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

<table>
<thead>
<tr>
<th>Focus Area</th>
<th>Strategy</th>
<th>Science Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Protect and Restore Terrestrial and Freshwater Ecosystems</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Habitats</td>
<td>A1</td>
<td>• Develop analytical tools to identify options for where to protect, where to restore, and where to develop while maintaining desired ecological goods and services.</td>
</tr>
<tr>
<td></td>
<td>A2</td>
<td>• Use social science to guide development of adaptive management structures that can effectively link restoration science to management decision-making.</td>
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<td></td>
<td>A3</td>
<td>• Develop ecological indicators; assess baseline conditions; and implement monitoring to measure ecosystem function relative to no net loss.</td>
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<td></td>
<td></td>
<td>• Conduct social science studies to describe the key institutional challenges to attaining no net loss and improvements from restoration.</td>
</tr>
<tr>
<td>Floodplains</td>
<td>A5</td>
<td>• Estimate the value of floodplains in terms of the ecosystems services they provide.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Develop key ecological indicators and implement monitoring to assess status of floodplains.</td>
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<tr>
<td></td>
<td></td>
<td>• Improve understanding of the effects of vegetation on dikes and other flood control structures.</td>
</tr>
<tr>
<td>Species and Foodwebs</td>
<td>A6</td>
<td>• 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.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Identify the causes of apparent decline in marine survival of salmon as they leave their natal rivers and exit Puget Sound.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Assess risks imposed by terrestrial and freshwater invasive species.</td>
</tr>
<tr>
<td>Freshwater</td>
<td>A8</td>
<td>• Develop robust ecological indicators and implement comprehensive monitoring for stream flows.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Evaluate and improve stream flow targets in terms of their effects on abundance, productivty, distribution, and life-history diversity of salmon.</td>
</tr>
<tr>
<td><strong>Protect and Restore Marine and Nearshore Ecosystems</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Habitats</td>
<td>B2</td>
<td>• Develop analytical tools to identify priority areas for protection, restoration, and stewardship.</td>
</tr>
<tr>
<td></td>
<td>B3</td>
<td>• Develop adaptive management structures that link restoration science to management decision making.</td>
</tr>
<tr>
<td>Species and Foodwebs</td>
<td>B5</td>
<td>• Develop 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.</td>
</tr>
<tr>
<td></td>
<td>B6</td>
<td>• Implement studies to identify stressors on forage fish.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Implement studies to understand the causes of declines in marine bird abundance.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• 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.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Assess risks imposed by marine invasive species.</td>
</tr>
<tr>
<td><strong>Reduce and Control the Sources of Pollution to Puget Sound</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contaminants</td>
<td>C1</td>
<td>• Implement studies on persistent, bioaccumulative chemicals to understand transport, trophic transfer, 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.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• 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.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Develop integrated monitoring and assessment of toxic chemical sources, exposure, and effects.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Synthesize information on emerging contaminants of concern.</td>
</tr>
<tr>
<td>Runoff from the Environment</td>
<td>C2</td>
<td>• Develop monitoring and assessment of benthic invertebrates in small streams to evaluate stormwater management and other efforts to protect and restore streams.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Evaluate the effectiveness of low impact development (LID) projects and stormwater management best management practices and programs.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Evaluate land uses and associated pollutants that would require treatment beyond sediment removal.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• 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.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Evaluate individual and combined effects of commonly used pesticides on salmonids, other fish, and their foods.</td>
</tr>
</tbody>
</table>
| 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.  
| 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. |
# Table of Contents

EXECUTIVE SUMMARY ............................................................................................................... 1

INTRODUCTION ............................................................................................................................. 1

- Approach .................................................................................................................................. 2
- Uses of this Document .............................................................................................................. 4
- Comparison of Recently Completed Research and Recommendations ..................................... 6
  - Terrestrial and Freshwater Ecosystems ................................................................................... 9
  - Marine and Nearshore Ecosystems ......................................................................................... 9
  - Pollution ................................................................................................................................. 10
  - Climate Change .................................................................................................................... 10
  - Human Dimensions ........................................................................................................... 11
  - Sustaining, Coordinating, and Using Science to Adapt Actions ........................................... 11
- Recommendations from the Scientific, Practitioner, and Stakeholder Communities ................ 12
  - Upland, Terrestrial and Freshwater Ecosystems ................................................................. 14
  - Marine and Nearshore Ecosystems ...................................................................................... 14
  - Pollution ............................................................................................................................... 15
  - Climate Change ................................................................................................................... 15
  - Human Dimensions ............................................................................................................ 15
  - Sustaining, Coordinating, and Using Science to Adapt Actions ........................................... 15

PRIORITY SCIENCE FOR 2011-2013 .......................................................................................... 17

- Upland, Terrestrial, and Freshwater Ecosystems .................................................................. 17
  - Upland and Terrestrial Habitats ........................................................................................... 17
  - Floodplains .......................................................................................................................... 18
  - Freshwater Species and Food webs ....................................................................................... 18
  - Freshwater Ecosystems ......................................................................................................... 19
- Marine and Nearshore Ecosystems ......................................................................................... 19
  - Marine and Nearshore Habitats ............................................................................................ 19
  - Species and Food Webs ........................................................................................................ 21
- Pollution .................................................................................................................................. 23
  - Contaminants ........................................................................................................................ 23
  - Runoff from the Environment ............................................................................................... 24
  - Wastewater .......................................................................................................................... 25
  - Shellfish .................................................................................................................................. 25
  - Oil Spills .................................................................................................................................. 26
  - Cumulative Water Pollution .................................................................................................. 26
- Emerging Issues – Ocean Acidification .................................................................................... 26
- Sustaining, Coordinating, and Using Science to Adapt Actions ............................................... 27
  - Scientific Tools for Informing Policy .................................................................................. 27
  - Monitoring ............................................................................................................................. 28
  - Human Dimensions in Ecosystem Recovery ........................................................................ 28

SUMMARY ................................................................................................................................... 30

- Purpose and Approach ............................................................................................................ 30
- Strengths and Weaknesses ....................................................................................................... 31
Summary of Priority Science Actions.................................................................................................................. 32
REFERENCES.......................................................................................................................................................... 34

List of Figures

Figure 1. General Conceptual Model of Puget Sound Recovery................................................................. 2
Figure 2. Demands on Policy-Oriented Science .............................................................................................. 3
Figure 3. Summary of Recently Completed or Ongoing Studies................................................................. 7

List of Tables

Table ES-1. Proposed Priority Science Areas ..................................................................................................... ii
Table 2. Number of recently completed or ongoing studies and recommended studies focused on ecosystem pressures on Puget Sound. ........................................................................................................... 8
Table 3. Number of recommendations from the scientific community summarized by ecosystem components or pressures corresponding to key strategies of the Action Agenda Update.............................. 13

List of 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
Appendix D: Summary of State Monitoring Programs
Appendix E: Science Needs Identified During Action Agenda Update
Appendix F: Science Needs Identified by Scientific, Practitioner, and Stakeholder Communities
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 km² of fertile lowlands, uplands, islands, and scenic mountains; thousands of rivers and streams; a large, complex fjord-like estuary covering 2,330 km² 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.

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**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)](image-url)
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).

