Webs	Unsustainable Fishing / Harvesting	Work with our tribal co-managers in each watershed to develop joint state/tribal hatchery and harvest management objectives and plans.	21st Century Salmon and Steelhead Initiative (WDFW, 2008)	Big challenges for wild salmon and steelhead require that management and recovery efforts be more strategic than ever. WDFW must: support the work of our partners to restore and protect habitat; ensure fisheries protect wild populations; and reform hatchery programs. WDFW formed a planning team−with expertise in science, habitat protection and recovery, hatchery management, fisheries, enforcement, and outreach−to build a new framework for 21st century salmon and steelhead management. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be judged. The framework is organized around six key outcome areas: Wild Fish Populations, Habitat, Fisheries, Co-Management, Internal Alignment, and External Support.	http://hccc.wa.gov/Integrated+Watershed+Management+Plan/WatershedDocumentsInventory/regional-plans/Downloads_GetFile.aspx?id=363200&fd=16
R0531	Marine - Species & Food Webs	Unsustainable Fishing / Harvesting	Coordinate law enforcement with our tribal partners.	21st Century Salmon and Steelhead Initiative (WDFW, 2008)	Big challenges for wild salmon and steelhead require that management and recovery efforts be more strategic than ever. WDFW must: support the work of our partners to restore and protect habitat; ensure fisheries protect wild populations; and reform hatchery programs. WDFW formed a planning team−with expertise in science, habitat protection and recovery, hatchery management, fisheries, enforcement, and outreach−to build a new framework for 21st century salmon and steelhead management. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be judged. The framework is organized around six key outcome areas: Wild Fish Populations, Habitat, Fisheries, Co-Management, Internal Alignment, and External Support.	http://hccc.wa.gov/Integrated+Watershed+Management+Plan/WatershedDocumentsInventory/regional-plans/Downloads_GetFile.aspx?id=363200&fd=17
R0532	Marine - Species & Food Webs	Unsustainable Fishing / Harvesting	Ensure high level of WDFW staff knowledge and expertise in working with tribal co-managers.	21st Century Salmon and Steelhead Initiative (WDFW, 2008)	Big challenges for wild salmon and steelhead require that management and recovery efforts be more strategic than ever. WDFW must: support the work of our partners to restore and protect habitat; ensure fisheries protect wild populations; and reform hatchery programs. WDFW formed a planning team−with expertise in science, habitat protection and recovery, hatchery management, fisheries, enforcement, and outreach−to build a new framework for 21st century salmon and steelhead management. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be judged. The framework is organized around six key outcome areas: Wild Fish Populations, Habitat, Fisheries, Co-Management, Internal Alignment, and External Support.	http://hccc.wa.gov/Integrated+Watershed+Management+Plan/WatershedDocumentsInventory/regional-plans/Downloads_GetFile.aspx?id=363200&fd=18
R0533	Marine - Species & Food Webs	Unsustainable Fishing / Harvesting	Annually evaluate and update hatchery, harvest, habitat, and hydro actions to ensure achievement of desired results.	21st Century Salmon and Steelhead Initiative (WDFW, 2008)	Big challenges for wild salmon and steelhead require that management and recovery efforts be more strategic than ever. WDFW must: support the work of our partners to restore and protect habitat; ensure fisheries protect wild populations; and reform hatchery programs. WDFW formed a planning team−with expertise in science, habitat protection and recovery, hatchery management, fisheries, enforcement, and outreach−to build a new framework for 21st century salmon and steelhead management. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be judged. The framework is organized around six key outcome areas: Wild Fish Populations, Habitat, Fisheries, Co-Management, Internal Alignment, and External Support.	http://hccc.wa.gov/Integrated+Watershed+Management+Plan/WatershedDocumentsInventory/regional-plans/Downloads_GetFile.aspx?id=363200&fd=19
R0534	Marine - Species & Food Webs	Unsustainable Fishing / Harvesting	Communicate progress on status of salmon and steelhead populations and implementation of hatchery and harvest reforms through the Department's website.	21st Century Salmon and Steelhead Initiative (WDFW, 2008)	Big challenges for wild salmon and steelhead require that management and recovery efforts be more strategic than ever. WDFW must: support the work of our partners to restore and protect habitat; ensure fisheries protect wild populations; and reform hatchery programs. WDFW formed a planning team−with expertise in science, habitat protection and recovery, hatchery management, fisheries, enforcement, and outreach−to build a new framework for 21st century salmon and steelhead management. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be judged. The framework is organized around six key outcome areas: Wild Fish Populations, Habitat, Fisheries, Co-Management, Internal Alignment, and External Support.	http://hccc.wa.gov/Integrated+Watershed+Management+Plan/WatershedDocumentsInventory/regional-plans/Downloads_GetFile.aspx?id=363200&fd=20
R0535	Marine - Species & Food Webs	Unsustainable Fishing / Harvesting	Identify fishery management objectives and provide post-season assessments of fishery management performance.	21st Century Salmon and Steelhead Initiative (WDFW, 2008)	Big challenges for wild salmon and steelhead require that management and recovery efforts be more strategic than ever. WDFW must: support the work of our partners to restore and protect habitat; ensure fisheries protect wild populations; and reform hatchery programs. WDFW formed a planning team−with expertise in science, habitat protection and recovery, hatchery management, fisheries, enforcement, and outreach−to build a new framework for 21st century salmon and steelhead management. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be judged. The framework is organized around six key outcome areas: Wild Fish Populations, Habitat, Fisheries, Co-Management, Internal Alignment, and External Support.	http://hccc.wa.gov/Integrated+Watershed+Management+Plan/WatershedDocumentsInventory/regional-plans/Downloads_GetFile.aspx?id=363200&fd=21
R0536	Marine - Species & Food Webs	Unsustainable Fishing / Harvesting	Coordinate hatchery, harvest, habitat, and hydro actions to work together toward clear salmon recovery and sustainable fisher goals.	21st Century Salmon and Steelhead Initiative (WDFW, 2008)	Big challenges for wild salmon and steelhead require that management and recovery efforts be more strategic than ever. WDFW must: support the work of our partners to restore and protect habitat; ensure fisheries protect wild populations; and reform hatchery programs. WDFW formed a planning team−with expertise in science, habitat protection and recovery, hatchery management, fisheries, enforcement, and outreach−to build a new framework for 21st century salmon and steelhead management. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be judged. The framework is organized around six key outcome areas: Wild Fish Populations, Habitat, Fisheries, Co-Management, Internal Alignment, and External Support.	http://hccc.wa.gov/Integrated+Watershed+Management+Plan/WatershedDocumentsInventory/regional-plans/Downloads_GetFile.aspx?id=363200&fd=22

Inventory of Scientific Study Recommendations

Ref #	Ecosystem Component	Primary Pressure	Recommended Study	Source Document	Study Details (if provided)	Weblink
R0537	Marine - Species & Food Webs	Unsustainable Fishing / Harvesting	Continue to provide technical support to watershed "Lead Entities," Regional Recovery boards, and Regional Fishery Enhancement Groups for habitat restoration.	21st Century Salmon and Steelhead Initiative (WDFW, 2008)	Big challenges for wild salmon and steelhead require that management and recovery efforts be more strategic than ever. WDFW must: support the work of our partners to restore and protect habitat; ensure fisheries protect wild populations; and reform hatchery programs. WDFW formed a planning team−with expertise in science, habitat protection and recovery, hatchery management, fisheries, enforcement, and outreach−to build a new framework for 21st century salmon and steelhead management. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be judged. The framework is organized around six key outcome areas: Wild Fish Populations, Habitat, Fisheries, Co-Management, Internal Alignment, and External Support.	http://hccc.wa.gov/Integrated+Watershed+Management+Plan/WatershedDocumentsInventory/regional-plans/Downloads_GetFile.aspx?id=363200&fd=23
R0538	Marine - Species & Food Webs	Unsustainable Fishing / Harvesting	Expand involvement of citizen advisory groups in management processes.	21st Century Salmon and Steelhead Initiative (WDFW, 2008)	Big challenges for wild salmon and steelhead require that management and recovery efforts be more strategic than ever. WDFW must: support the work of our partners to restore and protect habitat; ensure fisheries protect wild populations; and reform hatchery programs. WDFW formed a planning team−with expertise in science, habitat protection and recovery, hatchery management, fisheries, enforcement, and outreach−to build a new framework for 21st century salmon and steelhead management. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be judged. The framework is organized around six key outcome areas: Wild Fish Populations, Habitat, Fisheries, Co-Management, Internal Alignment, and External Support.	http://hccc.wa.gov/Integrated+Watershed+Management+Plan/WatershedDocumentsInventory/regional-plans/Downloads_GetFile.aspx?id=363200&fd=24
R0539	Marine - Species & Food Webs	Unsustainable Fishing / Harvesting	Support the Puget Sound Partnership in implementing the "Action Agenda" for restoring the health of Puget Sound.	21st Century Salmon and Steelhead Initiative (WDFW, 2008)	Big challenges for wild salmon and steelhead require that management and recovery efforts be more strategic than ever. WDFW must: support the work of our partners to restore and protect habitat; ensure fisheries protect wild populations; and reform hatchery programs. WDFW formed a planning team−with expertise in science, habitat protection and recovery, hatchery management, fisheries, enforcement, and outreach−to build a new framework for 21st century salmon and steelhead management. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be judged. The framework is organized around six key outcome areas: Wild Fish Populations, Habitat, Fisheries, Co-Management, Internal Alignment, and External Support.	http://hccc.wa.gov/Integrated+Watershed+Management+Plan/WatershedDocumentsInventory/regional-plans/Downloads_GetFile.aspx?id=363200&fd=25
R0540	Nearshore - Habitats	n/a	Feasibility studies to identify restoration projects in multiple locations in East Kitsap; investigation of soft bank alternatives in Dee-Enetai estuary; assess geomorphic history of Fowlweather marsh; evaluate effects of Hood Canal floating bridge on wave energy/sediment transport north of bridge; evaluate mouth of Gamble Creek; investigate imapcts at Kings Spit	East Kitsap Nearshore Assessment (Battelle, 2009)	Processes functional at site and landscape scale - high likelihood of restoration success; restoration will improve local conditions.	http://www.kitsapgov.com/dcd/nr/nearshore/NSA_REPORT/East_Kitsap_Assessment_Final.pdf
R0541	Nearshore - Habitats	n/a	Feasibility studies to identify restoration projects in multiple areas within the City of Bremerton: Phinney Bay, Mud Bay, Oyster Bay, Port Washington Narrows, Ostrich Bay, and Enetai Creek Estuary (in Dee).	West Kitsap Nearshore Assessment (Battelle, 2008)	research study needed to address fluvial deposition processes	http://www.kitsapgov.com/dcd/nr/nearshore/WEST_KITSAP_NSA/Appendix%20E%20Revised.pdf
R0542	All	n/a	Refine the 20 indicators on the Puget Sound Dashboard of Ecosystem Indicators adopted by the Leadership Council in 2011.	Puget Sound Science Update - Science Panel Conclusions Regarding Action Agenda Implications of the Science Update	1) Finalize specific indicator metrics of the indicators chosen in 2011. For example, what aspect(s) of salmon become indicators? 2) Determine how to modify existing monitoring program metrics to have them serve more broadly as ecosystem health indicators. 3) Develop sampling protocols and then identify responsibile parties for data colleciton, analysis, etc. 4) Identify funding sources where necessary.	http://www.psp.wa.gov/downloads/pssu2011/PSSUimplicationsforpolicymakers.pdf
R0543	All	n/a	Provide targets for as many of the 20 dashboard indicators as possible.	Puget Sound Science Update - Science Panel Conclusions Regarding Action Agenda Implications of the Science Update	This should commence immediately and consider the ecological and social (human health and well being) tradeoffs by simulatneously examining them during target setting.	http://www.psp.wa.gov/downloads/pssu2011/PSSUimplicationsforpolicymakers.pdf
R0544	All	n/a	Conduct a comprehensive analysis of threats to Puget Sound health	Puget Sound Science Update - Science Panel Conclusions Regarding Action Agenda Implications of the Science Update	This includes: 1) a process to link threats to ecosystem function, 2) a careful prioritization of threats for both the marine and non-marine portions of the ecosystem as well as the human well-being components of the system, and 3) an assessment of effective strategies to address key threats. This work would include collecting more information regarding people's attitudes, how they make decisions related to their actions, and the impacts they have on Puget Sound.	http://www.psp.wa.gov/downloads/pssu2011/PSSUimplicationsforpolicymakers.pdf
R0545	Humans - Social Conditions	n/a	Organize social scientists and advance the social science pieces of the recovery strategy for Puget Sound	Puget Sound Science Update - Science Panel Conclusions Regarding Action Agenda Implications of the Science Update	There are a variety of social science techniques available to elicit public opinions about the environment. These techniques should be used and this timing of this work should precede or coincide with the target setting of indicators (if possible). It should begin by assessing the market and non-market value of ecosystem goods and services, and developing mechanisms for evaluating trade-offs among different management options in ways that provide a direct tie between ecosystem services and current decision making.	http://www.psp.wa.gov/downloads/pssu2011/PSSUimplicationsforpolicymakers.pdf
R0546	All	n/a	Revisit the evaluation of ecosystem indicators work conducted in spring 2011 with a specific emphasis on peer-reviewed evidence.	Puget Sound Science Update, pg. 44	Evaluations of indicators were based on the presence or absence of peer-reviewed evidence that an indicator met each criterion established by the indicator work group. A more detail analysis would be to evaluate the rigor of the evidence. This would be done through careful review of the evidence and distinguishing between weak and strong evidence to support a particular criterion.	
R0547	Terrestrial - Habitats	Water Withdrawals & Diversions	Revisit the evaluation of ecosystem indicators work conducted in spring 2011 with a specific emphasis on Freshwater and Terrestrial Domains	Puget Sound Science Update, pg. 55	Future versions of this document would benefit from the evaluation of more indicators pertinent to the Freshwater and Terrestrial Domains, and the inclusion of more candidate indicators in the Marine Domain to ensure a full treatment of the key attributes identified in Section 3.2.3.3. Indicators of energy and material flows deserve particular attention in future assessments, as they were not the focus of the review by O'Neill et al.	
R0548	All	Non-Point Source Loading & Runoff	Revisit the evaluation of ecosystem indicators work conducted in spring 2011 and complete a full evaluation of all water quality indicators in marine, freshwater and interface environments.	Puget Sound Science Update, pg. 81	none provided	
R0549	Humans - Social Conditions	n/a	Document the connections between economic, social, and environmental factors and HWB, particularly those covering environmental factors in general and for Puget Sound in particular.	Puget Sound Science Update, pg. 173	One must be careful in drawing conclusions from the current literature, as the absence of evidence documenting the strength of a connection should never be taken as evidence of the absence of such a connection. Nevertheless, documenting such absences can identify potentially important areas for future research.	
R0550	Nearshore - Species & Food Webs	Residential, Commercial, Port & Shipyard	Long term assessment of major forage fish species is needed to evaluate their current population levels and trends so that the impacts of habitat loss, fishing and climate change can be determined.	Puget Sound Science Update, pg. 237	none provided	
R0551	Marine - Species & Food Webs	n/a	More information is needed to assess the current population sizes and future trends of all four key bentho-pelagic fish in Puget Sound.	Puget Sound Science Update, pg. 242	Specifically, analysis of long-term trends in abundance, population structure and dependence on environmental conditions is needed to ascertain status and key drivers.	
R0552	Nearshore - Species & Food Webs	n/a	Additional work is needed to determine whether changes in abundance of particular marine birds reflect actual population changes or shifts in regional distribution that would locally mimic population declines.	Puget Sound Science Update, pg. 284	Many marine birds migrate, overwinter or breed in regions quite distant from the area(s) they use in Puget Sound. The degree to which potentially significant limiting factors in those areas influence observed changes in abundance in Puget Sound is largely unknown.	
R0553	Terrestrial - Water	Water Withdrawals & Diversions	Conduct a full analysis of stream gauge data and appropriate vetting of methods and interpretations to fully assess the status of freshwater flows.	Puget Sound Science Update, pg. 389	none provided	
R0554	Humans - Social Conditions	n/a	Impacts of threats to human health and wellbeing - positive or negative - were not addressed and should be included in future editions.	Puget Sound Science Update, pg. 429	Future editions of this document should include both a review and evaluation of the threats relative to human systems (economies, HWB, cultural resources, etc.) as well as ecological systems. Specifically, evaluations of the linkages between threats, human sstems and ecological systems should be included, highlighting not just how enhancement of one system is costly to the other, but how the two systems benefit from each other.	
R0555	All	n/a	Work is needed to more comprehensively evaluate the impact of single threats as well as the interactions among them.	Puget Sound Science Update, pg. 434	A key information gap is quantitative and analytical approaches to ranking threats in Puget Sound. The literature review suggests the need for a more comprehensive, quantitative and systematic assessment that addresses uncertainty surrounding the relative magnitude of threats.	
R0556	Terrestrial - Water	Residential, Commercial, Port & Shipyard	Need an expanded discussion of impervious surface impacts on hydrology and soils.	Puget Sound Science Update, pg. 457	none provided	
R0557	Terrestrial - Habitats	Residential, Commercial, Port & Shipyard	Need an expanded discussion of altered soil conditions such as compaction and reduced absorption.	Puget Sound Science Update, pg. 457	none provided	
R0558	Terrestrial - Habitats	Residential, Commercial, Port & Shipyard	A more thorough investigation of federal, state and local government reports, as well as non-governmental organization documents, may provide significant information to fill many of the information gaps associated with residential, commercial and industrial development.	Puget Sound Science Update, pg. 460	Beyond data limitation, there is also the need to comprehensively analyze existing data, in order to understand the interplay between the distinct landscape characteristics of developed versus undeveloped lands. Expanded efforts at adapting existing ecosystem process models or developing new ones for the region could help us understand and predict the effects of development on biogeochemical fluxes.	
R0559	Terrestrial - Water	Water Withdrawals & Diversions	Requirements for groundwater recharge are needed to fill out the region's strategy on managing stormwater.	Puget Sound Science Update, pg. 603	WDOE's approach to stormwater management needs to include a groundwater recharge element and to treat channel protection in terms of duration instead of volume explicitly.	
R0560	Terrestrial - Water	Agriculture & Livestock Grazing	Further work is needed to institutionalize the strategy for agriculture BMPs in watersheds subject to the negative impacts of eutrophication and, in general, to provide more directed guidance on the full range of contaminant issues to Puget Sound agricultural concerns.	Puget Sound Science Update, pg. 616	none provided	