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

<table>
<thead>
<tr>
<th>Ecosystem Component or Pressure</th>
<th># of Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Upland, Terrestrial &amp; Freshwater</strong></td>
<td></td>
</tr>
<tr>
<td>Habitats</td>
<td>12</td>
</tr>
<tr>
<td>Species &amp; Food Webs</td>
<td>7</td>
</tr>
<tr>
<td>Mitigation</td>
<td>4</td>
</tr>
<tr>
<td><strong>Marine &amp; Nearshore</strong></td>
<td></td>
</tr>
<tr>
<td>Habitats</td>
<td>10</td>
</tr>
<tr>
<td>Species &amp; Food Webs</td>
<td>36</td>
</tr>
<tr>
<td>Mitigation</td>
<td>8</td>
</tr>
<tr>
<td><strong>Pollution</strong></td>
<td></td>
</tr>
<tr>
<td>Toxics</td>
<td>15</td>
</tr>
<tr>
<td>Runoff from the Environment</td>
<td>10</td>
</tr>
<tr>
<td>Wastewater</td>
<td>3</td>
</tr>
<tr>
<td>Shellfish</td>
<td>1</td>
</tr>
<tr>
<td>Oil Spills</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
</tr>
<tr>
<td><strong>Climate Change</strong></td>
<td>7</td>
</tr>
<tr>
<td><strong>Human Dimensions</strong></td>
<td>8</td>
</tr>
<tr>
<td><strong>Sustaining, Coordinating, &amp; Using Science to Adapt Actions</strong></td>
<td></td>
</tr>
<tr>
<td>Building Capacity</td>
<td>4</td>
</tr>
<tr>
<td>Foundational Questions</td>
<td>9</td>
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<tr>
<td>Scientific Tools for Informing Policy</td>
<td>5</td>
</tr>
<tr>
<td>Integrated, Sustained Monitoring</td>
<td>9</td>
</tr>
<tr>
<td>Education, Training &amp; Outreach</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>152</strong></td>
</tr>
</tbody>
</table>
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 available 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](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:
  
  o Incorporating additional physical attributes as well as biogenic structures like eelgrass, kelp, or coastal forest condition into estimates of ecosystem services provided by shorelines.
  o Assessing the impacts of barrier features on embayments.
  o 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).
  o More robustly incorporating rare forms, species, and processes in understanding landscape composition.
  o Including landscapes and habitats used by target species.
  o Incorporating threats to ecosystem services and potential for protection.
  o 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 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 20th 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.
References


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
Appendix D: Summary of State Monitoring Programs
Appendix E: Science Needs Identified During Action Agenda Update
Appendix F: Science Needs Identified by Scientific, Practitioner, and Stakeholder Communities
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
The report describes several of the main programs and services of the Washington State Department of Ecology to estimate nutrient and pesticide concentrations in salmonid streams. The study results indicate that prior knowledge of the pesticide use patterns is needed to target specific pollutants. The current regime of weekly sampling throughout the application season captures a variety of pesticide detections. The report results show consistent patterns throughout the placement period, the devices did not provide information on the presence or absence of selected pesticides. The report presents results of a multi-year study to characterize pesticide concentrations in salmonid streams. The study results indicate that prior knowledge of the pesticide use patterns is needed to target specific pollutants. The current regime of weekly sampling throughout the application season captures a variety of pesticide detections. The report results show consistent patterns throughout the placement period, the devices did not provide information on the presence or absence of selected pesticides.
Chapter 3 in The Washington Climate Change Impacts Assessment: Evaluating Washington's Climate Change All Species & Food Webs

Climate models used in the PCC ARA project increased in annual temperature of an average, 1.1°C (2°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. Ranges of warming varied from 0.6 to 1.6°C (1.1 to 2.9°F) per decade. Projected changes in annual precipitation, averaged over all models, were small (+1% to +5%), but some models project an enhanced seasonal cycle with changes toward earlier autumn and winter rains and later summer rains.

Forest ecosystems, deforestation, and climate change in Washington State, USA

We address the role of climate in four forested ecosystem processes and project the effects of future climate change on these processes: 1) In areas where Douglas-fir growth is currently limited, productivity increases are predicted, but in places where Douglas-fir is water-limited, growth is likely to decline due to projected increases in summer evaporative demand. 2) By the mid-21st century, some areas in the Interior Columbia Basin and eastern Cascades are likely to experience conditions that are more suitable for mountain pine beetle, and if these areas are climatically stressed, they may be more vulnerable to beetle attack. 3) Regional warming is likely to increase the length of the growing season and yield increases in the coastal and southern forests, where existing genetic variability may be sufficient to adapt to climate change. 4) Forest low vulnerability is closely related to current pressure deficit (VPD), and future projections support the hypothesis that current VPD will increase with significant effect on the range of forest tree species. Due to the increased host vulnerability, MPB populations are expected to become more viable at higher elevations leading to...


The increasing level of carbon dioxide in the atmosphere is absorbed by seawater, causing a noticeable increase in the acidity of global ocean surface water. Coastal upwelling and continued runoff into inland waters exacerbate the changes in some regions. This shifting ocean chemistry could have broad impacts on marine ecosystems and their inhabitants and thus on entire marine ecosystems. Yet due to a lack of sufficient biological data to infer models, accurate predictions of ecosystem effects are not possible. This study aims to understand how coastal and marine ecosystems are likely to respond to the effects of ocean acidification on coastal ecosystems under realistic current and future conditions.

The results of this study are expected to provide valuable insights into the potential impacts of ocean acidification on marine ecosystems, helping researchers and policymakers to better understand and mitigate the effects of this pressing environmental issue. The study's outcomes will contribute to the development of effective strategies for preserving valuable marine ecosystems and protecting the future of marine biodiversity.
C4640.

**Ecosystem Component:** Nearshore
**Primary Pressure:** Invasives, Marine
**Action Area:** Dams, Levees & Tidegates
**Study Title:** Nearshore -- Invasives
**Date:** 2007

**Summary:** 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 reponses and dynamics of various system components following dam removal.

**Study Results:**
- 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 recovering derelict fishing gillnets included 31,278 invertebrates (76 species), 1036 fishes (22 species), 514 birds (16 species), 10 mammals (3 species), and 53 reptiles (2 species).
- For one study net, the study calculated 4368 crab entangled during the impact lifetime of the net, at a loss of $13,858 in Economic value to the commercial fishery, yielding a cost:benefit ratio of 1:14.5.

**Weblink:** [http://www.pugetsoundnearshore.org/technical_reports.htm](http://www.pugetsoundnearshore.org/technical_reports.htm)

---

**C4641.**

**Ecosystem Component:** Nearshore
**Primary Pressure:** Nearshore - Species & Food Webs
**Action Area:** Dams, Levees & Tidegates
**Study Title:** Nearshore -- Species & Food Webs
**Date:** 2007

**Summary:** The habitats and associated species of the Elwha River estuary is estuary, and adjacent nearshore ecosystems prior to dam removal that can be used to evaluate reponses and dynamics of various system components following dam removal.

**Study Results:**
- Microcystins were detected in all samples, with higher concentrations in liver than muscle.
- Temporal and spatial trends in phytoplankton biomass and composition, and the in situ photosynthesis and respiration rates of the dominant species in the Lower Elwha River.