Inventory of Scientific Study Recommendations

Ref #	Ecosystem Component	Primary Pressure	Recommended Study	Source Document	Study Details (if provided)	Weblink
R0561	Marine - Habitats	n/a	Indicators are needed to monitor the progress of marine spatial planning with respect to inputs, activities, ouputs, and outcomes.	Puget Sound Science Update, pg. 649	Progress needs to be monitored at all levels of the system to provide feedback on areas of success, as well as areas where improvements maybe needed.	
R0562	Humans - Social Conditions	n/a	Conduct an assessment of social sciences for ecosystem management.	Human Dimensions of Puget Sound and Washington Coast Ecosystem-based Management - Workshop Report	PSP should consider assessing how it is currently using science (both natural and social). An assessment should include the dynamics of how social sciences research informs the policy decision-making process, its prioritization across recovery actions, the tradeoffs that are inherenct in recovery, and existing tensions between the social and biophysical sciences.	
R0563	Humans - Social Conditions	n/a	Develop a human dimensions actions framework.	Human Dimensions of Puget Sound and Washington Coast Ecosystem-based Management - Workshop Report	Several specific research projects were highlighted in discussion: a literature review, an institutional analysis of the Shared Strategy approach used by the PSP, an evaluation of public engagement and behaviors, and building a conceptual model so that the human dimensions components of the Open Standards Framework can be completed. Participants also highlighted the importance of spatial and temporal scale, especially in scenario analyses regarding future ecosystem states.	
R0564	Humans - Social Conditions	n/a	Develop a Social Sciences Strategic Plan targeted towards ecosystem recovery in Puget Sound.	Human Dimensions of Puget Sound and Washington Coast Ecosystem-based Management - Workshop Report	It is recommended that the PSP Social Science Advisory Committee review other coastal management social sciences strategic efforts for suggested plan outlines and, with this background, develop a preliminary draft work plan.	
R0565	All	Climate Change	Identify /inventory critical research and scientific information being generating by agencies and organizations, and make it accessible to a wide range of users.	Preparing for a Changing Climate: Washington State's Integrated Climate Change Response Strategy - DRAFT October 2011	Strategy: Partner with and support the research community in carrying out existing research activities to improve climate change projections and better understand how human and natural systems respond to climate impacts. Key Concept: Several governmental agencies, universities and non-profit organizations are generating scientific knowledge needed to understand, predict, and respond to climate change. We need to ensure that the science is responsive and applied to the needs of managers. 7 "Actions" are listed	
R0566	All	Climate Change	Identify and/or provide coordinated input on high priority research needs that would improve our understanding of climate impacts and responses of natural and human systems.	Preparing for a Changing Climate: Washington State's Integrated Climate Change Response Strategy - DRAFT October 2011	Strategy: Partner with and support the research community in carrying out existing research activities to improve climate change projections and better understand how human and natural systems respond to climate impacts. Key Concept: Several governmental agencies, universities and non-profit organizations are generating scientific knowledge needed to understand, predict, and respond to climate change. We need to ensure that the science is responsive and applied to the needs of managers. 7 "Actions" are listed	
R0567	All	Climate Change	Periodically update the comprehensive regional downscaled climate scenarios for Washington State, for example after each new IPCC report… working with CIG, CIRC, CSCs and others.	Preparing for a Changing Climate: Washington State's Integrated Climate Change Response Strategy - DRAFT October 2011	Strategy: Partner with and support the research community in carrying out existing research activities to improve climate change projections and better understand how human and natural systems respond to climate impacts. Key Concept: Several governmental agencies, universities and non-profit organizations are generating scientific knowledge needed to understand, predict, and respond to climate change. We need to ensure that the science is responsive and applied to the needs of managers. 7 "Actions" are listed	
R0568	Terrestrial - Water	Climate Change	Using hydrologic climate scenarios developed by CIG, update hydrologic models/information currently used in planning to better represent future scenarios for changes in water supply, stream flows and flooding patterns.	Preparing for a Changing Climate: Washington State's Integrated Climate Change Response Strategy - DRAFT October 2011	Strategy: Partner with and support the research community in carrying out existing research activities to improve climate change projections and better understand how human and natural systems respond to climate impacts. Key Concept: Several governmental agencies, universities and non-profit organizations are generating scientific knowledge needed to understand, predict, and respond to climate change. We need to ensure that the science is responsive and applied to the needs of managers. 7 "Actions" are listed	
R0569	All	Climate Change	Engage, in partnership with research communities, in piloting or applying research, and decision making tools to test, demonstrate and encourage support of policy makers and stakeholders.	Preparing for a Changing Climate: Washington State's Integrated Climate Change Response Strategy - DRAFT October 2011	Strategy: Partner with and support the research community in carrying out existing research activities to improve climate change projections and better understand how human and natural systems respond to climate impacts. Key Concept: Several governmental agencies, universities and non-profit organizations are generating scientific knowledge needed to understand, predict, and respond to climate change. We need to ensure that the science is responsive and applied to the needs of managers. 7 "Actions" are listed	
R0570	Humans - Social Conditions	Climate Change	Work with and listen to local governments, Tribes, businesses, NGOs and other stakeholders to identify needs for data, information, and resources that would foster their understanding of the socioeconomic consequences of climate change and what it would require to integrate climate information in their decision making.	Preparing for a Changing Climate: Washington State's Integrated Climate Change Response Strategy - DRAFT October 2011	Strategy: Partner with and support the research community in carrying out existing research activities to improve climate change projections and better understand how human and natural systems respond to climate impacts. Key Concept: Several governmental agencies, universities and non-profit organizations are generating scientific knowledge needed to understand, predict, and respond to climate change. We need to ensure that the science is responsive and applied to the needs of managers. 7 "Actions" are listed	
R0571	All	Climate Change	Support the research communities in developing downscaled regional climate projections and updating existing projections as information about climate impacts and variability and the response of human and natural systems improves.	Preparing for a Changing Climate: Washington State's Integrated Climate Change Response Strategy - DRAFT October 2011	Strategy: Partner with and support the research community in carrying out existing research activities to improve climate change projections and better understand how human and natural systems respond to climate impacts. Key Concept: Several governmental agencies, universities and non-profit organizations are generating scientific knowledge needed to understand, predict, and respond to climate change. We need to ensure that the science is responsive and applied to the needs of managers. 7 "Actions" are listed	
R0572	All	Climate Change	Encourage and facilitate implementation of monitoring programs with sufficient coverage to track climate patterns and changes in those patterns on management-relevant scales, as well as track changes in related physical or chemical environmental parameters (e.g., marine pH, salinity, base stream flow, etc.).	Preparing for a Changing Climate: Washington State's Integrated Climate Change Response Strategy - DRAFT October 2011	This action includes: Develop and maintain large scale monitoring of key early warning indicators for species of interest such as timing of migration, changes of population patterns, size at first reproduction, etc. Enhance statewide stream gauging networks to document climate change impacts on freshwater systems. Collaborate with various agencies to monitor the spread of pests, and diseases and to increase the overall efficiency and sensitivity of current surveillance systems. Monitor essential floodplain and riparian functions at risk from climate change, and track shifts in distributions of vegetation and species in wetlands and lakes. Enhance existing monitoring of physical, chemical and biological properties of marine systems to identify and track climate change impacts. Support monitoring and research of marine acidification to understand local extent and impacts to food web, water quality and shellfish industry. Implement and/or adjust monitoring programs to identify changes in natural systems and relate those changes to climate conditions, weather events, and related physical or chemical parameters (e.g., ocean acidification). Implement monitoring programs designed specifically to test assumptions underlying proposed adaptation actions (e.g., the assumption that pristine systems are more resistant or resilient to change). Implement monitoring programs designed specifically to test the effectiveness of adaptation actions. Encourage each agency/partner to monitor the implementation of its respective actions. Coordinate data collection needs, ensure data sharing and facilitate access to all relevant data among conservation partners (state and federal agencies, tribes and other organizations).	
R0573	All	Climate Change	Compile existing tools that can be used by agencies and communities to understand key vulnerabilities to climate impacts, such as the climate ready water utility toolbox.	Preparing for a Changing Climate: Washington State's Integrated Climate Change Response Strategy - DRAFT October 2011		
R0574	All	Climate Change	Seek funding to support vulnerability assessments by local communities and regional organizations.	Preparing for a Changing Climate: Washington State's Integrated Climate Change Response Strategy - DRAFT October 2011		
R0575	All	Climate Change	Ensure that information on climate change adaptation strategies and actions is accessible and targeted towards the needs of land and water managers and other decision makers.	Preparing for a Changing Climate: Washington State's Integrated Climate Change Response Strategy - DRAFT October 2011	This action includes: Improve the clearinghouse Incorporate climate change considerations into existing planning tools which evaluate the effects of alternative land-use policies (for example, ENVISION, INVEST, and models from the Natural Capital Project). Conduct pilot projects to develop decision analysis tools for land and water managers; for example, build on the USGS/NWS Methow Basin project for future runoff projections.	
R0576	All	Climate Change	Identify species and ecosystems within geographic areas most vulnerable to climate change	Preparing for a Changing Climate: Washington State's Integrated Climate Change Response Strategy - DRAFT October 2011	This action includes: Identify key indicators for climate change response in species and ecosystems.; Further develop research to support the Pacific Northwest Climate Change Vulnerability assessment for species and habitats, and identify additional assessments needed by scale and geography. Conduct a climate change vulnerability assessment for marine species.	

APPENDIX D: SUMMARY OF STATE MONITORING PROGRAMS

Matrix of State Monitoring Programs for Natural Resources Reform Initiative (Executive Order 09-07) (DRAFT)

Logistical attributes of key state monitoring programs to assist coordination of field sampling