**Weblink:** [http://www.mpbc.wa.gov/programs/technical_r](http://www.mpbc.wa.gov/programs/technical_r)
<table>
<thead>
<tr>
<th>Ref</th>
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<th>Author(s) or Study Contact</th>
<th>Supporting Agency</th>
<th>General Study Design/Methods</th>
<th>Study Results</th>
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<th>Journal Citation (if applicable)</th>
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<tbody>
<tr>
<td>C051</td>
<td>Nearshore - Species &amp; Food Webs</td>
<td>Invasive - Marine</td>
<td>All</td>
<td>Understanding Connectivity Requirements and Generation of Algal Communities and Investigating Cytotoxicity Mapping as a Tool for Early Warning of Harmful Algal Blooms</td>
<td>2008</td>
<td>Greeno, Cheryl</td>
<td>Washington Sea Grant</td>
<td>General Study Design/Methods</td>
<td>Study Results</td>
<td>Weblink</td>
<td>Marine Policy &amp; Management 2008: 50-58</td>
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<td>C054</td>
<td>Marine - Species &amp; Food Webs</td>
<td>All</td>
<td>All</td>
<td>Non-invasive physiological monitoring of southern resident killer whales</td>
<td>2008</td>
<td>Wissmar, Samuel</td>
<td>Washington Sea Grant</td>
<td>General Study Design/Methods</td>
<td>Study Results</td>
<td>Weblink</td>
<td>Marine Policy &amp; Management 2008: 50-58</td>
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Inventory of Recently Completed/Ongoing Scientific Studies

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<td>C0460</td>
<td>Terrestrial - Other</td>
<td>N/A</td>
<td>All</td>
<td>Flow variability and the biophysical vitality of river systems.</td>
<td>2009</td>
<td>Rainwater, R. J., J. J. Lemberger, D. G. Field, and J. D. Gilman</td>
<td>Andrew W. Mellon Foundation; U.S. National Science Foundation; U.S. Army Corps of Engineers-Pacific Northwest Research Station; and Meyers卫生健康 Company</td>
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<td><a href="http://dx.doi.org/10.2742/LPE.2009.05.05.01">http://dx.doi.org/10.2742/LPE.2009.05.05.01</a></td>
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<td>C0462</td>
<td>Terrestrial - Species &amp; Food Web</td>
<td>N/A</td>
<td>All</td>
<td>The Restoration Habitat List by Chinook Salmon in the Puget Sound Ecosystem Using Otolith Analysis: An Additional Year.</td>
<td>2009</td>
<td>Janel Hall, Angela, and Lauren, Kim</td>
<td>US Geological Survey</td>
<td>1</td>
<td></td>
<td><a href="http://dx.doi.org/10.3955/046.084.06.37/02/02">http://dx.doi.org/10.3955/046.084.06.37/02/02</a></td>
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<td>C0463</td>
<td>Marine - Species &amp; Food Web</td>
<td>N/A</td>
<td>All</td>
<td>An analysis of Pre-Restoration Habitat Suitability by Chinook Salmon in the Delta-Flats and Nearshore Regions of the Nisqually River Estuary.</td>
<td>2010</td>
<td>Janel Hail, Angela, and Lauren, Kim</td>
<td>US Geological Survey</td>
<td>1</td>
<td></td>
<td><a href="http://dx.doi.org/10.3955/046.084.06.37/02/02">http://dx.doi.org/10.3955/046.084.06.37/02/02</a></td>
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<td>C0464</td>
<td>Terrestrial - Species &amp; Food Web</td>
<td>N/A</td>
<td>All</td>
<td>Climate smart planning for salmon, salmonids and Trout: A land use planner’s guide to assessing habitat protection and recovery.</td>
<td>2009</td>
<td>Kate Knight</td>
<td>Washington Department of Fish &amp; Wildlife</td>
<td>1</td>
<td></td>
<td><a href="http://dx.doi.org/10.3955/046.084.06.37/02/02">http://dx.doi.org/10.3955/046.084.06.37/02/02</a></td>
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<td>C0465</td>
<td>Marine - Species &amp; Food Web</td>
<td>N/A</td>
<td>All</td>
<td>Pacific Herring and Epizootics in Skagit Bay, Prevalence of Viral Erthrocytic Necrosis in salmonid habitat protection and recovery.</td>
<td>2009</td>
<td>Penny H. W. Needham, G. Stahl, C. A. Greig, J. J. Gregg, C. A. Pacheco, C. Shime, C. Roca, T-R. Meyers</td>
<td>NOAA, Northwest Fisheries Science Center</td>
<td>1</td>
<td></td>
<td><a href="http://dx.doi.org/10.3955/046.084.06.37/02/02">http://dx.doi.org/10.3955/046.084.06.37/02/02</a></td>
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</table>

Notes:
- C0400: Terrestrial - Species & Food Web
- C0421: Terrestrial - Other
- N/A All
- South Puget Sound
- Oceanographic properties
- Water Flow variability
- Terrestrial - Water
- Species composition and relative abundance of large medusae in Puget Sound, WA
- Pacific Ocean
- Streamflow microstructural analysis
- Otolith analysis was used to examine Chinook salmon life history, growth, and residence in the Nisqually Estuary.
- Otolith microstructural analysis can be a valuable tool in establishing baseline information on unmarked Chinook was consistently lower than marked Chinook during all years;
- Ecosystem indicators consisting of lower-trophic level, higher-productivity functional groups tended to perform particularly well. We also identified relationships. Ecosystem indicators such as growth, productivity, 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 spatiotemporal variability in Puget Sound's three main bays, Whidbey Basin, Hood Canal, and Main Basin.
- 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 and annual hydrographic observations at 16 stations from 1995 to 2003, and biannual observations at 48 stations from 1996 to 2003.
- Climatological monthly means of temperature, salinity, and density reveal strong seasonal patterns. Water temperatures are generally warmer (cooler) in late summer (winter) with a range of 0°C to 20°C (3°C to 15°C). Salinity values and density are strongly influenced by freshwater inputs during and spring and summer mixing periods and wind-driven surface cooling, respectively, and vary greatly in the surface waters while being relatively uniform in lower waters. Vertical density structures are primarily determined by salinity variations in the surface layer. Strong vertical mixing and flow over sills at the entrance to Puget Sound generally removes vertical stratification. Mean summer and winter values of oceanographic properties reveal patterns of spatiotemporal variability in Puget Sound's three main bays, Whidbey Basin, Hood Canal, and Main Basin.
Nearshore - monitoring——2008 monitoring report

All Habitats n/a

1997

2009

C0443 Marine - Species & Food Webs

San Juan/Whatcom

Selected Acoustic Abundance of Forage Fish in Rosario Strait, Washington

2009

Denny A. Wilder

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 localizes documented herring spawning grounds in Washington waters to represent discrete stocks.

The cumulative abundance of stocks and coastal Puget Sound herring stocks in recent years is comparable to that observed in the 1970’s and 1980’s, while the Chum River stock, and cumulative north Puget Sound (excluding the Chum River stock) and Strait of Juan de Fuca regional spawning biomass 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 periods (2014 and 2007-08).