Ongoing Monitoring Program	Agency	Comments	Question Answered	Media Sampled	Location	Fixed, Rotating or Variable	Sampling	Number of Sampling Sites	Access	Partners	Contact Name
Stream flow monitoring	ECY	Shares stream flow monitoring with the USGS	What is the daily, monthly and annual flow of selected streams?	Freshwater	Statewide	Fixed	Continuous (Monthly)	~100	In-stream and bridges	No	
Ambient water quality monitoring	ECY	Long term non-random sites. Used to support federal NPDES program and TMDL actions.	What is the status of water quality at selected sites scattered across the state?	Freshwater	Statewide	Fixed	Monthly	62	In-stream and bridges	No	
National Coastal Condition Assessment	ECY	National assessment sponsored by EPA	What is the status of Washington marine environment relative to other parts of the nation?	Marine water, habitat, fish, sediment	Marine waters along the coast and Puget Sound	?	5 years	?	Boat and shoreline	No	
Marine water quality monitoring	ECY	Mission critical	What is the status of water quality in Puget Sound and coastal marine waters?	Marine water	Marine waters of Puget Sound	Fixed and rotating	Monthly	40	Boat and plane	No	
Marine sediment monitoring	ECY	Mission critical	What is the status of toxics, marine invertebrates and sediments in the marine areas?	Marine sediment	Puget Sound	Rotating	Annual	30 per 6 urban bays 30 per 8 regions	Boat	No	
Washington State Toxics Monitoring Program	ECY	Trend and exploratory toxics monitoring	What is the status of toxics such as PCBs in freshwater lakes and streams and in fish tissue?	Freshwater, sediment, fish, SPMD	Statewide	Variable	Annual	Variable	Boat	No	
Toxic Pollution Studies	ECY	Specific studies to analyze toxics in freshwater and fish tissues	What is the status of toxics such as PCBs in freshwater lakes and streams and in fish tissue?	Freshwater, sediment, fish	Statewide	Variable	Annual	Variable	Boat	Tribes	
Total Maximum Daily Load Studies	ECY	Used to measure pollutant load reductions near pollution sources	Have pollution load levels been reduced in areas identified as impaired?	Water, sediment, fish	Statewide	Variable	Annual	Variable	Variable		
Beach Environmental Assessment	ECY-DOH	Monitors bacteria at saltwater swimming beaches for DOH	What is the status of harmful bacteria at saltwater swimming beaches?	Marine water	Puget Sound	Fixed	Weekly (Summer only)	46	Boat and beach	Local health jurisdictions	
Status and Trends for Watershed Health and Salmon Recovery	ECY	Stream reference sites for comparing impaired waters	What are the status/trends of biological communities at selected statewide reference sites with ideal habitat conditions?	Freshwater, habitat, biology	Statewide	Rotating	Annual	50/Salmon Recovery Region	In-stream	No	
Forest Practices Adaptive Management Program	DNR-WDFW-ECY	Effectiveness, extensive and intensive monitoring of forest practices rules	Are the forest practices rules for aquatic resources achieving resource objectives and performance targets?	WQ, in-stream and riparian habitat, fish and primary productivity,	Statewide	Variable	Variable	Variable	Variable	Yes	
Natural Heritage Monitoring	DNR	Inventory of state's significant ecological features	Where are the natural areas of the state located and what are their attributes?	biological, other	Statewide	Variable	Variable	Variable	public land	Yes	
Kings Lake Bog Water Quality Study	DNR	Tracks changes in bog chemistry and hydrology	What is the status/trend of water chemistry and hydrology at Kings Lake bog?	WQ, hydrology	Select reaches	Fixed	Monthly	uk	public land	No	
State Lands HCP Monitoring Program	DNR	State Lands HCP implementation, effectiveness and validation monitoring	Are HCP objectives being met?	WQ, biological, in-stream, riparian and upland habitat, etc.	Mostly WWA	Variable	Variable	uk	public land	Yes	
State Lands HCP Roads Improvement Monitoring	DNR	Inventories DNR forest roads and fish barriers	How many fish passage barriers have been corrected, and how many miles of road have been constructed, reconstructed or	stream crossings and road segments	Statewide	Variable	Annual	Variable	public land	No	
Puget Sound Nearshore Monitoring	DNR	Tracks information about intertidal biotic communities such as kelp and eelgrass.	What are the status/trends of the biological communities of the nearshore marine areas of Puget Sound?	Biological, other	Marine waters	Variable	Variable	uk	Boat, beach, shoreline, aerial	Yes	
Dredge site monitoring	DNR	Maintains an inventory of dredge spoil site in Puget Sound and the coast.	Where are the dredge spoil sites in Washington? What is the impact of those sites on local environment?	Geologic, marine and esturine WQ	Statewide	Rotating	Variable	uk	Boat	Yes	
Forest Practices Compliance Monitoring	DNR	Biennial compliance audits of forest practices rules	Are forest practices being conducted in compliance with the rules?	rule prescriptions	Statewide	Variable	Annual	~100/year	Variable	Yes	
Adult salmon spawner abundance	DFW	Maintains annual estimates of spawner abundance by river and species for selected populations	What is the annual abundance of spawning adult salmon by water and by species? What are the trends?	Live adult salmon and/or adult salmon carcasses	Statewide	Fixed annual schedule (when funded)	Dam passage, redd counts, weir counts, carcass surveys, etc.	Variable depending on study design and accessibility	Salmonid Stock Inventory (database) and SalmonScape	Various Tribes, Counties, and State and Federal Governments	Ken Warheit/ Dayv Lowry
Angler License Telephone Survey	DFW	Tracks the number of active recreational anglers in Washington state	How many anglers are active? How many fishing trips were made? What are the targeting species?	Anglers	Statewide		Bi-Monthly	1,500 phone calls every two months	Telephone	no	Eric Kraig
Coastal Groundfish Tagging Survey	DFW	Estimates groundfish population abundance, track population movement, and other biological and ecological information	What are the status and aboundance trends of coastal groundfish, such as black rockfish? What are their spacial ditributions?	groundfish	Coast		Annual		Boat and boat ramps	no	Theresa Tsou
Columbia River Harvest Monitoring	DFW	Ensure compliance with ESA limits. Tracks catch allocations between Columbia River treaty tribes and commercial and sport	Are fisheries within ESA limits? What is the overall harvest of salmon in the Columbia River by species? Have allocation guidelines	Fresh water salmonids, sturgeon.	Columbia River - mouth at Buoy 10 upstream to McNary Dam -	Variable (this applies to both location and sampling). Both	~ weekly - dependant on fishery	Variable - 240 river miles (B10- McN). Sample as needed, driven by fishery.	Boat, plane,foot (creel), fish processing plants.	ODFW, CRITFC	Cindy LeFleur
Commercial Groundfish Landing Monitoring	DFW	Monitors species compositions of landed commercial catches, collect associated biological information, provide key	What are the species reported in the mixed species market category? What are the size/age of landed fish?	groundfish	Westport Neah Bay La Push Bellingham	fixed	Continuous	4	Port	no	Theresa Tsou
Counting Juvenile salmon migrating to the sea	DFW	Maintains annual estimated of the abundance of juvenile salmon migrating to the sea from specific selected streams	What is the freshwater production of salmon for selected streams and species by year?	Freshwater	Statewide	Fixed	Daily	31 WDFW sampling sites (depending on funding)	Boat and shoreline	Tribes, NOAA, LLTK, USFWS	Ken Warheit/ Mara Zimmerma
Food Chain and Habitat Assessments, Status, and Trends	DFW			Primarily NAIP data Remote Sensing landuse land cover	Currently Puget Sound watersheds	fixed	Inventory	By WRIA	Once fully developed, open access	RCO, PSP, Lead Entities, local govenments, tribes	Dave Price Tim Quinn
Hatchery marking and coded wire tag Program	DFW	Marks hatchery released salmon with a special tag allowing identification in harvest fisheries throughout the Pacific Ocean	Where are Washington hatchery salmon being caught? What is the relative proportion of the catch in each Pacific coastal fishery?								James Dixon
Hydraulic Permit Compliance Monitoring	DFW	Determines whether applicants who receive a hydraulic permit to work in a river or stream complied with their permit	What is the compliance rate of those who obtained permits to perform work within the high water mark of any lake river or stream?	fresh and salt water	statewide	variable	random by important types	none (lack of funds)	car		Marc Daily/ Tim Quinn
Hydropower effectiveness monitoring	DFW	Monitors effectiveness of mitigation actions at various hydropower installations in meeting FERC license	What is the effectiveness of mitigation actions by each project?	Freshwater	Upper Columbia watersheds		Stratified		Shoreline and boat	Yakama Nation, Colville Tribes, PUDs	Marc Daily/ Bill Tweit
Intensively monitored watersheds	IAC-WDFW-ECY	Intensively monitors salmon populations and habitat restoration actions to show that more salmon are produced as a result of	Do habitat restoration actions cause a positive response in overall fish production in selected watersheds?	Freshwater	Hood Canal, Lower Columbia	Fixed	Daily	20 EMAP habitat survey sites on each watershed (20*7 = 140), 7 outmigrants7	Shoreline	ECY, NOAA, Weyerhauser	Mara Zimmerma n/Kirk Krueger
Invasive species monitoring	DFW	Tracks occurrence and movement of aquatic and terrestrial invasive animal species such as green crab	What is the status of invasive animal species distribution in Washington? What are the trends?	Fresh and marine waters; transportation pathways	Statewide	Variable	Species and season dependent	Variable	Shoreline and boat	ECY, DNR, PSP, RCO	Allen Pleus/ Bill Tweit
Marine video acoustics Surveys	DFW	Tracks rockfish populations and other species associated with marine rocky reefs.	What is the status/trend of rockfish, lingcod, and other fishes on rocky reef habitat of Puget Sound?	Marine water, habitat, and associated biota	Puget Sound and coastal water	Variable (???)	depend on funding	depend on funding	Boat	no	Theresa Tsou
Ocean Groundfish Harvest Monitoring	DFW	Tracks recreational catches for groundfish species, including halibut and rockfishes, off Washington coast	What is the overall harvest, landed and released, of coastal groundfish by species, month, MCA, and target type?	Boats, anglers, and landed catch from recreational fisheries.	Catch Record Card Areas 1, 2, 3 & 4 on Washington's coast	Variable	Angler interviews at boat ramps along Washington's coast; monthly or weekly, depending on fishery	12 on coast and 8 inside bays but could change from year to year	Boat ramps		Doug Milward Wendy Beeghley
Ocean Salmon Harvest Monitoring	DFW	Tracks catch allocations between coastal ocean fisheries set by the PFMC for treaty tribes and commercial and sport non-Indian	What is the overall harvest of salmon in Ocean Catch Record Card Areas 1-4 by species, month, and Catch Record Card Area? How	Boats, anglers, salmon and bottom fish catches from fisheries.	Catch Record Card Areas 1, 2, 3 & 4 on Washington's coast	Variable	Sample and expand to exit count. Commercial fish tickets. Monthly or weekly, depending on fishery	12 on coast and 8 inside bays but could change from year to year	Docks, boat ramps and buying stations	Oregon DFW and sometimes Tribes	Doug Milward Wendy Beeghley
Puget Sound ambient monitoring program for birds and mammals	DFW	Monitors trends in distribution and abundance of marine birds, mammals in Puget Sound	What are the status/trends in marine birds and mammals in Puget Sound?	bird and mammal abundance	Puget Sound and Strait of Juan de Fuca	Variable	Variable	Variable	Airplane and boat	US Fish and Wildlife, universities, NOAA, non-profits	Scott Pearson/ John Pierce
Puget Sound Assessment and Monitoring Program (PSAMP) Toxics in Biota Component	DFW	Monitors status and trends of toxic contaminants in fish and of associated health impacts throughout Puget Sound including	What is the extent and magnitude of toxic contaminants in Puget Sound fish, what are the health impacts of contamination, and how are these	fish tissues for toxic contaminants	Puget Sound-wide and 5 river mouths	Fixed and rotating	semi-annual by species	English sole (10); Coho Salmon (5); Pacific herring (3); Other species variable	boat based, or purchase from tribal or other fisheries	NOAA Fisheries	Jim West
Puget Sound bottom trawl monitoring	DFW	Estimates population of bottomfish and invertebrates within the various basins	What are the status/trends in marine bottomfish and invertebrates for specific basins of Puget Sound?	Marine water, habitat, and associated biota	Puget Sound	Fixed (???)	Annual	50	Boat	no	Theresa Tsou
Puget Sound Groundfish Harvest Monitoring	DFW	Tracks recreational catches for groundfish species, including halibut and rockfishes, in Puget Sound	What is the overall harvest, landed and released, of Puget Sound groundfish by species, month, MCA, and target type? What is the impact	Boats, anglers and landed catch from recreational fisheries.	Marine Catch Areas 5 through 13 in Puget Sound.	Variable	Angler interviews at boat ramps throughout Puget Sound; year-round catch sampling each week,	Hundreds throughout Puget Sound	Boat ramps		Doug Milward Laurie Peterson

Puget Sound Herring Stock Assessments	DFW	Critical for determining annual abundance of herring in Puget Sound. Herring are the basic food source for salmon, seals, rockfish,	What is the status/trend of the various herring populations residing within the Puget Sound?	Marine vegetation/ herring eggs	Documented herring spawning grounds throughout Puget Sound	Variable within documented spawning grounds	Biweekly to semiweekly Jan. thru June depending on area; approx. 150 surveys/year	Approx. 24 different areas sampled annually; approx. 6,000 sample locations/year	Boat	Occasional tribal involvement	Rich Childers/ Mark O'Toole/Ku
Puget Sound Salmon Harvest Monitoring	DFW	Tracks catch allocations between Puget Sound treaty tribes and commercial and sport non-Indian fisheries	What is the overall harvest of Puget Sound salmon by species, month, Marine Catch Area (or Catch Record Card Area), and by river? How is	Boats, anglers, salmon and bottom fish catches from recreational	Catch Record Card Areas 5 through 13 in marine waters of Puget Sound; also	Variable	Angler interviews, Murthy estimator method to produce creel estimates; Catch Record Cards and	Hundreds throughout Puget Sound	Docks, boat ramps and buying stations	Treaty tribes	Steve Thiesfeld Doug Milward
Sport Harvest catch Record card	DFW	Tracks sport catch in the smaller rivers and streams of the state	What is the sport catch of salmon in the state and by river and ocean area?	Fresh and marine waters	Statewide	Fixed (annual)	Random sample of catch reports returned by anglers	N/A	N/A		Eric Kraig
Stock ID and Fish Age Structure Program	DFW	Uses fish body parts to determine age structure, growth and survival	What is the cohort reconstruction of each salmon run? What effect did ocean environmental conditions have on growth and survival?	Live adult salmon, fishery caught & broodstock carcasses	Statewide	Variable depends on fisheries	depends on design	Variable depending on study design and accessibility	Variable	Various Tribes, Counties, and State and Federal Governments	Ken Warheit/ Dayv Lowry
Stock Identification and Genetics Program	DFW	Uses DNA analysis to identify specific wild salmon populations. Identifies linkages between populations to determine unique	Where is the major wild population groups of salmon located? What fisheries are intercepting Washington wild salmon?	Biological tissue	Statewide	Variable	Variable	Variable	Variable	Yes	Scott Blankenshi p
TFW Cooperative monitoring (CMER)	DNR-WDFW-ECY	Testing the effectiveness of TFW prescriptions	What is the effectiveness of Forest-Fish forest practice rule changes in improving fish habitat?	Riparian vegetation, freshwater habitat	west side	variable (limited term effectiveness monitoring)	depends on design	variable depending on study desing	Variable	variable	Tim Quinn
Wildlife Status and Trends Monitoring	DFW	Estimates abundance and trends of important game, indicator, and special status species. Critical for evaluating harvest levels and	What are the status and trends of game, indicator, and special status species (endangered, threatened, etc)? Are conservation actions	Animal abundance and trends	Statewide	Variable	Annual	Variable	Variable	U.S. Fish and Wildlife, universities, non-profits, and citizen	John Pierce/ Scott Pearson
Limiting Factors Analysis	WCC	Provided initial assessment of factors limiting salmon production by watershed	What are the salmon limiting factors by WRIA for the state?								
Project scale effectiveness monitoring	RCO	Measures changes in habitat at the project scale at restoration projects and compares them to a control area.	What categories of restoration actions are most effective? Are most cost effective? Have the greatest longevity?	Freshwater & riparian	Statewide	Fixed and rotating	Annually	~ 90 project sites	in-stream	No	
Restoration project Implementation/ compliance monitoring	RCO	Tracks projects to insure that they are completed according to plan and specifications	Are the projects implemented as approved? Are funds expended in a timely manner?	Freshwater & riparian	Statewide	Variable	On-site review at project completion	Varies	In-stream, bridges, private lands	Local sponsors	
Shellfish Growing Area Marine Biotoxin monitoring	DOH	Monitor PSP toxin in shellfish	Do shellfish from harvest areas meet national standard for PSP toxin?	Shellfish	Puget Sound, Coastal bays and Pacific Coast	Fixed	Bimonthly	100	Shore	Yes, Tribes, LHJs, DNR, WDFW	
Shellfish Growing Area Marine Biotoxin monitoring	DOH	Monitor domoic acid in shellfish	Do shellfish from harvest areas meet national standard for domoic acid?	Shellfish	Puget Sound, Coastal bays and Pacific Coast	Fixed	Bimonthly	100	Shore	Yes, Tribes, LHJs, DNR, WDFW	

APPENDIX E: SCIENCE NEEDS IDENTIFIED DURING ACTION AGENDA UPDATE

Appendix E - Science Needs Identified During Action Agenda Update

As part of the strategy development process for the Action Agenda Update, interdisciplinary teams of scientists, conservation practitioners, policy analysts, and other stakeholders were convened. Teams were focused on either a topic (e.g., land development , runoff from the built environment, nearshore ecosystems) or a geographic area (e.g., San Juan Action Area or South Sound Action Area) and worked together to determine priority strategies and near-term actions. During this process, teams and working groups were also asked to use conceptual models to systematically assess and document areas of scientific uncertainty and decision critical needs.

The following are "science needs" as determined by Interdisciplinary Teams during development of Soundwide strategies and near-term actions of the Action Agenda Update. They are organized into the relevant sections of the Action Agenda Update outline.

A. Protect and Restore Terrestrial and Freshwater Ecosystems

A1 - Focus land development away from ecologically important and sensitive areas

- Continue to collect, refine, analyze, integrate and overlay landscape characterization information and data using information from existing assessments, and local and regional work including PSNERP, Salmon recovery plans, Aquatic Landscape Prioritization, local assessments and shoreline inventories, WDFW priority habitats and other sources.