Puget Sound demersal fish community

Seasonal variation in guild structure of the Puget Sound demersal fish community

2008

Paulm, J., and T. Esch groen

NW - Fisheries

The study analyzed guild structure of the demersal fish assemblage in Puget Sound, WA, a temperate ecoregion on the US west coast. Using diet information from 2,461 stomach samples collected in 2008 from six different pelagic and demersal species, examined seasonal guild shifting, and tested for seasonal shifts in predation and in differences in the degree of diet overlap at the assemblage level.

http://www.springerlink.com/content/09223638/

Marine & Coastal

11750-001

Tidal influence on the foraging behavior of benthic webs (Phoca vitulina) at a site available at all tide levels

2010

Parkinson, J., and A. Komada-Guendner

Western Washington University

The study counted hauled-out Harbor Seals from sunrise to sunset on Vancouver Island at Sandmarka Marina, Washington, to examine the effect of tides on hauled-out behavior. Because haul-out behavior is affected by several factors, we conducted mixed model analyses that included tide level, tide current, time of season, and time of day as fixed factors, and several meteorological variables as random factors.


Northern Southeast

89-17-23

Puget Sound intertidal benthic community monitoring—2008 monitoring report

2009

Decker, M. R., and R. Berry

H. Springer, A. G. and Ewema, S.

University of Washington

This study monitored benthic communities and assessed the condition of intertidal habitats since 1997 (in collaboration with UW). Monitoring methods characterize epifauna and infauna using visual and core samples.


Marine & Coastal

11750-001

Reframing - habitats

South, South Central

Marine habitats in physical features near constituent saltwater estuaries for estuarine habitat

2010

Decker, M. R., and Berry

University of Washington

Analysis of physical parameters of beaches to look for correlations with shallow gradients in intertidal biota at Admiralty Inlet Possession Sound and San Juan islands.


Marine & Coastal

11750-001

Reframing - habitats

San Juan, San Juan Archipelago

Rethinking Marine Sites of Sur and Strait of Juan de Fuca, Whidby

2010

Roser, E. M., J. R. and Turmer, M. Y. Wilson

FWWS and others

Analysis of diets of Surf Smelt collected in northern Puget Sound. Washington during 2005-2006 using following alternative methods: analyzing diets from two feeding periods, potting gut contents, excluding plased gut contents, averaging foram percentages across birds versus potting gut contents for all birds, and using energy or ash-free dry mass versus wet mass values of foods.


Eastern Point

110-266

Marine Bird and Mammal Component of the Puget Sound Ecological Monitoring Program w/ reports.

2010

Eriksen, J.R. D.B.

Rodewald, B.L. Moroney, and A.A. Crole

Washington Department of Fish & Wildlife

The dataset includes distribution and density estimates of a selected subset of the major groups of marine birds and diving waterfowl species seen by aerial surveys conducted since 1992 by Western Washington University on the inner marine waters of Washington State. The area of data extends from the western end of the Strait of Juan de Fuca eastwards, and from the Canadian border near Point Roberts south to the southern end of Puget Sound.


Western Point

111-30

Reframing - habitats

San Juan, San Juan Archipelago

Recreation of Eulalia Depth Bathes in Greater Puget Sound

2011

Zwol, P.

Washington Department of Natural Resources

The study monitored benthic communities and assessed the condition of intertidal habitats since 1997 (in collaboration with UW). Monitoring methods characterize epifauna and infauna using visual and core samples.


Eastern Point

111-30

Marine Bird and Mammal Component of the Puget Sound Ecological Monitoring Program w/ reports.

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Western Point

111-30

Reframing - habitats

San Juan, San Juan Archipelago

Region of Great Lakes Depth Bathes in Greater Puget Sound

2011

Berry, M.D. and L. Fetter

Washington Department of Natural Resources

The study monitored benthic communities and assessed the condition of intertidal habitats since 1997 (in collaboration with UW). Monitoring methods characterize epifauna and infauna using visual and core samples.


Western Point

111-30

Marine Bird and Mammal Component of the Puget Sound Ecological Monitoring Program w/ reports.

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Western Point

111-30

Marine Bird and Mammal Component of the Puget Sound Ecological Monitoring Program w/ reports.

2010

Eriksen, J.R. D.B.

Rodewald, B.L. Moroney, and A.A. Crole

Washington Department of Fish & 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 are tailored towards PSNERP’s goals and objectives, and are therefore most directly relevant to managers, and lead coordination efforts. The MPA Work Group developed 17 recommendations for improving the use of MPAs as a management tool and established the Submerged Vegetation Monitoring Project (SVMP) to track this valuable resource. The study demonstrated that current environmental conditions do not support Z. marina survival at these three tested tidal elevations at the head of Westcott Bay and it is not feasible to return the site to its historical condition.

The study describes the ecology of biodiversity in King County, discusses biodiversity management in county governance, and provides an overview of biodiversity inventory and assessment efforts. The occurrence and soundwide distribution of sites with significant declines is of concern for habitat connectivity and ecological functions. The Puget Sound may not be a single homogenous ecosystem, and there are no data sources that encompass monitoring at 1,028 lakes in the lower 48 U.S. States. The 2003 eelgrass response cannot be used as an indicator of ecological condition, or as an accepted reference condition, for ecosystems in Puget Sound. The study provides a foundation for future research and monitoring efforts, including establishment of a Submerged Vegetation Monitoring Project (SVMP) to track this valuable resource.

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<th>Author(s) or Study Contact</th>
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<tr>
<td>C048</td>
<td>Marine - Species &amp; Food Webs</td>
<td>NA</td>
<td>San Juan/Whidbey</td>
<td>Incorporating catastrophic risk assessments into setting conservation goals for Pacific salmon</td>
<td>2008</td>
<td>T. F. Good, J. R. Davie, R. J. Burke, M. H. Richardson</td>
<td>NOAA, Northwest Fisheries Science Center</td>
<td>Explored the likelihood of Puget Sound chinook salmon ESU persistence by examining spatial patterns of catastrophic risk and linking ESU viability recommendations for 20 populations of the threatened Puget Sound chinook salmon ESU.</td>
<td>Recovery strategies that reflect the two distinct populations in each of two geographic regions had lower risk than random strategies. Strategies that included the historical diversity had even lower risk. Geographically distributed populations have varying demographic risk profiles, thus identifying and reinforcing the spatial and life-history diversity critical for populations to respond to environmental change or needed to secure severely depleted or extirpated populations. Recovery planning can promote viability of Pacific salmon ESUs across the landscape by incorporating catastrophic risk assessments.</td>
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<td>Marine - Species &amp; Food Webs</td>
<td>NA</td>
<td>All</td>
<td>The role of bald eagles in declines of predators in Puget Sound and the impact of Sea Level Rise</td>
<td>2011</td>
<td>Welsh, R.</td>
<td>SeaDoc Society (funding), University of Washington</td>
<td>Explored the role of bald eagles in declines of predators in Puget Sound and the impact of sea level rise.</td>
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<td>NA</td>
<td>All</td>
<td>The role of bald eagles in declines of predators in Puget Sound and the impact of Sea Level Rise</td>
<td>2011</td>
<td>Welsh, R.</td>
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<td>-</td>
<td><a href="http://www.nwsub.net/publications/display?docmetadataid=1">http://www.nwsub.net/publications/display?docmetadataid=1</a></td>
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<tr>
<td>C060</td>
<td>Marine - Species &amp; Food Webs</td>
<td>NA</td>
<td>All</td>
<td>The role of bald eagles in declines of predators in Puget Sound and the impact of Sea Level Rise</td>
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**Ref** Reference Number, **Ecosystem Component** Ecosystem component, **Primary Pressure** Primary pressure, **Action Area** Action area, **Study Title** Study title, **Date** Date, **Author(s) or Study Contact** Author(s) or study contact, **Supporting Agency** Supporting agency, **General Study Design/Methods** General study design/methods, **Study Results** Study results, **Weblink** Weblink
C0527 Marine - Species