C. Reduce and Control Sources of Pollution to Puget Sound

C1 – Reducing the Sources of Toxic Chemicals Entering Puget Sound

- Conducting scientific investigations of topics such as chemical causes of endocrine disruption (apparent as reproductive impairment) in Puget Sound fish, studies of the amount, fate, and transport of petroleum releases from drips and leaks, and gathering source data for PBT chemicals that were not included in the Puget Sound Toxics Loading Study.

C2 - Reducing Pressures on the Puget Sound Ecosystem from Runoff from the Built Environment

- Will there be any effects on groundwater (i.e., hydrology or quality) from increased infiltration of stormwater?
- Do we need better treatment than basic (80% TSS removal) for discharges to Puget Sounds? (refers to pollutants not binding to sediments, like oil and grease and dissolved metals and nitrogen). If yes, for which pollutants, and under which circumstances (from which land uses)? Is it better to provide a higher level of treatment for some portion of an area, or provide basic treatment to a broader geographical area? (Tacoma is one resource for this – they're modeling this – how dense do we need to put in BMPs to reduce impacts of effects?)
- Our region will benefit from a better understanding of the benefits and limitations of LID.
- How much retrofit is needed to meet goals? What "level" of effort is needed, in terms of number of projects and acreage retrofitted?

C3- Prevent, reduce and/or elimate pollution from centralize wasterwater systems

- Support for DOH's ongoing work on technologies for nutrient reduction from on-site sewage systems.
- Fate and impact of micropollutants on groundwater quality from reclaimed water discharges to land or wetlands.
- Effect of wastewater plant designs on micropollutant removals.

The following are "science needs" as determined by other working groups during development of strategies and near-term actions of the Action Agenda Update.

Salmon Recovery Team

Water Quantity

- There continues to be much uncertainty around the level and consistency of water in all the rivers where salmon live. Technical and policy work is needed to advance our regional understanding and work to implement protective water quantity measures.

Water Quality

- There is currently a lot of work regionally around significant work across Puget Sound to improve water quality. The key uncertainty around existing water quality programs and the implementation of the salmon recovery plans is whether this work is supporting the needs of salmon recovery or whether it needs to be directed in a different way.

Monitoring and Adaptive Management

- There is a significant gap in our understanding of landscape changes and how this impacts our ability to recover salmon. Investment in watershed-based habitat status and trends monitoring, as well as project effectiveness monitoring, is key to our understanding of how to adequately adapt the implementation of the plans

Nearshore Ecosystem Team (WDFW, WDNR, PSNERP)

(Note: This is an excerpt of nearshore science/analysis needs identified in the peer-reviewed but still-in-press "Strategies for Nearshore Protection and Restoration in Puget Sound.")

- A more broadly developed estimate of the ability of beach systems to provide ecosystem services that incorporates additional physical attributes like slope, sediment source, watershed condition, and stream mouth structure, as well as biogenic structure like eelgrass, kelp, or coastal forest condition, while resolving the extreme variation of beach system length for the purposes of prioritization and planning, and using more precise estimates of sediment source.
- An assessment of the potential and degradation of individual barrier-type embayments and coastal inlets that considers a mix of both physical and biogenic habitat attributes, the relative importance of barrier features, as well as the condition of those up-drift sediment systems anticipated to affect each barrier feature.
- Identification of discrete or overlapping units for evaluating ecosystem potential and degradation at a scale larger than a process unit. This would better support analysis of rarity and representation at a scale. This could involve division of Puget Sound based on circulation patterns.
- A more robust consideration of rarity and other aspects of landscape composition and configuration in the evaluation of potential restoration actions. This requires a finer definition of what kind of sites attributes are relevant to rarity evaluation, such that variation in their spatial distribution strongly controls the quantity or quality of ecosystem services.
- Models of landscape use by target species, for the purpose of comparing past, current, and proposed future landscapes to provide ecosystem services specific to target organisms.
- Data resources and modeling strategies for cost effective planning of protection and restoration of sediment supply in diverse and complex sediment systems.

- A more robust evaluation of current and potential protection status of ecosystem sites, including an assessment of the distribution of existing protected lands in the nearshore. Such an analysis would better define the relative threat to ecosystem services by anticipated landscape change as compared to the existing intensity and sustainability of regulatory, educational, and acquisition measures. This may involve a re-evaluation of the use of parcel density as an indicator of degradation in the Beach Strategy.
- Evaluate sites where roads and railroads along shorelines provide the primary source site degradation, as a mechanism to identify where restoration can collaborate with transportation projects to increase shoreline function.

The following are "science needs" as determined by Local Integrating Organizations during development of strategies and near-term actions of the Action Agenda Update. (Note: Not all Action Areas identified science needs.)

South Sound Action Area

- Monitoring of rate at which shorelines are being armored
- Monitoring rate of conversion of hard armoring to natural shorelines
- Monitoring rate of conversion of private to public shoreline
- Deep submerged habitats
- Explanation of relationship between water quality dissolved oxygen and survivability of salmon redds
- Bacteria re-growth in sediments as a source of contamination in shellfish beds
- Link between restoration projects and salmon production (e.g. Red Salmon Slough coho)
- Total amount of habitat lost to date in South Puget Sound Action Area (establishment of a baseline)
- Impacts of road building on habitat in smaller coves and bays (fragmentation and sediment input especially)
- Locations of on-site septic systems in South Puget Sound Action Area
- Large-scale versus small-scale impacts of restoration activities (e.g. OSS maintenance issues)
- Comprehensive food web study in South Puget Sound, including historic biomass and species partitioning (especially in relation to coho and steelhead survival)
- Usability of clean dredge spoil in habitat restoration projects
- Forage fish and shoreline armoring: how much armoring is too much for forage fish?
- Causes of low juvenile salmonid survival in South Puget Sound Action Area

Strait of Juan de Fuca Action Area

- Clean Water District Plans - Eastern Jefferson County Water Quality Program: Continue to conduct pollution identification and correction projects to locate and correct failing oss, inadequate animal waste management practices, and illicit connections to storm water systems.
- Clean Water District Plans - Sequim-Dungeness Bay - Pollution Identification and Correction: At minimum, would include 4 tasks from the Clean Water Strategy Action Plan:
- Sample all seeps flowing into Dungeness Bay (and other investigative sampling) over the course of a year (to capture summer-time and winter-time results/potential temporal patterns) for fecal coliform, nutrients, metals and pesticides, possibly including Microbial Source Tracking, to identify pollution sources.
- Clean Water District Plans - Sequim-Dungeness Bay - Water quality monitoring/assessment: This would include additional water quality monitoring and further review of recent and historical water quality monitoring data for research (such as landscape analyses of water quality (including use of GIS) and/or further nutrient analyses) to help with understanding mechanisms of pollutant distribution in Bay and watershed .

- Climate Change Mitigation, Adaption, and Implementation of Programs and Plans - Forest and Farming Resources: Support projects and programs that: b.) Assess wildfire risk (e.g., USFS and DNR lands)
- Climate Change Mitigation, Adaption, and Implementation of Programs and Plans - Marine and Estuarine Shorelines: a.) Assure effects of sea level rise and intensity and frequency of storms are accounted and planned for within updates of SMPs by local jurisdictions (e.g., increased and rolling setbacks, buffers, and easements, clustered coastal development, relocation incentives, etc.)
- Climate Change Mitigation, Adaption, and Implementation of Programs and Plans – Outreach, Education, and Planning Efforts: Support: c.) Identification of hazardous areas, including those areas that may become more hazardous in the future
- Climate Change Mitigation, Adaption, and Implementation of Programs and Plans – Ocean Acidification: Support funding for continuous monitoring programs and projects (e.g., mooring buoys)
- Elwha River Ecosystem Recovery – Stock Preservation and weir operation: Stock preservation and weir operation. The weir will be critical to obtain broodstock for stock preservation. Preservation is defined as bringing fish into the hatchery to prevent complete loss due to sedimentation resulting from dam removal and potential adult relocation above the dams to initiate natural production, nutrient improvements, and protection fro catastrophic loss. All juvenile will be released from the station. The number brought into the hatchery will be determined by 1) hatchery space availability, 2) stock maintenance requirements, and 3) genetic considerations. Stocks not listed (i.e., even year pinks, sockeye, summer run steelhead, cutthroat) are left of for stock verification and/or due to potential for natural recolonization from in-basin stocks (i.e., kokanee, resident rainbows)
- Elwha River Ecosystem Recovery – Monitoring (adults, smolts, tagging, etc.): Required to adaptively manage the project. Are adults returning, numbers increasing, productivity.
- Forest Practices – Culvert Inventory for Private Lands: Complete inventory of culverts on small forestlands, like through the Family Forest and Fish Program
- Forest Practices – Culvert Inventory for Clallam and Jefferson County Roads: Inventory fish passage barriers (no program currently)
- Landfill Assessments, Closure, and Remediation – Port Angeles Landfill Sediment Characterization – Chemical Analysis
- Landfill Assessments, Closure, and Remediation – Port Angeles Landfill Sediment Characterization Plan Development
- Forest Practices – Adaptive Management Incentives: Support funding for adaptive management and incentives (state and federal) including wetlands mitigation (See Adaptive Management Element of the Forest HCP for specific projects)
- Marine Resource Plans – Clallam MRC: Marine and Nearshore Trend Monitoring – Monitor marine population trends in the nearshore of birds, sediment and macro invertebrates (supports Shoreline Master Program update)
- Landfill Assessments, Closure, and Remediation – Port Angeles Landfill Sediment Characterization – Ecological (Vegetation and Benthic)
- Marine Resource Plans – Jefferson MRC Eelgrass Surveys and Protection
- Marine Resource Plans – Jefferson MRC Olympia Oyster Surveys and Monitoring

- Migration Corridor Integrity – Support and Promote Adult Salmonid Investigations along Strait of Juan de Fuca: Improve understanding of adult salmonid use of habitat along entire Strait of Juan de Fuca
- Migration Corridor Integrity – Support and Promote Juvenile Salmonid Investigations (including Kelp Habitat) along Strait of Juan de Fuca: Improve understanding of habitat use by juvenile salmonids, including a focus on use of kelp habitat along entire Strait of Juan de Fuca
- Migration Corridor Integrity – Support and Promote Ocean Conditions Investigations on Salmonids along Strait of Juan de Fuca: Improve understanding of effect of ocean conditions on salmonids along entire Strait of Juan de Fuca
- Outreach, Education, Public Involvement – B. Technical Assistance – Jefferson Conservation District Water Quality Monitoring – Monitor water quality on Andrews, Snow and Salmon Creeks
- Port Angeles Harbor Ecosystem Recovery - Port Angeles Harbor Marine Wood Waste Analysis / Characterization and Removal / Remediation
- Port Angeles Harbor Ecosystem Recovery - Clean Up and Restore Port Angeles Harbor "Baywide Toxic Sites", including Rayonier Mill Site (Note: Additional sampling and analysis may be needed.)
- Salmon Recovery Plans Hood Canal Coordinating Council LE - 3-Year Work Plan: Implement the 3-Year Work Plan (Note: See assessment and monitoring projects.)
- Shoreline Master Program - Clallam County SMP Adaptive Management: Develop a method for adapting the results of monitoring the No Net Loss indicators.
- Shoreline Master Program Intergovernmental Coordination and Implementation - Ecosystem Valuation: Develop the economic baseline for the ecosystem functions that will be monitored by the No Net Loss indicators.
- Shoreline Master Program Intergovernmental Coordination and Implementation - Enhanced Shoreline Protection - Identify and implement a framework for measuring and tracking No Net Loss.
- Stormwater Management Program Update and Implementation - Clallam County Stormwater Monitoring and Data Analysis: Provide baseline conditions for stormwater throughout the county. Continue Streamkeepers' ambient monitoring program & analyze all available data for trends
- Stormwater Management Program Update and Implementation - Clallam County Land use analysis: Assess the impact of land development on stormwater quality and quantity. Interpret landscape changes at a sub-basin level using CCAP data
- Watershed Planning Detailed Implementation Plan - WRIA 17 East Jefferson Watershed Council (EJWC) Phases II and III of Water Demand, Supply, and Availability Study: Phase II: assess agricultural demand for water, and develop and study strategies to mitigate mismatches in water demand, supply, and availability in WRIA 17. Phase III: conduct a detailed, comprehensive evaluation of the mitigation strategies deemed most promising in Phase II.
- Watershed Planning Detailed Implementation Plan - WRIA 17 East Jefferson Watershed Council (EJWC) Comprehensive Surface and Groundwater Monitoring Plan (Develop and Implement): Develop and implement a comprehensive surface and groundwater monitoring program to differentiate between the cumulative effects of human-caused impacts and natural conditions. Ensure data collected complies with appropriate scientific methods and is archived and shared

appropriately. Coordinate with the comprehensive monitoring program in the Hood Canal Action Area.

- Working Lands and Tidelands Protection - Adaptive Management Incentives: Support funding for adaptive management and incentives (state and federal) including wetlands mitigation and Forest Riparian Easement Program and Riparian Open Space Program (See Adaptive Management element of Forest HCP for specific projects)
- Salmon Recovery Plans North Olympic Peninsula LE - 3-Year Work Plan: Implement the 3-Year Work Plan (Note: See assessment and monitoring projects.)

San Juan Action Area

*(Note: items to be approved in consideration of public comment per San Juan AA working group. * indicates submission by one commenter; + indicates item relates to Marine Stewardship Area Monitoring Plan)*

- Investigate effects of increasing ocean and air temperature on local species*
- Investigate effects of ocean acidification on local species*
- Investigate effects of invasive species on native species and communities*
- Investigate the causes of failure of pinto abalone to repopulate the region*
- Investigate the extent to which intertidal and subtidal communities are changing as physical conditions change, and which species are most affected*+
- Identify key areas of aquifer recharge and develop methods of protecting them*
- Investigate habitat and prey resources used by juvenile salmon
- Investigate causes of Orca population decline or failure to increase
- Investigate nature, extent and frequency of toxic algal blooms
- Investigate the causes of failure of rockfish populations to recover+
- Investigate interactions between rockfish and potential predators
- Investigate extent and degree of bull kelp population decline+
- Investigate causes of marine bird declines+
- Complete Cascade Creek Streamflow analysis as baseline research to support future instream flow decisions and to protect newly secured in stream flow.

Hood Canal Action Area

- Develop a state of the science summary of the current low dissolved oxygen and determine gaps or research left to be completed.
- Explore pathways to mitigate natural inputs into nitrogen in the Hood Canal.

Whidbey Action Area

(Note: Science needs relate to climate change only. Information from Whidbey Basin Science Symposium September 30, 2011. Items should be considered in draft form and are under review)

- Need to develop information on the non-ecological costs of climate change, so people can see the costs in context of their own lives. Speak in terms of currencies that people care about. Some examples might include:
    - Human health costs
    - Jobs lost
    - Ecological communities lost

- Develop sea level rise estimates at finer scales – down to the parcel level, in some cases
- What local actions affect NO_x and So_x?
- Reduce uncertainty surrounding the variety of factors that are contributing to increasing flood frequency
- Best Management Practices for adaptation and resilience to climate change
- Develop adaptive management and monitoring plans
- Information on existing conditions in specific ecological communities – such as forests –would help inform an understanding of how those conditions interact with existing (and future) land use, plus existing (and future) climate change
- How do future climate scenarios inform our management and land use strategies for specific landscape types? Should we be protecting and/or restoring more, or harvesting less?
- What is the suite of ecosystem services that we want to maintain, and what are the costs/benefits of those strategies?
- Where are current opportunities for building resilience/adapting?
- Will development pressures shift from lower watersheds to upper watersheds, as flooding and rising sea levels cause people to move away from the coast?
- How can we maintain water availability for all users in the future?
- With higher sea levels in the future, how will stormwater management infrastructure need to change?
- How does Shoreline Master Program guidance need to be adapted in light of the challenges presented by climate change?
- How would food bills, energy bills, etc. change under different climate change scenarios?