C0528 Marine - Species

C0529 Marine - Species

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)
--- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | ---
C0527 Marine - Species & Food Web | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A

Ref # Ecosystem

Webs

Species & Food Webs n/a All A genetic linkage map for coho salmon in the new habitat.

C0529 Marine - Species | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A

Ref # Ecosystem

Webs

Species & Food Webs n/a All Pacific salmon Oncorhynchus spp. are capable of exploiting vacant habitat, but most research has focused on rearing and colonization by adults. However, dispersal of juvenile salmon from existing species, such as coho salmon O. kisutch, may also be an important component of colonization. Construction of this genetic linkage map on the Cedar River, Washington, and subsequent scale migration into the newly accessible habitat provided a rare opportunity to investigate colonization as coho salmon reached across 25 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.

C0528 Marine - Species | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A

Ref # Ecosystem

Webs

Species & Food Webs n/a All The focus of this study is to determine the dynamic relationship between piscivorous birds, such as cormorants, and the avian communities in the system. The colonies are located on the island of Oahu, Hawaii, USA.

C0527 Marine - Species | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A

Ref # Ecosystem

Webs

Species & Food Webs n/a All The effects of intertidal air exposure on the physiology and the killing ability of hemocytes in the pacific oyster, Crassostrea gigas (Thunberg).

C0528 Marine - Species | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A

Ref # Ecosystem

Webs

Species & Food Webs n/a All Advances in molecular technology and their impact on fisheries genetics.

C0529 Marine - Species | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A

Ref # Ecosystem

Webs

Species & Food Webs n/a All Spacial and temporal characteristics of stress-related genes in a shallow, temperate pond.

C0528 Marine - Species | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A

Ref # Ecosystem

Webs

Species & Food Webs n/a All Population dynamics of guppy, Poecilia reticulata, in a tropical pond.

C0527 Marine - Species | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A

Ref # Ecosystem

Webs

Species & Food Webs n/a All A genetic linkage map for coho salmon (Oncorhynchus kisutch).
Ontogeny of Recently Completed/Ongoing Scientific Studies

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<tbody>
<tr>
<td>C0534</td>
<td>Marine - Species &amp; Food Webs</td>
<td>All</td>
<td>Marine - Species &amp; Food Webs</td>
<td>Genotypic isolation by location and localized first population structure in Pacific cod (Gadus macrocephalus) limited effective dispersal in the northeastern Pacific Ocean.</td>
<td>2009</td>
<td>Cunningham ML, Canelis MP, Spies MB, Heisser L.</td>
<td>Washington Sea Grant</td>
<td>Marine genotypic population of Pacific cod was examined across much of its northeastern Pacific range by screening variation at 11 microsatellite DNA loci.</td>
<td>Samples suggested that effective dispersal is limited among populations. Genetic divergences were highly correlated with geographic distance in an unstable-island (SSI) pattern along the entire coastal continuum in the northeastern Pacific Ocean, extending from Washington to the Atlantic rollers, and over smaller geographic distances for salmonid species. Analysis of 11 microsatellites suggested average dispersal distance between birth and reproduction of less than 29 km. Exemplar patterns were found in samples taken from spindrift environments in the Georgia Basin, where populations were differentiated from coastal samples. Our results showed population structure at spatial scales related to fisheries management, both ca by limited dispersal along the coast and by entry barriers to migration linking smaller stocks in coastal spindrift environments.</td>
<td><a href="http://www.pmel.noaa.gov/foci/publications/2009/cunn0670.pdf">http://www.pmel.noaa.gov/foci/publications/2009/cunn0670.pdf</a></td>
</tr>
<tr>
<td>C0535</td>
<td>Marine - Species &amp; Food Webs</td>
<td>All</td>
<td>Marine - Species &amp; Food Webs</td>
<td>Development and optimization of quantitative PCR assays for Oostrea lurida and Ostrea lurida larva - Midwater marking efforts.</td>
<td>2009</td>
<td>Night NA, Suckling J, Pedrotti SL, Friedman CS</td>
<td>Washington Sea Grant</td>
<td>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 D-loop region of the species-specific 16S (COI) to use in quantitative polymerase chain reaction (qPCR).</td>
<td>The study presents a review of the processes of evolution as they pertain to morphological and cultural. Fishes and illustrate the discussion with examples of the evolution of within and outside the field of phylogeography. Recommendations are made for experimental artificial populations of O. lurida, followed by quantification of the evolutionary potential for experimental artificial populations.</td>
<td><a href="http://www.deusex.org/sfp/caruso-ecology/i-0509.pdf">http://www.deusex.org/sfp/caruso-ecology/i-0509.pdf</a></td>
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<tr>
<td>C0536</td>
<td>Marine - Species &amp; Food Webs</td>
<td>All</td>
<td>Marine - Species &amp; Food Webs</td>
<td>Terrestrial - Species &amp; Food Webs</td>
<td>Temperature effects on the Deposition of Mono paraehemolyticus and Vibrio vulnificus from the American Oyster (Crassostrea virginica).</td>
<td>2009</td>
<td>Chen M, Cheney D, and Vo Y-C.</td>
<td>Washington Sea Grant</td>
<td>This study investigated temperature effects on depuration for reducing V. parahaemolyticus and V. vulnificus in American oysters. Raw systems were inoculated with 5 × 10⁴ cfu of V. parahaemolyticus or V. vulnificus to levels of 10⁵ to 10⁶ MPN (most probable number) and depurated in artificial seawater (ASW) at 22, 15, 10, and 5 °C. Decreasing water temperature to 15 °C increased the efficiency of depuration in V. parahaemolyticus and V. vulnificus in oysters. Reductions of V. parahaemolyticus and V. vulnificus in oysters increased by 1 and 2.8 log MPN/g, respectively, after 48 h of depuration at 15 °C. However, depuration at 10 and 5 °C were less effective than at 15 °C in reducing the Vibrio levels. Extension depuration at 10 °C for 96 h increased reductions of V. parahaemolyticus and V. vulnificus in oysters to 2.8 and 3.3 log MPN/g, respectively.</td>
<td>The study presents a review of the processes of evolution as they pertain to morphological and cultural. Fishes and illustrate the discussion with examples of the evolution of within and outside the field of phylogeography. Recommendations are made for experimental artificial populations of O. lurida, followed by quantification of the evolutionary potential for experimental artificial populations.</td>
</tr>
<tr>
<td>C0539</td>
<td>Marine - Species &amp; Food Webs</td>
<td>All</td>
<td>Marine - Species &amp; Food Webs</td>
<td>Terrestrial - Species &amp; Food Webs</td>
<td>Temperature effects on the Deposition of Mono paraehemolyticus and Vibrio vulnificus from the American Oyster (Crassostrea virginica).</td>
<td>2009</td>
<td>Night NA, Suckling J, Pedrotti SL, Friedman CS</td>
<td>Washington Sea Grant</td>
<td>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 D-loop region of the species-specific 16S (COI) to use in quantitative polymerase chain reaction (qPCR).</td>
<td>The study presents a review of the processes of evolution as they pertain to morphological and cultural. Fishes and illustrate the discussion with examples of the evolution of within and outside the field of phylogeography. Recommendations are made for experimental artificial populations of O. lurida, followed by quantification of the evolutionary potential for experimental artificial populations.</td>
</tr>
</tbody>
</table>
C0547 Marine - Species & Food Webs
n/a All Visualizing “green oil” in live algal cells. 2010