APPENDIX F: SCIENCE NEEDS IDENTIFIED BY SCIENTIFIC, PRACTITIONER, AND STAKEHOLDER COMMUNITIES

Appendix F – Science Needs Identified by Scientific, Practitioner, and Stakeholder Communities

The Puget Sound Partnership contacted approximately 200 interested scientists from academia, state, federal, local agencies, tribes, and environmental organizations and other stakeholders to request input on science needs for this Biennial Science Work Plan. Respondents were asked to provide responses to the following two questions:

1. Within your area of focus, where is scientific uncertainty the greatest? What are the key questions that are important for Puget Sound recovery about mechanisms, interactions, and responses remain unanswered? Please describe qualitatively how good the information is you have to support your assessment of uncertainty (e.g., high – lots of scientific papers; moderate – some papers or local studies, or theoretical support; needs a lot of improvement – no data, or anecdotal evidence, etc.).

2. Where based on your understanding is the lack of social, natural, or physical scientific work (e.g., measurement, analysis, prediction, and communication) most impeding our ability to recover the Puget Sound?

The Partnership received approximately 45 responses with a total of 150 suggestions. Suggestions have been condensed and summarized are presented below in categories matching the key priority areas of the Action Agenda Update. Responses were categorized by ecosystem components and/or pressures to align the topics with the priority areas of the Action Agenda Update (Table 2). A list of contributors is provided at the end of this appendix.

Table 1. Responses by Category

Ecosystem Component or Pressure		# of Responses
Upland, Terrestrial & Freshwater	Habitats	12
	Species & Food Webs	7
	Mitigation	4
Marine & Nearshore	Habitats	10
	Species & Food Webs	36
	Mitigation	8
Pollution	Toxics	15
	Runoff from the Environment	10
	Wastewater	3
	Shellfish	1
	Oil Spills	0
	Other	1
Climate Change		7
Human Dimensions		8
Sustaining, Coordinating, & Using Science to Adapt Actions	Building Capacity	4
	Foundational Questions	9
	Scientific Tools for Informing Policy	5
	Integrated, sustained monitoring	9
	Education, training, & outreach	3
Total		**152**

Upland, Terrestrial & Freshwater Ecosystems

Habitats

Habitat and Fish Production. How does habitat over time relate to fish production, assuming enough adults to fully seed the habitat? Standard models carry calculations to flow and habitat, but do not carry these results to numbers of fish. Related to this is the previous question, but this question can be restated as: how much quality x quantity of habitat is needed for each fish? This question is probably influenced by water quality and primary and secondary productivity. Dr. Henriette Jager (Oak Ridge National Laboratory) and Dr. Steve Railsback (Humboldt State University) are two of a number of people who could be consulted as both have done considerable individual-based modeling (which is much more intensive than the instream flow modeling).

Corridor Ecology. We need better understanding of corridor ecology in light of urbanization and climate change especially as it relates to movements by local endemic, non vagile species (e.g., gastropods).

Isolation. What is the degree of isolation of organisms between basins in Puget Sound? When is it important to manage by basin? How do natural processes and productivity differ between the basins?

Empirical Evidence. The science community has largely taken a coarse filter approach to conservation of terrestrial biodiversity with little empirical evidence that ecological systems are the right unit to plan around. We need more empirical evidence relating species occurrence, density and viability with coarse filter typology.

Landscape-Level Planning. If WDFW wants to encourage landscape-level land use planning that effectively conserves wildlife then we need more field research to estimate landscape-level parameters, such as housing density and percent forest cover, that relate the degree of urbanization to the density of various native species.

Flow-Dependent Habitat. What is the best way to quantify flow-dependent fish habitat? The standard option in most instream flow modeling weights suitabilities of depth, velocity, and substrate or cover equally (i.e., they are multiplied together to generate an index of quality x quantity of habitat). There are a number of questions related to this and WDFW staff have been working on this question for many years, particularly development and testing of suitability for depth, velocity, substrate, and cover.

High Flows. How do different magnitudes of high flows change low flow channels? Under what circumstances do they make channels wider? Under what circumstances do they make channels more incised? Dr. Derek Booth (University of Washington) should be consulted in refining the questions and research.

Hydraulic Continuity. A critical question for softening the conflict around instream flows is quantification of hydraulic continuity. Site-specific geology will influence the relationship, but to what extent do distance and depth of wells modify their impact on stream flow? Can management rules be developed to address and modify the standards in the Postema decision (www.ecy.wa.gov/programs/wr/caselaw/images/pdf/postema.pdf) from the State Supreme Court? The existing standard implies a 100% instantaneous effect of well water withdrawal on stream flow, putting any new well in conflict with instream flows without allowing for diminution of impact with distance. Hydrogeological models exist or can be developed to model the degree of impact over distance, but such models are expensive and data intensive. No policy considers diminution of impact.

Land Use and Flows. How does land use influence peak flows and high flows that modify channels? Research should be addressed to different parts of watersheds: headwaters, lower tributary headwaters, foothills, lowlands, floodplains. Dr. Derek Booth (University of Washington) should be consulted in refining the questions and research.

Stream Flow Pressures. The Puget Sound Partnership Leadership Council has adopted Puget Sound Ecosystem Recovery Targets for Summer Stream Flows. These targets are based on trends in 13 Puget Sound tributary rivers and streams. But, the Pressures that specifically affect flows in these streams have not be analyzed and identified. A key next step for linking the targets to implementation is to conduct the analysis to determine which Pressures affect stream flow, what particular Pressures are critical in creating the observed trends in stream flow, and prioritizing the Pressures for which implementing management activities are most likely to improve stream flows. This research would not only link targets to specific implementation in these 13 rivers and streams, but could also inform broader policy and program initiatives for maintaining and improving stream flows basinwide.

Precipitation and Ground Water. Where is precipitation focused on a very local scale? What areas absorb most of the groundwater and the least of it, and how does the ever increasing presence of non-permeable surfaces affect that? There may be some areas where we want to completely avoid installing non-permeable surfaces. We know very little about the residence time of ground water in Kitsap County, for example. We don't know the total amount, how connected the underground system is and what the absorption rates are as a function of geographic location. Models have been and are being developed, but it's important to the health of the Sound and, in Kitsap County, to our understanding of how we can use our ground water. Do we measure run-off properly?

Species & Food Webs

Effects of land use change versus fish management on salmon. Considerable time and money are being spent to manage land use effects and restore habitat for salmon. However, there is also considerable confusion about what is driving salmon productivity at the local scale. Recently (Hoekstra et al 2006, Stanford http://afs.confex.com/afs/2011/webprogram/Paper5318.html) have concluded that harvest and hatchery effects may be more a factor than freshwater impacts yet there is much clamor that land use is by far the major if not sole factor limiting salmon production. A big concern is whether the legacy and ongoing effects of fish management are contributing to reduced productivity over and above habitat impacts. For example, hatchery fish have been shown to reduce fitness in several ways and hatchery fish are pervasive in many streams. Although not as well assessed, harvests are selective and not consistent with natural selection. Therefore, it is likely that harvest is also reducing fitness. The combination of harvest and hatcheries is almost certainly causing loss of fitness, and therefore lowered productivity, of natural spawning stocks. So, the question arises whether harvest and hatchery actions are undermining the effectiveness of habitat actions.

Restoration needed to meet B-IBI target. What mix of land use, stormwater and stream restoration programs and projects is needed to meet the 2020 recovery target of insects in streams? Specifically the restoration component of this target: By 2020, 30 stream drainages with "fair" B-IBI scores are restored so they now have "good" B-IBI scores.

Juvenile Salmonid Downstream Migrants. What are the annual abundance, timing and life histories of juvenile salmonid downstream migrants in all of our river systems? The information would allow us to better manage our fisheries and protect fish habitat through the hydraulic code which in turn should help maintain or improve populations of fish.

Non-Game Fish and Mussels. Almost nothing is known regarding the distribution, abundance and status of non-game stream fish and freshwater mussels in Washington. Management or conservation of species is not possible if we do not know where they occur and we cannot respond to changes in geographic distributions due to climate change or human activities to avoid imperilment if we do not know where species occur and do not understand their habitat requirements. This information is invaluable for directing conservation, monitoring and restoration.

Non-Vagile Animal Communities. We need a better understanding of mechanisms for how particular non vagile animal communities (amphibians, small mammals and invertebrates) change across an urbanizing gradient.

Predators. Develop a better understanding of predator impacts on critical/suppressed fish stocks/runs.

Salmon. Population abundance estimates of adult and juvenile salmon used to evaluate population limiting factors are based on outdated methods. Although current methods (developed in the 1970s) have some value re: consistency, their accuracy and precision are questionable. Validation studies are needed to compare newer methods, with the old ones, with the aim to (1) implement more accurate and precise (unbiased) abundance estimation methods and (2) develop bias-correction factors to compare old results with new. Validation studies would run for 2-3 years, conducting old and new methods in parallel.

Mitigation

Effectiveness of stormwater management measures and riparian habitat restoration in recovery of native stream biodiversity. There is great scientific (and management) uncertainty as to whether measures to mitigate the negative effects of urbanization on stream biota through storm water management measures and instream and riparian habitat restoration will result in recovery of native stream biodiversity. More directed research, including monitoring and basin-scale experimentation, is needed to determine how much biological improvement can be expected in response to the most aggressive restoration measures.

Effectiveness (and cost-effectiveness) of stormwater management measures. These issues have been identified by the stormwater work group, so are not described in detail here. The range of information needs are on several scales, ranging from the effectiveness of individual treatment structures, to the effectiveness Puget Sound wide actions such as public education campaigns.

Estuaries and Wetlands. We know very little about the use of estuary and wetland habitat by salmon or the effectiveness of restoration actions in these habitats. An estuary research project, similar to the Intensively Managed Watersheds (IMW) Project, would provide valuable guidance for restoration actions.

Habitat Repopulation. How long does it take fish to repopulate habitat that is made available through the removal of manmade fish blockages or restoration projects? This is a measurement of success that frequently comes up and we lack good information. This is part of the story of salmon recovery that we should be using to increase support for salmon recovery on a broad scale

Marine & Nearshore Ecosystems

Habitats

Habitat Use Patterns. Knowledge about the small- and large-scale movement patterns and resultant seasonal distribution of herring, sandlance, and all species of smelt in Puget Sound are largely unknown, except with respect to spawning. Without knowing the geographic and temporal scope of habitat use patterns during all times of the year it is impossible to evaluate the effects of habitat recovery actions or fishery management decisions on these species.

Reproductive Habitat. There is uncertainty about the value of shorelines as reproductive habitat. Not enough known about surf smelt and others that may be obligate users.

Nearshore Habitats as Nurseries. Uncertainty about value of nearshore habitats as nurseries for key species including rockfish and lingcod.

Connectivity. There is a major gap in knowledge about the connectivity between Puget Sound populations and their conspecifics in the Salish Sea and the Washington coast. Puget Sound is often treated as a self-contained ecosystem, and although this may be valid for its physical characteristics, it is problematic when it comes to conserving and managing marine fish and invertebrates within Puget Sound. Any anthropogenic and natural effects on Puget Sound populations, be it freshwater run-off, pollution, fishing or habitat modification, may be moderated by immigration from populations on the Washington coast, leading to a potential underestimation of local population effects of such disturbances. Although a number of other studies have also shown isolation between Puget Sound and Washington coast populations, these studies are concentrated towards a small and somewhat biased subsection of Puget Sound's biodiversity. More importantly, there is no meta-analysis that synthesizes this information in a format that is useful for managers and stakeholders. I believe that a better understanding of connectivity and local adaptation will be crucial in efforts to recover the biodiversity of Puget Sound.

Eelgrass. The greatest uncertainties on eelgrass habitat exists in the: a) historical abundance and distribution of eelgrass in Puget Sound; and b) magnitude and spatial extent of stressors in Puget Sound.

Eelgrass Site Selection. Development of an eelgrass restoration site selection model and protocols to maximize transplant success. Recovery efforts will need to focus on the science of eelgrass restoration and develop effective tools that will increase eelgrass transplant success and persistence (ability to withstand future stressors).

Kelp. Kelp is recognized as a critical resource world-wide due to its role as biogenic habitat and primary producer. For these reasons, it is identified in the Action Agenda (2009) and related work as an important indicator of ecosystem health. Despite its recognized importance, very little is known about the status and trends in kelp in Puget Sound (Mumford 2007). The greatest uncertainties include: the historical and current abundance and distribution in Puget Sound of canopy-forming, prostrate and stipitate species (historical and current knowledge is limited and focused primarily on canopy-forming kelp); use of kelp by key species in Puget Sound; and key stressors to kelp in Puget Sound. The scientific work that is most needed to strengthen our ability to recover Puget Sound would provide the following: information on current kelp abundance and areas of loss. This information is needed to prioritize areas for restoration and protection; and understanding of the impact of key stressors. This information is needed to prioritize actions to minimize stressors.

Puget Sound Beaches. Improving our knowledge of the physical processes and rates of change of Puget Sound beaches would provide valuable information for better conditioning HPA permits.

Beach Armoring and Sediment. The "off site" effects of beach armoring (i.e., bulkheading) with respect to the sediment supply to down-drift beaches are incompletely understood, especially when bulkhead

are placed in transport zones. While some level of reduction in sediment is typical, the degree to which a given change in sediment quantity affects ecology is poorly studied. Evidence suggests that the quality (i.e., particle size) of the sediment also matters and that beach coarsening has measurable effects on habitat use by forage fishes.

Elwha Nearshore Biology and Habitat. Actions to promote full ecosystem restoration of the Elwha Nearshore include: 1.Continue long term monitoring of fish use of Elwha nearshore by CWI and PC/WWU, NOAA,LEKT, and others, including genetic composition of ESA stocks of salmon and forage fish-at a cross regional scale. 2. Macroinvertbrate assemblage of Elwha and comparative. 3. Post process eelgrass data for macroalgae and fish presence. 4. Conduct additional field surveys to define fish composition and extent in and of understory macro algae beds of Elwha and comparative nearshore. 5. LWD, riparian mapping, Elwha and comparative nearshore. 6. Bird surveys of Elwha nearshore for baseline info (both live and stranded birds) and linkages to other monitoring elements. 7. Marine mammal tracking (harbor seals).

Species & Foodwebs

Food webs. A greater mechanistic understanding of food web interactions and relationships is necessary for increasing our ability to recover Puget Sound. This requires natural scientific measurement, analysis, and prediction to test current food web model relationships.

Food Web Interactions. There are two major sources of uncertainty. First, the populations, distributions and ecology of many important marine organisms (for example, crustacean and gelatinous zooplankton, bottom-dwelling fishes, and most forage fishes) are poorly understood, due to a general lack of long-term monitoring. Second, the Puget Sound ecosystem is connected to many other systems through transboundary processes—migrations, oceanographic fluxes, runoff, and human activities, to name a few. How these transboundary processes affect the internal dynamics of the marine ecosystem has, to my knowledge, not been fully addressed. Needs include: 1. Spatiotemporal monitoring of abundance, distributions and diets of zooplankton, demersal fishes and pelagic (forage) fishes; 2. Prioritization and modeling of processes that regulate marine ecosystem dynamics, including processes that operate across ecosystem boundaries; and 3. Assessment of current ecosystem modeling capacity.

Trophic Levels. There is uncertainty about lower trophic levels in Puget Sound's pelagic habitats. Lacking knowledge re: primary producers (e.g., phytoplankton) and primary consumers (e.g., copepods and krill). How does productivity affect abundance of higher trophic levels (e.g., herring and salmon) on a basin-specific level. What is the carrying capacity of these systems re: hatchery releases of salmon and other species?

Marine Ecology of Salmon Juveniles. There is insufficient research on the early marine ecology of salmon juveniles, which may be a critical component of total marine production for many salmonids. Predation and competition in the Salish Sea might control their populations.

Juvenile Estuarine Use. What is the extent of estuarine and associated tidal and seasonal wetland use by sub-yearling coho and other juvenile salmonids in coastal estuaries? This information would allow us to better utilize the Hydraulic Code to protect these fish from construction impacts.

Salmon in the Salish Sea. We need to improve our understanding of the factors affecting the growth, condition and survival of salmon and steelhead while the outmigrate and reside in the Salish Sea as a top priority. The juvenile stages of salmon and steelhead as they outmigrate and reside in the marine and estuarine environment are critical to the overall survival of salmon and steelhead, and they largely function as a "black box" in fisheries management. Questions within this subject area include but are

not limited to: 1) where is mortality occurring in the marine environment? 2) what role does outmigrant condition play in mortality? 3) Is mortality size selective? (Duffy et. al. 2010-11 publications indicate this with hatchery Chinook, but should be expanded to wild Chinook and other species) 4) Has the environment changed so that the life-history characteristics of certain salmon and steelhead populations no longer line up appropriately? Is this exacerbated by limited life-history diversity in existing populations?

Salmon Recovery. Increased long term post-implementation monitoring and effectiveness monitoring would help us see more clearly which activities bring us closer to salmon recovery. Key questions include: Are listed populations abundant and productive? *Are* freshwater and estuarine habitats healthy and productive? Is water clean enough to support wild salmon? Do rivers and streams have flows that support wild salmon? Are hydroelectric facilities operating in a fish friendly manner? Are streams accessible to wild salmon? Do hatchery practices protect wild salmon? Does harvest management protect wild salmon?

Forage Species. We have poor knowledge as to why forage species such as sandlance, hake, and Pollock undergo significant population changes. For many of the key prey species, we don't have enough information to make definitive statements as to the directionality of population change. These species determine the diets, growth, and survival of mammals, birds, and predatory fish.

Surf Smelt. It is not know whether surf smelt in Puget Sound spawn once and die (semelparous) or spawn in consecutive seasons (iteroparous). Additionally, it is not known whether surf smelt return to their natal beaches to spawn. Evaluating these life history attributes is imperative to evaluating population stability, as well as evaluating rebound potential after overexploitation, overpredation, or natural disaster.

Recreational Smelt Harvest. Recreational surf smelt harvest is not currently monitored or estimated in any way. More to the point, as estimate of surf smelt abundance, or an index thereof, is not produced anywhere in Washington. Ecosystem-based management requires balancing fisheries take, consumption by predators, and all other “sinks” of prey items against production and immigration (“sources”).

Eulachon Populations. Eulachon spawning populations are known from the outer Washington coast and the Fraser River, and a relict population exists in the Elwha Basin. Fish of all of these stocks likely rear in Puget Sound. No monitoring of eulachon presence or abundance currently occurs, despite the species being ESA-listed.

Sandlance. Though genetic analyses have recently indicated that surf smelt in Puget Sound are a single, panmictic population, no genetic work has been done for sandlance. Recent genetic work in the Bering Sea and southeast Alaska has documented two new species of sandlance and it is possible there is more than one species in Washington. Additionally, it is possible that even a single species of sandlance could exist in Puget Sound in highly distinct and isolated stocks that merit independent management/protection.

Forage Fish. What techniques can we use to evaluate the annual abundance of forage fish (example; spawning ground surveys, ocean index in conjunction with current NOAA salmonid work)? This information would help us determine how to better protect and maintain forage fish populations.

Pacific Herring. Areas of uncertainty include: genetic population structure (needed to better manage stocks and to inform recovery efforts); population abundance for key stocks - need acoustic/ trawl methods for certain stocks, and to augment spawn-deposition method; population age/size structure,

mortality, and recruitment of key stocks; the reasons for the decline in the Cherry Point herring stock; and the migration/movement patterns of Pacific herring.

Groundfish. Uncertainty related to all population metrics for species not susceptible to bottom-trawl surveys including ESA-listed rockfish including. Metrics include population abundance, natural mortality, population age structure, population genetic structure, and geographic distribution.

Dissolved Oxygen and Groundfish. What is the impact of low dissolved oxygen on groundfish populations, especially listed species?

Current Status of Rockfish Populations. NMFS' and WDFW's recent assessments of the status of rockfish populations in Puget Sound relied on incomplete and inadequate (and some might argue inappropriate) data sets. There is a dire need to conduct statistically robust and rigorous rockfish monitoring to determine: 1) Population abundance of adult and juvenile rockfishes; 2) Spatial distribution of adult and juvenile rockfishes; and 3) Patterns of recruitment in rockfishes.

Threats to rockfish (and other bottom fishes). A recent status review of 5 species of Puget Sound rockfish led the ESA listings of canary rockfish, yelloweye rockfish and bocaccio. In their assessment of risks facing these species (and all rockfish), NMFS identified a number of key uncertainties regarding the threats facing depleted rockfish populations. These are: What is the effect of degraded water quality (contaminants, excessive nutrients, low dissolved oxygen, etc.) on rockfish survival, growth, and reproduction? How does predation from high trophic level species such as harbor seals, Stellar sea lions, and lingcod affect rockfish populations? What risks to rockfish face from the artificial propagation of salmon, lingcod or other species? What are rates of rockfish bycatch in recreational fisheries? What is the impact of derelict fishing gear on rockfish populations? What impact do changing biotic and abiotic habitat conditions have on rockfish survival, growth and reproduction? Increasing our understanding of the impacts of these threats on rockfishes will enhance our ability to recover rockfish populations and the ecosystem within which they reside.

Strategies to recover rockfish populations. A number of strategies have been proposed for rockfish recovery. Chief among these are Marine Protected Areas (MPAs). The efficacy of a network of MPAs is dependent on increasing our knowledge of a number of key ecological attributes of rockfish . These include: 1) An understanding of the degree of connectivity of local rockfish sub-populations via larval dispersal or adult movement. 2) An understanding of habitat use of juvenile and adult rockfish. 3) An understanding of home range size (both the mean and variance) of adult rockfishes. 4) An understanding of the relationship between maternal age and size on reproductive success. 5) An understanding of spatial and temporally variability of rockfish recruitment in Puget Sound.

Rockfish Monitoring. Future management approaches would be enhanced with statistically robust and rigorous rockfish and habitat monitoring to determine: current population abundance and spatial distribution of adult and juvenile rockfishes (i.e. with methods such as remotely operated vehicles); current spatial and temporally variability patterns of recruitment in rockfishes; the collection and analysis of historical fisheries data to better define past fishing effort, species catch-rates, composition and spatial distribution of fisheries, which will assist recovery efforts and provide a contrast to present day populations and species assemblages; habitat use of juvenile and adult rockfish. Home range size (both the mean and variance) of adult rockfishes; the relationship between maternal age and size on reproductive success; benthic habitat mapping and characterization with geophysical tools available such as multibeam echosounders, side-scan sonar, and subbottom seismic reflection profile mapping systems (as has been completed within some of the San Juan Archipelago); and the degree of connectivity of local rockfish sub-populations via larval dispersal or adult movement.

Threats to Rockfish. Our recent status assessment (Drake et al. 2010) and WDFW's 2009 assessment (Palsson et al. 2009) collectively identified a number of areas of uncertainty regarding the possible threats facing depleted rockfish populations. They included: what is the effect of degraded water quality (contaminants, excessive nutrients, low dissolved oxygen, etc.) on rockfish survival, growth, and reproduction? How does predation from high trophic level species such as harbor seals, Stellar sea lions, and lingcod affect rockfish populations (particularly ESA-listed rockfish that typically occupy deep waters as adults)? What risks do rockfish face from the artificial propagation of salmon, lingcod or other species? What is the impact of derelict fishing gear, (particularly gear deeper than 100 feet deep) on rockfish populations and habitat? What impact do changing biotic and abiotic habitat conditions have on rockfish survival, growth and reproduction? For instance, kelp provides critical rearing habitats for juvenile canary rockfish and bocaccio, as well as numerous other fish species. Research of kelp habitat in Puget Sound should be designed to assess the resilience of kelp habitat to stressors linked to anthropogenic disturbance. How does climate regime changes and ocean acidification affect juvenile recruitment and food webs?

Genetic Connectivity. What is the genetic connectivity of populations of key species in Puget Sound, especially relative to populations seeding other areas? This is key for understanding the efficacy of Marine Protected Areas. It is key knowledge for protecting population genetic characteristics.

Migratory Species in the Salish Sea. A source of uncertainty is the relative importance of the Salish Sea versus other places as sources of population change among migratory species. There is little point trying to recover a species in the Salish Sea if the issues are occurring elsewhere. Mathematical models using data across a species range can assist in assessing what factors are likely important and where to look. There are several papers on this subject using birds in the Salish Sea (e.g. western sandpipers, snow geese, and great blue herons). Some careful selection of a few species that will provide insight in and outside the Salish Sea might be worth pursuing.

Bird Declines. Long-term bird declines were one of the primary indicators used to suggest that the Salish Sea was in poor ecological condition. What we don't understand is why those birds are declining. I recommend research focused on understanding the mechanism(s) responsible for these declines so that we can inform conservation actions.

Marine birds. The relationship between emerging toxicants (pollutants of anthropogenic origin such as metals, polychlorinated biphenyls, other petroleum hydrocarbons, pharmaceuticals, and other toxicants) and the survival and reproduction of resident and migratory marine birds in Puget Sound is an area of moderate to high uncertainty/recommended research. Few studies have focused on the mechanisms involved in the incidence of contaminants in fish prey of resident marine birds and the potential bioaccumulative effects of contaminant exposure via the food web. Current monitoring is very limited, and little follow-up work on past studies has been done.

Bird Abundance. A major uncertainty in the conservation of birds is whether trend data reflect real changes in abundance. The conventional approach to monitor birds trends is from counts often spanning many years. At the end, we rarely know how to respond to changes detected in the data. For this reason, monitoring programs need to be designed upfront around hypotheses for change. Hypotheses that are supported by the results will help guide future work to respond to the causes for change and recovery. This approach has been adopted by the US Forest Service and its partners in a hemisphere wide project to track shorebirds.

Western Grebe. The population decline of the Western Grebe requires additional attention. Questions include: are declines due to demographic constraints on birds that consistently winter in Puget Sound,

OR are they do to continental-scale redistributions? In either case, why has habitat quality in the Salish Sea changed relative to other wintering areas? Is it related to changes in prey (forage fish) abundance? Changes in predator communities? Answers to these questions would likely be relevant to other marine birds as well.

Marbled Murrelet. An important line of work would be to better understand the stressors and drivers of the distribution and trend of the Marbled Murrelet, a Threatened seabird that uses Puget Sound waters. Washington's marine and terrestrial ecosystems are linked by the Marbled Murrelet's unique life-history, which requires foraging in coastal waters as well as nesting platforms in large diameter mature coniferous trees. This critical dependence on both marine and terrestrial habitat makes the Marbled Murrelet a key umbrella species and indicator of Washington's coastal ecosystem health. Future change in climate and forestry management is likely to alter the extent and configuration of murrelet habitat.

Bivalves. Value of bivalves as sentinels for ecosystem condition and effectiveness monitoring re: recovery efforts.

Native Oyster. Critical research needs include: Native Olympia oyster restoration and Japonica marina interactions; Native Olympia oyster genetics; Native Olympia oyster restoration and resulting salmonid recovery benefits; Native Olympia oyster restoration and groundfish/rockfish recovery benefits; Native Olympia oyster historical distribution and abundance; Native Olympia oyster's effect on water quality, mineralization of sediments, water clarity, localized ecosystem services, etc.; and Native Olympia oyster habitat values - species richness, trophic interactions, etc.

Dungeness Crab. Dungeness crab is a major fishery resource in Washington State. Little is known about the wild year to year fluctuations in catch and hence the recruitment of crab megalopae 4 years prior. WDFW has embarked on a citizen-based sampling of megalopae in traps on private and public docks throughout the region. These traps are effective samplers and maybe able to tell us about the physical oceanogrpahic parameters that accompany good and bad crab recruitment years. This is an important area for research for sampling, fishery data and genetics.

Ecology of Zooplankton. Key questions that are important for Puget Sound recovery are: What are the zooplankton species that are important to key food web components such as juvenile rockfish, juvenile salmon, and baitfish? How have zooplankton communities changed over time and how will they change in the future (there are several repositories of historical samples that can be utilized)? To what extent are toxicants and pollutants concentrated in and passed through zooplankton? How have key zooplankton players responded to environmental stressors in other regions, and are there lessons that can be applied to Puget Sound? How do zooplankton communities respond to hypoxia, eutrophication, temperature increases, and other environmental changes?

Lack of marine phytoplankton expertise. There is a lack of marine phytoplankton taxonomists with the expertise to identify phytoplankton to the genus or species level. There is also a lack of taxonomists with benthic infauna expertise, which leads to only a few taxonomists analyzing most of Puget Sound samples.

Abundant Species. Why are certain species such as pink salmon and Dungeness crab (recent examples) doing so well? What are the environmental or other conditions that promote the abundance of key species?

Critical Stages. What are the "critical stages" of development (if any) for key species? How do humans affect critical stages? How do environmental conditions affect critical stages?

Sentinel Species. Are we missing key sentinel species that could be used to track ecosystem conditions and recovery goals? Need comprehensive evaluation/comparison of marine and anadromous species. Possibly use a grouping or guild of "juvenile salmonids" as sentinels for estuarine condition. Long-lived species as recorders of changes in environmental conditions.

Non-indigenous species. Key questions that are important for Puget Sound's future health are: What is the extent of invasions of aquatic habitats by non-indigenous (NIS) species? What impact do they have on species that provide important ecosystem services? Can we predict where and when new invasive species may arrive, and can we model their impacts? Are there any practical control or eradication measures that can be used to control NIS? There is a moderate amount of scientific data about some aspects of NIS in Puget Sound. How can we manage important resources that are already impacted by NIS? How do we keep new NIS out of Puget Sound? Some information is known about how ballast water introduces NIS into Puget Sound, but little or nothing is known about the role of fouling organisms on boat and ship hulls. What are the NIS of most concern with regard to the damage they could do and the likelihood that they may be introduced to Puget Sound? What is the quantitative spatial extent of NIS that have already invaded Puget Sound? This would identify the magnitude of the problem and also provide a benchmark for future measurements of the problem.

Mitigation

Beach Nourishment. Does beach nourishment adequately mitigate fish habitat impacts for bulkhead projects that prevent sediments from reaching the beach? A greater understanding of sediment delivery and beach nourishment would allow us to adapt mitigation requirements to fully mitigate impacts to fish habitat.

Fisheries Management. Are we managing our fisheries to take advantage of fish habitat that is being opened up or restored through the various salmon recovery efforts? This research would assist us in managing our fisheries to adequately seed habitat with returning adults to maximize natural production and increase benefit to user groups.

Marine Protected Areas. What is the optimal design for and use of Marine Protected Areas for species conservation and recovery?

Seasonal Work Windows. Nearshore construction and development is currently limited to seasonal work windows that are, in large part, based on the known spawn timing of herring, sandlance, and surf smelt. In many Tidal Reference Areas spawn timing assessment has not occurred across the entire year, making these timing windows inadequate tools for use in resource protection.

Elwha Nearshore Modeling and Monitoring. A number of activities are needed to promote full ecosystem restoration of the Elwha nearshore, including: 1) Model linkages between current habitat extent (for example west estuary extent , use (for example fish abundance) and sediment processes in lower river and shoreline to predict post dam removal sediment fate and anticipated near and long term habitat function response. 2) Develop adaptive management actions to respond to nearterm restoration process. 3) Prioritize additional nearshore long term restoration actions prior to dam removal, specifically augmenting of Elwha bluffs shoreline to optimize sediment delivery and identifying additional restoration actions. 4) Monitoring (lower river, estuary, and shoreline of Elwha and comparative drift cells).