Petersen T, and Cattolico Coop M, Hardin W, Cunningham KM, Hauser Canino MF, Spies IB, Atlas WI, Pess GR, Quinn Fulton EA, Jennings S, Dethier, MN Washington Sea Grant

The study measured the form, direction, and strength of selection on body size and date of arrival to identify breeding grounds over the first three cohorts (2003-2005) of a coho salmon (Oncorhynchus kisutch) population containing 33 km of habitat made accessible by modification of Landsburg Dam, on the McKenzie River, in Oregon, USA. Salmons were sampled biweekly before spawning, and the percentage was assigned based on genotypes from 16 microsatellite loci, and standardized selection gradients were calculated using the number of returning adult offspring as the fitness metric.

C0553 Marine - Species & Food Webs
n/a All Variation in recruitment does not drive the trophic fingerprint of marine fisheries. 2010

Soule J, Green J, Mathis S, Thompson L Washington Sea Grant

The study investigated whether spatial patterns of larval recruitment along an estuarine gradient could account for the observed decline in adult diversity. On 10 occasions spread over 10 to 13 years, 7300 juvenile fish were collected. Differences between recruitment sites were larger in different sources, but similar differences were found among seasons. In addition, sampling strategies are used to determine if recruitment is consistent across the study area. Intra-annual differences were smaller, indicating that recruitment at these sites mostly shows high diversity and abundance patterns initially established by recruitment. These processes could include predation on juveniles, growth competition, or physiological stress of adverse conditions.

C0554 Marine - Species & Food Webs
n/a All Selection on breeding date and body size in spawning coho salmon.


The study measured the form, direction, and strength of selection on body size and date of arrival to identify breeding grounds over the first three cohorts (2003-2005) of a coho salmon (Oncorhynchus kisutch) population containing 33 km of habitat made accessible by modification of Landsburg Dam, on the McKenzie River, in Oregon, USA. Salmons were sampled biweekly before spawning, and the percentage was assigned based on genotypes from 16 microsatellite loci, and standardized selection gradients were calculated using the number of returning adult offspring as the fitness metric.

C0555 Marine - Species & Food Webs
n/a All Temperature and diet modulated swimming selection of larval sand dollar.

Chen K, Yu, Grunbaum D Washington Sea Grant

The study investigated whether spatial patterns of larval recruitment along an estuarine gradient could account for the observed decline in adult diversity. On 10 occasions spread over 10 to 13 years, 7300 juvenile fish were collected. Differences between recruitment sites were larger in different sources, but similar differences were found among seasons. In addition, sampling strategies are used to determine if recruitment is consistent across the study area. Intra-annual differences were smaller, indicating that recruitment at these sites mostly shows high diversity and abundance patterns initially established by recruitment. These processes could include predation on juveniles, growth competition, or physiological stress of adverse conditions.

C0556 Marine - Species & Food Webs
n/a All Weakening “green oil” in live algal cells.

Copp G, Harnett W, Payne T, and Carlin VA Washington Sea Grant

The study measured the form, direction, and strength of selection on body size and date of arrival to identify breeding grounds over the first three cohorts (2003-2005) of a coho salmon (Oncorhynchus kisutch) population containing 33 km of habitat made accessible by modification of Landsburg Dam, on the McKenzie River, in Oregon, USA. Salmons were sampled biweekly before spawning, and the percentage was assigned based on genotypes from 16 microsatellite loci, and standardized selection gradients were calculated using the number of returning adult offspring as the fitness metric.

C0551 Marine - Species & Food Webs
n/a All Visualizing “green oil” in live algal cells. 2010

B-13
The study quantified the juvenile rearing and migratory patterns of individuals from a population of the spawning Chinook salmon in Oregon's Suislaw River estuary using otolith microchemistry and microstructure.

The study confirmed the early periodicity of growth increments in a sexual adult population under field conditions and validated fundamental assumptions about increased stock recruitment: calcium values during entry into saline waters. The study results indicated that more than 75% of the subadult Chinook salmon sampled near the mouth of the Suislaw 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 otlolith results depict a continuum of behavior and ecological relationships that are consistent with reports of considerable phenotypic plasticity in Chinook salmon. Otolith analyses offer the potential to quantify the relative contributions of different juvenile-rearing patterns to adult returns.


Keefer, McCullough, and Simenstad. Washington Sea Grant.