Elwha Nearshore Sediment and Physical Processes. Actions to promote full ecosystem restoration of the Elwha Nearshore include: 1) More detailed and comprehensive sediment mapping and study of

lower river and estuary; specifically extending current sediment mapping in the lower river north to include river mouth. 2) Definition of relative contribution of bluff erosion to sediment budget of Elwha, Dungeness drift cells. Ground based shoreline LiDaR. 3) Expansion of 2009 Lidar study to include estuary, boat and land based Lidar for bluffs along lower river and shoreline, to and including Dungeness Spit; 4)Wave buoys (CDIP). 5) Continue and expand nearshore habitat report and sediment mapping (USGS) update to include: a. Further east and comparative areas; b. Offshore and inshore to include eelgrass area (MLLW-25-30'). 6) Comprehensive assessment of water quality in impounded, east, and west estuary including turbidity and nutriends (both CTD's and hand held YSI readings). 7) Mapping of the historic Elwha nearshore (Brad Collins style study); 8) Monitor of discharge of river from suspended sediments prior to dam removal.

Elwha Nearshore Management. Actions to promote full ecosystem restoration of the Elwha Nearshore include: 1. Develop and implement an Elwha nearshore restoration action plan. Priorities of plan include preservation of Freshwater Bay and lower river nearshore thru property CE/acquisition, ecosystem restoration of the Elwha estuary, and restoration of Elwha feeder bluffs and Ediz Hook. Incorporate feed rate into bluff management. 2. Analysis of sedment projections to estuary and development of adaptive management actions that might be anticipated; 3. Preserve feeder bluffs of Dungeness drift cell, which are comparative sites and of extremely high ecological importance. 4. Identify ELJ sites if any in Elwha nearshore 5. Cost benefit analysis of changing pipeline alignment so not on beach along feeder bluffs 6. Adaptive management priority actions (contingency actions) for sediment processes in river 7. Data clearing house for data managers, data integration, shoreline atlas 8. Continue working with citizens, local colleges and education groups.

Pollution

Toxics

Impact of toxic stressors on freshwater ecosystems. There is significant uncertainty in the ability to track toxic contaminants in freshwater ecosystems; monitoring data are limited in many water bodies. Since most of the contaminants deposited in Puget Sound originate in upland areas and are transported to the Sound via freshwater streams and rivers it makes sense that we have a better understanding of the impact of these stressors on freshwater ecosystems. While the existing Ecosystem Recovery Targets focused on freshwater evaluate "water quality" they provide limited insight on the impacts of contaminants to freshwater ecosystems. For example, neither of the two freshwater based targets would be able to track the high levels of contaminants in Lake Washington fish, or the incidence of coho pre-spawn mortality in streams. While the B-IBI can measure general conditions of stream health and conventional water quality parameters (DO, temperature, nutrients etc, this measure is not currently designed to be sensitive to the effects of contaminants that can be common in many streams. As such, there is significant uncertainty associated with the ability to understand the impact of contaminant stressors on freshwater ecosystems.

PBDE Flame Retardants. A focus on points of entry of polybrominated diphenylether (PBDE) flame retardants should be established so that pollution can be prevented. These compounds have contaminated wildlife, especially top aquatic carnivores (e.g. Orcas) in the Pacific Northwest. With people discarding foam rubber, treated fabrics, computers, and other contaminated materials, there is a very time-sensitive need for containment. Manufacturers may also be important sources.

Toxics Monitoring. Develop an integrated toxics monitoring program that includes marine mammals, fish, and other appropriate models to gain a better understanding of the movement (or lack of) through the food web and a better understanding of those chemicals that are likely having ecosystem impacts.

Health of Biota. What are acceptable levels of toxic contaminants in biota, relative to their own health and the health of their consumers (including humans). Need effects thresholds.

Biota at Population Level. What is the effect of toxic contaminants on marine and anadromous biota at the population and community level?

Bioaccumulative Contaminants. How/where do bioaccumulative contaminants enter the food web? Directly via water-to-pelagic organisms or indirectly via water-to-sediments-to organisms?

Point Sources. We're getting much better at identifying point sources of pollution in the Sound and Hood Canal – this is extremely important and should be a major research focus.

Range of Pollutants. What are we measuring? We only see what we look for and many chemicals are being overlooked, in terms of what's dumped (primary chemicals) and how they react with their environment (secondary chemicals). We need be able to identify a greater range of potential pollutants.

Pollutant Mapping. We should have a map of pollutants in the Sound. It would be a good communication tool and it could be improved as our understanding does. It would be nice to see a Google Earth map where you could focus in and get very local water quality info. Point source introduction of pollutants is a huge contribution, so small scale mapping is very important.

Septic Systems. Sample and monitor the quality of sewage effluent (nitrogen & bacteria, primarily) down-gradient of septic system drainfields that have been designed, located, and installed in conformance with modern septic system rules (1996 – present). The purpose of this monitoring/sampling would be primarily twofold: 1. To gain more certainty on the fate and transport of nitrogen from septic systems (that are <u>not</u> located with 100 feet of a shoreline, which is the super-majority of all existing septic systems); and 2. To better identify the types of septic systems, soils, and/or setbacks that achieve the highest levels of nitrogen reduction (influent vs. post-drainfield "effluent"). There is still a large degree of uncertainty for this area, and many models, decisions, and planning are being made with assumptions that may or may not be accurate.

Source of bacteria in nearshore following participation events. There is uncertainty regarding fecal coliform and enteroccoci bacteria in the marine nearshore following precipitation events and the source of bacteria (e.g., human, domestic animals, waterfowl, etc). Understanding this will help enable better targeting of recovery actions.

Marine sediment toxicity tests as indicator. There is uncertainty regarding the validity of using marine sediment toxicity tests as an indicator of sediment quality. Concerns with these tests have been raised multiple times in the scientific literature and by multiple scientists. A workshop or other gathering of scientists to specifically address this issue has not occurred to date and should be addressed.

Toxics in Marine Food Webs. Through our work with the beached transient orca, CA-189, which showed some of the highest levels of organic pollutants ever found in a marine mammal, we have also become concerned by persistent and emerging toxic compounds in the Salish Sea. Emerging pollutants, such as endocrine mimicking compounds, flame retardants, plasticizers, and pharmaceuticals introduced into marine waters are poorly studied. There is relatively little information available about effects of these compounds on human and wildlife health, ways to reduce human exposure or ways to reduce the loading rate of these compounds into the Salish Sea.

Toxic Chemicals. Additional targeted science on specific sources, transport, and fate of toxic chemicals in the Puget Sound ecosystem would focus management activities on key processes. For example, we found high levels of many chemicals of concern in streams draining commercial lands and agricultural areas under the Toxic Chemical Loading Assessment. Further isolating the sources of these chemicals within these landscapes and identifying effective treatment technologies would inform programs targeting these specific sectors. As another example, refining contributions from roofing materials will improve future management and protect the cleanup sites we have already invested in. For nutrients, pathogens, and other conventional contaminants, we generally lack direct measurements of rate parameters. Most programs focus on assessing levels of contaminants in the environment, and relatively little information is available on the transfer or attenuation of these contaminant sources.

Relative Impacts. We have few assessments that compare relative impacts of multiple sources. For example, a Puget Sound model of flame retardants (PBDEs) or metals such as copper would link contaminant loads to food web components. This could be used to evaluate reductions necessary to meet specific environmental endpoints and to identify the most influential sources. We have moderate information from similar assessments of PCBs but no compilations for these specific parameters.

Runoff from the Built Environment

Lack of marine bacteria on an appropriate temporal and special scale. There is a lack of bacteria data on a sufficiently high temporal and spatial scale for marine nearshore beaches. While a long-term monitoring effort may not be required to address all the uncertainties regarding marine bacteria, a multi-year sampling effort would assist in meeting the marine swimming beach recovery target.

Lack of sufficient data in regard to marine phytoplankton and high resolution nutrient and dissolved oxygen. There is an insufficient amount of marine phytoplankton data available (chlorophyll measurements as well as community structure) in addition to an insufficient amount of high temporal resolution nutrient and dissolved oxygen data to assess nutrient and dissolved oxygen dynamics. There is good communication between the entities collecting the majority of water quality data (i.e., King County, Ecology, and UW) and the newly formed marine water quality working group will facilitate communication between these groups as well as others and should continue to be supported.

Lack of models that discern anthropogenic and natural sources of dissolved oxygen. We know the regions that are the likely places for low DO issues/highest concern, particularly constrained basins with long residence times, such as southern Hood Canal, and various southern end-bays and inlets, however, we are still parsing apart the anthropogenic signature from natural/ocean-derived nutrients in these areas. We need better primary production modules which are ecologically self-organizing to improve the quantification of the uncertainties and help refine research needs (better data to capture the diversity of the pelagic ecology, for example, may be needed to adequately capture DO dynamics). In addition, although loading estimates have been generated, the lack of gages for quantifying the total streamflow/load for various streams (downstream of stations/ungaged flows) in the PS watershed still compromises the quality of these estimates, which should be refined (as models are improved and more data become available).

Sampling and Testing. Further sampling and testing, such as molecular typing by smaller organizations might be indicated to elucidate pathogen source(s) and help mitigate their deposition into Puget Sound in coordination with local stakeholders and OH scientists. Such findings can help encourage coordination amongst regional stakeholders, such as wildlife, environmental and human health agencies, and OH scientists to improve upon prevention of outbreaks of waterborne pathogens and to coordinate

response should pathogens be detected. The OH approach will consider multiple aspects of pathogen detection and distribution, including pathogen surveillance and determining if they are of animal or human source. These aspects will involve local, state and federal regulatory responsibilities and constituent water use, and are best addressed at the community level where local stakeholder priorities and possible solutions can be evaluated together for the most optimal outcomes.

Source of Pathogens. The greatest scientific uncertainty is the source of pathogenic bacteria, fungi, protozoa viral diseases that have been identified, and the need to compile this data to: 1) compile a baseline, and 2), start to investigate sources of pollution and the degree of risk to the public and natural resource to reduce sources of water pollution and drive management of those sources that can be related to population growth.

Monitoring Gaps. We lack monitoring data that lead to uncertainty in our understanding and modeling of dissolved oxygen dynamics. We have extremely limited information on vertical particle flux, yet the oxygen drawdown is directly related to this rate. In addition, we have some recent monitoring programs focused on Admiralty Inlet and the Tacoma Narrows, but additional information is needed to characterize the movement of oceanic and other water masses. We have extremely limited information on pH and ocean acidification.

Nutrient dynamics. One key question to address for Puget Sound recovery is nutrient dynamics and the biological response to nutrients and subsequent effect on dissolved oxygen concentrations. While monthly nutrient data are available throughout most of Puget Sound, there is some uncertainty about nutrient pathways from incoming oceanic water, particularly on a finer temporal and spatial scale. In situ monitoring systems will assist with this temporal aspect of uncertainty, but these systems are only in limited locations. The amount of information available on nutrient pathways is moderate at best. There also is a large amount of uncertainty regarding the biological response to nutrients as monthly chlorophyll data are inadequate for assessing phytoplankton response to nutrient availability given the timescales on which phytoplankton can respond. In addition, little data are available for phytoplankton community structure (even at the broader taxa level) and their response to nutrient inputs. This is an area that needs improvement in order to address nutrient-phytoplankton-oxygen dynamics Puget Sound-wide and provide information for the dissolved oxygen recovery target. We urge continued diligence on this topic as ongoing studies by the Department of Ecology relating to dissolved oxygen in Puget Sound, given the importance of developing effective targeted solutions to address these problems. (Note: there are also data needs associated with understanding the extent and cause of harmful algal blooms, although it appears that these are being addressed by others, e.g. NOAA's ECOHAB and PS-AHAB projects).

Fate and transport, and source identification, of anthropogenic nitrogen. Although much work has been done in the region to quantify and evaluate the fate and transport of nitrogen into sensitive areas of the Puget Sound (e.g., Hood Canal, Quartermaster Harbor, South Sound) there remains a large amount of uncertainty regarding fate and transport. This affects the ability to formulate management responses and effective strategies. Innovative measures, such as utilizing emerging contaminants as tracers or pathway indicators, is needed.

Dissolved Oxygen in Hood Canal. Low dissolved oxygen is an issue in Hood Canal. The most significant uncertainty is the amount of human related nitrogen from the near shore on-site septic systems that results in drawdown of dissolved oxygen during the critical summer months. Reducing the uncertainty is essential to developing corrective action to improve the dissolved oxygen in Hood Canal and reduce the stress on the marine life.

Hood Canal Monitoring. There is a need for a sustained marine monitoring program for Hood Canal within the Puget Sound Partnership (PSP) Biennial Science Work Plan. There is a need to continue certain aspects of marine monitoring in support of corrective action recommendations and evaluation of implemented actions. Monitoring the marine system is useful as a gauge which reflects the terrestrial input, the marine dynamics and the scale of natural variability. In the long run there will be monitoring needs focused on specific regions of Puget Sound which will be integrated regionally. The Hood Canal marine monitoring program should serve as component to the larger Puget Sound marine monitoring program as yet to be detailed.

Wastewater

Chemicals of emerging concern. A significant area of scientific uncertainty lies in the lack of understanding, on many levels, regarding chemicals of emerging concern (endocrine disputers, pharmaceuticals and personal care products, PFOS, Bisphenol A, etc.). While some monitoring programs and special studies have evaluated a handful of these chemicals, most are not routinely monitored. While little is known about the presence of most of these chemicals, even less is known about their potential to cause adverse effects to both aquatic life and humans in the Puget Sound region. Limited data collected by NOAA and WDFW suggests that chemicals capable of disrupting the endocrine system are present in Puget Sound at levels sufficient to cause reproductive impairment. However, the specific chemical(s), responsible, and the degree and spatial distribution of this impairment throughout the Sound has not been specifically identified. A better understanding of the specific causal agent(s) is necessary before any action to address the issue can be identified.

Emerging Contaminants. By definition, emerging contaminants warrant additional information to determine sources, transport, and fate in the environment. Early work also could focus on the degree to which current source control or treatment technologies are successful. Also by definition, we have anecdotal evidence sufficient to raise the question for specific emerging contaminants.

Loading of emerging contaminants. Emerging Contaminants can be thought of as chemical species that are being produced in significant quantities anthropogenically and have the potential to be toxic to both human health and the environment, but are currently unregulated and for which well-developed analytical methods do not yet exist. These compounds are typically small organic molecules such as caffeine, ibuprofen, triclosan (an antimicrobial agent), etc. Emerging contaminants may be valuable as chemical markers of anthropogenic inputs (i.e., wastewater effluent, agricultural runoff, stormwater) to the Puget Sound. Method development is needed to allow accurate quantification.

Shellfish

Shellfish and DSP. The greatest area of uncertainty for Department of Health is estimating impacts to humans through shellfish consumption related to DSP. This relates to the absence of monitoring data for this biotoxin. For mechanisms related to distribution of and triggers for DSP, key questions are basic information on presence and distribution in Puget Sound shellfish. For interactions, the key question relates to interactions of temperature, climate, nutrients, and timing of DSP blooms. For responses, the key question relates to whether shellfish will continue to have DSP after remediation actions such as decreased nutrient outputs from septic systems. Qualitatively, the information we have to support our assessment of uncertainty is low – the presence of DSP is new to Washington. However, there are some papers from nearby waters in British Columbia. We are missing information on when and where DSP occurs in Puget Sound and on what triggers toxicity. For human health, DOH has interest in understanding and reducing pressures via septic systems, agricultural practices, industrial waste,

pollution (runoff from roofs, pilings, etc.), pharmaceuticals in wastewater treatment and other non-point sources. The DOH laboratory must have new equipment to be able to test for this toxin. Public health cannot be adequately protected if this capability is not developed.

Other

Plastics in the Marine Environment. PTMSC has been involved in evaluating plastics in the marine environment and plastics ingestion by marine fauna. We sampled beaches in all twelve US Salish Sea counties and documented the ubiquitous presence of large and small plastic debris in beach sediments. We also documented the ingestion of plastics by seagulls. Based on our analysis of research done regionally, more research could be done on ingestion of plastic by other species in the marine ecosystem. The degree to which plastics act as vehicles and attractants for lipophilic toxic compounds needs further study, as does the impact of plasticizers such as phthalates leaching from degrading plastics. The fate and transport of plasticizers, their movement in the food web, and their impacts on human and wildlife health need more study.

Marine Debris. We need to classify, quantifying identifying the source of, and remove debris from the marine environment. Key unanswered question: Identifying the debris sources. Are our watersheds in fact 'debris sheds.' It would be useful to our understanding of the Salish Sea to understand debris in other areas. There are other collection and identification programs but there appears to be no overall Puget Sound data gathering effort. Debris (components and amounts) varies greatly within the Salish Sea.

Variability. Our monitoring programs indicate a variety of hotspots in the ecosystem and overall ambient conditions but may not capture high spatial or temporal variability. We should identify parameters and media where continuous monitoring and remote sensing investments make the most sense. We have moderate information based on recent advances in ferry-based data platforms, profilers, and remote sensing.

Climate Change

Future impacts from climate change. It presents several key questions affecting Action Agenda, including "How will ocean acidification impact our food web?" How will climate change impact species ranges, including invasive species, and how will those range shifts impact health of our ecosystems? How will climate change impact timing of migrations and movements of species that depend on one another for one or more critical stages in their life histories? The Action Agenda and Biennial Science Plan should recognize and consider these questions.

Ocean Acidification. We need aggressive evaluation of baseline conditions so we can understand degree of ongoing change.

Temperature Monitoring. Monitoring of stream and lake temperature, especially during summer, would provide valuable information for planning for and adapting to climate change. Almost no temperature monitoring is conducted in Washington, but it increasingly simple and inexpensive to monitor.

Benthic Communities. Changes to benthic communities in relation to habitat and climate change require additional attention.

Climate variation. There is a growing body of evidence that climate variation (including cyclic variation like PDO and longer-term anthropogenic change) affects shellfish performance in many ways, with potential influences through trophic interactions (including for scoters, a marine bird of concern).

Genetic Variability and Adaptation. Have populations lost genetic variability to the point where they have diminished abilities to respond to changing environments? What are the molecular connections between genomic variability, adaptive gene complexes, and factors limiting population recovery?

Weather Station Data. We should have all the public and private weather station data stored in a repository so we can track climate change. Such a large data set would be extremely valuable to the people trying to evaluate Sound conditions in 30, 50, 80 years. A changing climate will result in changing vegetation and other biotics. Warmer stream water, for example, acts as a viable host for more types of bacteria. If we know how the climate is changing, we can predict what new biotics we might expect.

Human Dimensions

Social Science. There is a profound need to invest in robust, peer review quality social science of Puget Sound conditions, management effectiveness and opportunities. This includes sociological, anthropological, economic and legal studies. Human dimensions research should be linked to natural and physical science research. Management, as a social construct, must be informed by detailed assessments, not hunches, to identify 'best practices'. Furthermore, while important, further ecological and oceanographic studies will not identify management options or opportunities. Numerous examples (California MLPA, Australia Great Barrier Reef) have clearly demonstrated the need for empirical, applied social sciences. It is surprising that this has not been an emphasis to date.

Baseline Literature Review. A baseline social science literature review is needed to identify current resources and determine where gaps remain. This literature review would include studies directly pertaining to Puget Sound. It would also incorporate studies from other major basin systems in the nation (e.g. Chesapeake Bay, the Everglades) for relevant findings.

Public Engagement Assessment. Recognizing different demographics' role and connection to ecosystem services there is a need to complete a comprehensive characterization (baseline data collection effort) and evaluation of public engagement in support of ecosystem recovery (behaviors, patterns, preferences, etc.) including citizen science, stewardship, and changes in behavior. This knowledge will inform programmatic design and implementation over time. Engaging the arts, religious groups and other non-traditional communities would be a means by which to expand "public" support, involvement, and engagement over time.

Human Dimensions and Open Standards for Conservation. The human dimensions portion of the Open Standards for the Practice of Conservation Framework should be completed. This would involve the development of a conceptual model of contributing factors for our current state of the ecosystem as a means to define objectives/outcomes needed to advance ecosystem recovery goals for the human dimension of the ecosystem. This framework could be refined for unique "place based" analysis such as is being done by the Hood Canal Coordinating Council. Human dimension indicators and targets could then be developed based on individual area's stressors and valued social, economic, and cultural components.

Ecosystem Services Valuation. Ecosystem restoration and enhancement is not just good for the environment, it is good for people too. That is, people derive benefits from services provided by a healthy environment. To achieve recovery goals, the Partnership must measure the process and

effectiveness of recovery not only in terms of ecosystem health, also in terms of the impacts that recovery has on people. Numerous studies have been conducted to estimate the value of marine ecosystems (Pendleton, 2008; coastalvalues.org/work/reseources.html), including studies of the economic values of restoration in other parts of the United States (Austin et al, 2007). But few studies have been conducted that show empirically that restoration and preservation have had an effect on human uses of ecosystem services. This is particularly true for the Puget Sound. It is recommended that the PSP invest in ecosystem service valuation studies that cover a range of provisioning, regulating, and cultural services as outlined in the Millennium Ecosystem Assessment Framework.

Economic Incentives. There is a wide array of economic incentives, including tax reductions, conservation easements, transfer of development rights, and fee simple land purchase. We need research to determine the most cost-efficient combination of regulatory and voluntary programs for controlling the conversion of native habitats to residential development.

Habitat Value. What is the biological/production value of ALL habitats and how does this value vary over time?

Fisheries. There is uncertainty about the economic and social impacts of closing fisheries because of low population abundance, including impacts on commercial and recreational fishers and on related industries (boating, stores, bait suppliers, etc.).

Sustaining, Coordinating, & Using Science to Adapt Actions

Building capacity

Institutional Analysis. There is a need apply institutional analysis to the overall management framework to evaluate where the PSP (Shared Strategy) approach is the most efficient and effective. This research could take the form of institutional/management mapping, network analysis and an evaluation of existing social capital and organizational capacity (within and across institutions) to achieve ecosystem recovery goals. Are there other models that might work better to reach ecosystem recovery goals? It is time to readdress opportunities and constraints to more effectively and efficiently restore the Puget Sound. An outcome from this analysis would be to increase the capacity for institutions, NGOs, and the tribes to work better together, recognizing the need to bridge (in particular) western and tribal values and management approaches.

Interdisciplinary Coordination. Lack of coordination between social, natural, and physical science disciplines is a factor impeding development of realistic recovery strategies. Researches should help each other understand the meaning and relevance of their work. It is also necessary to coordinate with user groups and the public.

Governance. The strengths and weakness of the current Puget Sound governance system is poorly understood. The last overarching study was in the early 70s by Bish. Management seems to be operating on a basis of available opportunities and policy maker understanding of what is feasible/preferable. The global standard is to base management decisions on applied social ecological research.

Ensuring adequate scientific basis of actions. In efforts to update the Action Agenda (and identify near term actions), and haste to implement them, the Partnership should not lose sight of the need that they be supported by best available science (evidence) to demonstrate that they will be both effective and cost-effective. This requires work in the natural, physical, and social sciences. The public will demand that actions be effective and a good expenditure of funds, and failures of actions to produce

demonstrable results (because they were determined in the absence of science, or with poor application of existing science) will undermine public confidence, waste resources, and be detrimental to the overall effort. Uncertainty will always exist, but there should be a scientific basis that each action is truly needed (will be effective, and cost-effective). At the same time, it is important to scientifically test assumptions that certain activities are not problematic (and thus not included) simply because of lack of knowledge (i.e. to challenge, assumptions that no action is needed because it has not been shown to be a problem). Simply put, focused scientific work should help confirm that actions are likely to be effective and nothing big is missing.

Foundational Questions

Need for additional work at appropriate ecosystem scales. The partnership should promote a scaled approach to ecosystem recovery (including salmon protection), considering both the larger (whole species populations and ecosystem processes) in addition to individual projects / basins (implementing concepts described in the attached article). For example, successfully seeing such a vast area truly recovered would necessitate "recovering" even vaster areas (parts of the Pacific Ocean, for example) as well as witnessing changes in other socio-economic and Tribal/First Nations variables such as harvesting – not just in Puget Sound, but everywhere that impacts biology and ecological processes in Puget Sound. There need to be mechanisms that ensure and oversee inter-jurisdictional cooperation to understand how individual projects affect populations affect entire populations and communities of fish.

Land Use and Marine Environments. In Puget Sound, urban development, shoreline alteration, agriculture, industrial development, logging among other human activities are the major pressures on estuarine and marine species. While the PSP recognizes this, quantitative links between land use / land cover and Puget Sound marine species and food webs is lacking. Filling this research gap requires investigations of when, where and how land-based human activities influence ecosystem function in Puget Sound marine environments.

Conservation. We need more information on how to maximize values of land-use conservation approaches to aquatic and terrestrial systems simultaneously. That is, how do we structure land-use patterns (at whatever level policy decides) that maximize benefits to both aquatic and terrestrial biodiversity at the same time?

Lack of awareness and general confusion about the spatial distribution of biological values and land use effects. Simplistic or "one size-fits all" approaches leads to poor understanding of the problem(s) as well as unclear, unachievable, ineffective and sometime counter-productive goals, objectives and actions and undermines credibility of the science.

Differentiating between natural variability versus human-driven change. In assessing effectiveness, there is insufficient understanding about the role of natural variability in space and time versus real land-use driven change. For example, B-IBI scores are good predictors of very bad conditions (urban and sub-urban development) but there is high variability among scores in rural areas. Similarly, variability of salmonid use is very high outside urban and sub-urban development densities and there is a poor understanding of how site and reach-scale conditions contribute to variability in diversity, abundance and productivity of biota. Understanding natural variability is key to differentiating between natural vs human-caused change, assessing effectiveness of actions and for development of effective strategies to protect and restore critical biota and habitats.

Historical Conditions. What are the key aspects of historical conditions that we need to understand? Changes in nutrient regimes? Long-term cycling in abundant species e.g., herring and pink salmon? Oscillations or changes in climate condition?

Pristine Areas. What are baseline ecosystem conditions of pristine areas?

Historical Studies. There is a need for historical (e.g., paleo) ecology studies to document the post glacial (especially modern human) biological character of the system.

Spatial distribution of biological values. Identifying important and un-important places – Not all places/habitats are equal but they are often treated as such. The question of what areas have very high and very low intrinsic value or that are so heavily constrained by existing development that they are unlikely to provide much biological value beyond current condition is important for prioritizing time, money, level of regulations, etc. King County undertook such an evaluation in 2004 as part of its regulatory update (http://your.kingcounty.gov/ddes/cao/PDFs/mapKC-BasinShorelnCond-15051AttachA.pdf) and has made additional similar efforts. This is particularly important in regard to the Partnership's role in targeting and prioritizing actions.

Scientific Tools for Informing Policy

Marine Spatial Planning. We are zoning the terrestrial environment and considering impacts but are not devoting similar efforts to the marine environment. This requires a better understanding of the distribution of species and habitats and a better integration into a comprehensive GIS product.

Mapping. Location and inventory of physical features and biological resources in Puget Sound – continue efforts to map these characteristics in compatible layers.

Key Stressors. Research to advance our limited understanding of the magnitude and spatial extent of key stressors in Puget Sound. This information is needed to prioritize work to minimize stressors.

Prioritization. How do we prioritize recovery efforts and identify important gaps in these efforts? Use ecosystem models to help with this?

Adaptive Management. We need to have an adaptive management plan and science agenda that can assess the ecological consequences (validity) of watershed characterization for terrestrial, freshwater aquatic and nearshore biodiversity.

Integrated, sustained monitoring

Intensively Monitored Watersheds. There is a need to better understand the effectiveness of stream restoration activities by continuing, and expanding where appropriate, the Intensively Monitored Watersheds (IMW) Project.

Restoration Project Monitoring. Monitor the success and longevity of permitted restoration projects across Washington. Many projects, such as road crossings, large wood placement, etc. likely fail, but we cannot make improvements because we have little information on rates or causes of failure.

Hydraulic Permit Authority. Monitor and measure compliance and effectiveness of the Hydraulic Permit Authority program.

Critical Area Ordinances. Monitor and measure compliance and effectiveness of GMA critical area ordinances.

Integrated Monitoring. Develop a monitoring plan that integrates bird, mammal, salmon, forage fish, and zooplankton monitoring in space and time (perhaps from the same vessel) to come up with an integrated assessment of ecological condition.

Effectiveness Monitoring. A key component missing from many management programs is effectiveness monitoring. Effectiveness monitoring of environmental endpoints must be conducted in conjunction with source control and other management actions to evaluate whether they are reducing contaminant inputs. Effectiveness monitoring information is critical to our adaptive management strategy.

Assessment and Monitoring. There is a need for broad (spatially, temporally, taxonomically) biological assessment and monitoring that incorporates the full range of natural and anthropogenic gradients into sampling designs.

Type and extent of monitoring data for ecosystem recovery targets. Monitoring data are necessary for the success of the recently developed Ecosystem Recovery Targets. However; as budgets for local, regional and state monitoring programs continue to be cut, it reduces the availability of monitoring data to track ecosystem changes defined by the targets. This increases the uncertainty associated with the ability to track ecosystem changes and our ability to meet the targets. To more effectively target limited monitoring funds, a better understanding of the specific data needs necessary to effectively use the targets to track progress and conditions would be desirable. What type(s) of data (and how much) are necessary to determine if we are meeting the targets? What is the spatial distribution/scale of data necessary to make meaningful conclusions on a Sound-wide or regional basis? The Ecosystem Recovery Targets have been showcased as a key tool in the recovery of Puget Sound; however, in some cases data may be insufficient to both establish a baseline from which to measure change and to understand if we are meeting the defined goals. A number of issues related to data needs necessary to track the targets need clarification to better focus limited monitoring funds.

Dashboard Indicators. Develop more scientifically driven dashboard indicators (appropriate sampling design)

Education, training & outreach

Education. Organism (health and condition) "tell us" about problems in the ecosystem. How can we use this to help educate people about key problems? How do we get the message across that Puget Sound is not ok? We should encourage people to act locally by educating residents about PS conditions where they live. How do we make the emotional connection with people are: the problem of "death by 1000 cuts" that seems to be occurring?

Pollution Education. The Town of Friday Harbor Sewage Treatment Plant takes care of pathogens and some chemicals but the manager said that if someone dumps turpentine down the toilet it is about the same thing as pouring off of the dock. A project could be done to engage local communities. Take a baseline sample establishing a panel of 8 to 10 of the most pernicious chemicals contributed by residential use followed by 12 more monthly samples. Implement a well defined duplicatable advertising campaign involving the local paper and the schools. The idea is to use creative advertising that clearly makes the link between what goes down the drain and the food chain. The goal is to change the chemical loads by using preferred products.

Education and Outreach. It is critical that the PSP recommend the use of effective education programs - education and outreach that leads to real change that is appropriate and specific to various populations. There is a need for research that investigates impacts of experiential education and how elements found to be most successful can be translated to others.

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