B14
<table>
<thead>
<tr>
<th>Ref</th>
<th>Ecosystem Component</th>
<th>Primary Pressure</th>
<th>Action Area</th>
<th>Study Title</th>
<th>Date</th>
<th>Author(s) or Study Contact</th>
<th>Supporting Agency</th>
<th>General Study Design/Methods</th>
<th>Study Results</th>
<th>Weblink</th>
<th>Journal Citation (if applicable)</th>
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<tbody>
<tr>
<td>C596</td>
<td>Marine - Species &amp; Food Webs</td>
<td>Non-Point Source Loading &amp; Runoff</td>
<td>All</td>
<td>Using Microbes for the Evaluation and Monitoring of Puget Sound Ecosystems</td>
<td>2008</td>
<td>Vrettos, Elizabeth</td>
<td>Washington Sea Grant</td>
<td>Literature Review, GIS analyses. Computation of loading estimates for 17 toxic chemicals of concern.</td>
<td>The Puget Sound ecosystem is a complex web of natural and human-produced ingredients. This study will assess the effects of this transfer of processes into the system by monitoring metrics — any measurable organism or processes that are at risk from the food web. Analyses of transported pollutants, including species composition, density, diversity and species richness, correlated with selected parameters, will yield a picture of the effects of routes such as (research, current, rivers, stormwater and sewage effluent).</td>
<td>The difference in toxic loading between year 2008 and 2009 increased from 2 to 3.5 times. Stream gaging activities were conducted at an average of 0.5 to 1.5 times the rate when comparing year 2009 to year 2008. Bacteria show two large spikes not seen in previous years. Overall, the water quality of the puget sound is very good, comparable to drinking water standards.</td>
<td><a href="http://www.wdfw.wa.gov/publications/pub.php?id=011630">http://www.wdfw.wa.gov/publications/pub.php?id=011630</a></td>
</tr>
<tr>
<td>C594</td>
<td>Marine - Water</td>
<td>Non-Point Source Loading &amp; Runoff</td>
<td>All</td>
<td>Control of Toxic Chemicals in Puget Sound</td>
<td>2008</td>
<td>Palsson, P. and S. Hoult</td>
<td>Washington Department of Ecology</td>
<td>Ecology conducted the technical study to set total Maximum attainable loads (TMAls) for toxics. Based on 2002 and 2003 data, a CQ-QM-002 lake model and an HSPP watershed model were developed. Land uses in the watershed model were adjusted to evaluate lake water quality.</td>
<td>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 project to develop source-control strategies for toxic contaminants, the Puget Sound Toxics Box Analysis (PSTBA) project quantifies concentrations within and leading to Puget Sound. Ultimately, guiding management decisions.</td>
<td><a href="http://www.ecy.wa.gov/biblio/0810084.html">http://www.ecy.wa.gov/biblio/0810084.html</a></td>
<td></td>
</tr>
</tbody>
</table>
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)
--- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | ---
C039 | Marine - Species & Food Webs | Non-Point Source Loading & Runoff | Hood Canal | The influence of midwater hypoxia on sedentary vertical migration | 2009 | Parker, S. L., J. I. Babcock, and M. M. Langness | Hood Canal Estuarine Oxygen Program through Naval Sea Systems Command contract | using acoustics (28 and 120 kHz), the 2007 night ODM patterns of residence were quantified before June, August, and during (September) in OML. All months had similar patterns suggesting that the 2007 OML did not affect coastal assemblages in its progression in the benthic food web. | | http://www.esa.org/pdf/journal/v6/6/125.pdf | R.S. Journal of Marine Science 66:200-202
C044 | Marine - Species & Food Webs | Non-Point Source Loading & Runoff | Hood Canal | Quantifying hypoxic impacts on an estuarine demersal community: using a hierarchical approach | 2010 | Zaslawsky, T.E. and Paulson, CE | UW - Fisheries | Applied conventional and hierarchical ensemble analysis 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. | | | marineecosystemsarticle125.pdf | Ecosystems 13, Number 7, 1139-1148
C045 | Nearshore - Habitats | Non-Point Source Loading & Runoff | San Juan Islands, Admiralty Inlet, and the San Juan Inlets | Sediment Quality Assessment of the Bay, 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, toxicology, and invertebrate community structure were measured. | 2009 | Long, C. D., Aaron, M. Dubbs, K. Wahe, and V. Partidge | Washington Department of Ecology | During 2002 and 2003, a sediment quality survey was conducted in the bay 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, toxicology, and invertebrate community structure were measured. | | | http://www.doc.wa.gov/ep/2004/2004-07-96.html | Marine Pollution Bulletin 40:1022-1028
C047 | Marine - Species & Food Webs | Non-Point Source Loading & Runoff | San Juan/Whatcom, County | Species Changes in Shoreline Biot on Eastside of the San Juan Islands | 2009 | Kaetzer, M.H. and H.D. Berry | Washington Department of Natural Resources | Shorebird communities were monitored at multiple tidal heights using quadratic and core sampling techniques, and compared current data to historical records ranging from 1970-1986. | | | | Marine Pollution Bulletin 40:1022-1028
C048 | Marine - Water | Non-Point Source Loading & Runoff | Hood Canal | Recent deep hypoxic impact marine food webs and fisheries evaluating distributional shifts in Hood Canal | 2009 | Zaslawsky, Tim | Washington Sea Grant | Recent hypoxia has widespread threat to industries, coastal and estuarial near worldwide. Hypoxia has been identified as a key threat to the Puget Sound ecosystem. The study used trawl surveys in southern Hood Canal for the years 2007-2009 to document potential changes in fish assemblages that may be more ecologically significant than more visible impacts, such as fish kills. | | | | http://icesjms.oxfordjournals.org/content/66/6/125.full | Marine Pollution Bulletin 40:1022-1028
C057 | Marine - Water | Non-Point Source Loading & Runoff | Puget Sound | SoundCitizen: Students and Citizens Working Together to Evaluate Sources and Fate of Emerging Pollutants in Puget Sound | 2009 | Kelly, Richard | Washington Sea Grant | SoundCitizen is a collaborative research effort to investigate the effects of emerging contaminants of concern in southeast Puget Sound. This project will evaluate the effectiveness of green stormwater infrastructure in reducing the harmful effects of runoff on aquatic resources, including contaminants, habitat loss and environmental degradation. The project 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. | | | | Marine Pollution Bulletin 40:1022-1028
C060 | Nearshore - Habitats | Non-Point Source Loading & Runoff | Puget Sound | Effects of Waterfront Stormwater Sediment Solutions on Prototypes on Water Quality in Puget Sound Tide: Zone of Conspicuous | 2009 | Tolle, Nancy | Washington Sea Grant | Unfiltered oysters in all of the leading causes of degradation to Puget Sound and causes toxic effects that threaten aquatic natural resources. Stormwater treatment units can provide the first opportunity to improve stormwater quality before entering the Sound. This project will assess the effectiveness of green stormwater infrastructure in reducing the harmful effects of runoff on aquatic resources, including contaminants, 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. | | | | Marine Pollution Bulletin 40:1022-1028
C0381 Marine - Water

Crake, S. Incoland's Reservoir.

Study Title: Quality Assurance Project Plan: Dredge Harbor Water Quality Monitoring.

Date: 2010

Supporting Agency: Washington Department of Ecology

General Study Design/Methods: This project was designed to provide an understanding of the sediment contamination in the Dredge Harbor Reservoir. The study involved the collection of sediment samples from the reservoir and the analysis of their chemical composition.

Study Results: The study results showed that the sediment from the Dredge Harbor Reservoir contained high levels of metals, including lead, copper, and zinc. These metals were found to be leachable and could be potentially harmful to the ecosystem and human health.


Journal Citation (if applicable): None

C0382 Marine - Water

Study Title: A Study of the Effects of a Marine Reservoir on the Watershed.

Date: 2010

Supporting Agency: Washington Department of Ecology

General Study Design/Methods: This study aimed to investigate the impact of a marine reservoir on the adjacent watershed. The study focused on the chemical composition of the water and sediment samples collected from the reservoir and surrounding areas.

Study Results: The study results showed that the chemical composition of the water and sediment samples collected from the reservoir and surrounding areas was different from that of the adjacent watershed. The reservoir water contained higher levels of dissolved oxygen and lower levels of nutrients compared to the surrounding areas.


Journal Citation (if applicable): None

C0383 Marine - Water

Study Title: An Investigation of the Effects of a Marine Reservoir on Fish Populations.

Date: 2010

Supporting Agency: Washington Department of Fish & Wildlife

General Study Design/Methods: This study aimed to investigate the impact of a marine reservoir on fish populations. The study focused on the collection of fish samples from the reservoir and surrounding areas and the analysis of their chemical composition and health.

Study Results: The study results showed that the chemical composition of the fish samples collected from the reservoir and surrounding areas was different from that of the adjacent watershed. The fish from the reservoir contained higher levels of metals and lower levels of nutrients compared to the surrounding areas.


Journal Citation (if applicable): None

C0384 Marine - Water

Study Title: An Investigation of the Effects of a Marine Reservoir on Aquatic Ecosystems.

Date: 2010

Supporting Agency: Washington Department of Ecology

General Study Design/Methods: This study aimed to investigate the impact of a marine reservoir on aquatic ecosystems. The study focused on the collection of water and sediment samples from the reservoir and surrounding areas and the analysis of their chemical composition and physical properties.

Study Results: The study results showed that the chemical composition of the water and sediment samples collected from the reservoir and surrounding areas was different from that of the adjacent watershed. The reservoir water contained higher levels of dissolved oxygen and lower levels of nutrients compared to the surrounding areas.


Journal Citation (if applicable): None

C0385 Marine - Water

Study Title: An Investigation of the Effects of a Marine Reservoir on Aquatic Ecosystems.

Date: 2010

Supporting Agency: Washington Department of Ecology

General Study Design/Methods: This study aimed to investigate the impact of a marine reservoir on aquatic ecosystems. The study focused on the collection of water and sediment samples from the reservoir and surrounding areas and the analysis of their chemical composition and physical properties.

Study Results: The study results showed that the chemical composition of the water and sediment samples collected from the reservoir and surrounding areas was different from that of the adjacent watershed. The reservoir water contained higher levels of dissolved oxygen and lower levels of nutrients compared to the surrounding areas.


Journal Citation (if applicable): None

C0386 Marine - Water

Study Title: An Investigation of the Effects of a Marine Reservoir on Aquatic Ecosystems.

Date: 2010

Supporting Agency: Washington Department of Ecology

General Study Design/Methods: This study aimed to investigate the impact of a marine reservoir on aquatic ecosystems. The study focused on the collection of water and sediment samples from the reservoir and surrounding areas and the analysis of their chemical composition and physical properties.

Study Results: The study results showed that the chemical composition of the water and sediment samples collected from the reservoir and surrounding areas was different from that of the adjacent watershed. The reservoir water contained higher levels of dissolved oxygen and lower levels of nutrients compared to the surrounding areas.


Journal Citation (if applicable): None

C0387 Marine - Water

Study Title: An Investigation of the Effects of a Marine Reservoir on Aquatic Ecosystems.

Date: 2010

Supporting Agency: Washington Department of Ecology

General Study Design/Methods: This study aimed to investigate the impact of a marine reservoir on aquatic ecosystems. The study focused on the collection of water and sediment samples from the reservoir and surrounding areas and the analysis of their chemical composition and physical properties.

Study Results: The study results showed that the chemical composition of the water and sediment samples collected from the reservoir and surrounding areas was different from that of the adjacent watershed. The reservoir water contained higher levels of dissolved oxygen and lower levels of nutrients compared to the surrounding areas.


Journal Citation (if applicable): None

C0388 Marine - Water

Study Title: An Investigation of the Effects of a Marine Reservoir on Aquatic Ecosystems.

Date: 2010

Supporting Agency: Washington Department of Ecology

General Study Design/Methods: This study aimed to investigate the impact of a marine reservoir on aquatic ecosystems. The study focused on the collection of water and sediment samples from the reservoir and surrounding areas and the analysis of their chemical composition and physical properties.

Study Results: The study results showed that the chemical composition of the water and sediment samples collected from the reservoir and surrounding areas was different from that of the adjacent watershed. The reservoir water contained higher levels of dissolved oxygen and lower levels of nutrients compared to the surrounding areas.


Journal Citation (if applicable): None

C0389 Marine - Water

Study Title: An Investigation of the Effects of a Marine Reservoir on Aquatic Ecosystems.

Date: 2010

Supporting Agency: Washington Department of Ecology

General Study Design/Methods: This study aimed to investigate the impact of a marine reservoir on aquatic ecosystems. The study focused on the collection of water and sediment samples from the reservoir and surrounding areas and the analysis of their chemical composition and physical properties.

Study Results: The study results showed that the chemical composition of the water and sediment samples collected from the reservoir and surrounding areas was different from that of the adjacent watershed. The reservoir water contained higher levels of dissolved oxygen and lower levels of nutrients compared to the surrounding areas.


Journal Citation (if applicable): None

C0390 Marine - Water

Study Title: An Investigation of the Effects of a Marine Reservoir on Aquatic Ecosystems.

Date: 2010

Supporting Agency: Washington Department of Ecology

General Study Design/Methods: This study aimed to investigate the impact of a marine reservoir on aquatic ecosystems. The study focused on the collection of water and sediment samples from the reservoir and surrounding areas and the analysis of their chemical composition and physical properties.

Study Results: The study results showed that the chemical composition of the water and sediment samples collected from the reservoir and surrounding areas was different from that of the adjacent watershed. The reservoir water contained higher levels of dissolved oxygen and lower levels of nutrients compared to the surrounding areas.


Journal Citation (if applicable): None

C0391 Marine - Water

Study Title: An Investigation of the Effects of a Marine Reservoir on Aquatic Ecosystems.

Date: 2010

Supporting Agency: Washington Department of Ecology

General Study Design/Methods: This study aimed to investigate the impact of a marine reservoir on aquatic ecosystems. The study focused on the collection of water and sediment samples from the reservoir and surrounding areas and the analysis of their chemical composition and physical properties.

Study Results: The study results showed that the chemical composition of the water and sediment samples collected from the reservoir and surrounding areas was different from that of the adjacent watershed. The reservoir water contained higher levels of dissolved oxygen and lower levels of nutrients compared to the surrounding areas.


Journal Citation (if applicable): None

C0392 Marine - Water

Study Title: An Investigation of the Effects of a Marine Reservoir on Aquatic Ecosystems.

Date: 2010

Supporting Agency: Washington Department of Ecology

General Study Design/Methods: This study aimed to investigate the impact of a marine reservoir on aquatic ecosystems. The study focused on the collection of water and sediment samples from the reservoir and surrounding areas and the analysis of their chemical composition and physical properties.

Study Results: The study results showed that the chemical composition of the water and sediment samples collected from the reservoir and surrounding areas was different from that of the adjacent watershed. The reservoir water contained higher levels of dissolved oxygen and lower levels of nutrients compared to the surrounding areas.


Journal Citation (if applicable): None

C0393 Marine - Water

Study Title: An Investigation of the Effects of a Marine Reservoir on Aquatic Ecosystems.

Date: 2010

Supporting Agency: Washington Department of Ecology

General Study Design/Methods: This study aimed to investigate the impact of a marine reservoir on aquatic ecosystems. The study focused on the collection of water and sediment samples from the reservoir and surrounding areas and the analysis of their chemical composition and physical properties.

Study Results: The study results showed that the chemical composition of the water and sediment samples collected from the reservoir and surrounding areas was different from that of the adjacent watershed. The reservoir water contained higher levels of dissolved oxygen and lower levels of nutrients compared to the surrounding areas.


Journal Citation (if applicable): None

C0394 Marine - Water

Study Title: An Investigation of the Effects of a Marine Reservoir on Aquatic Ecosystems.

Date: 2010

Supporting Agency: Washington Department of Ecology

General Study Design/Methods: This study aimed to investigate the impact of a marine reservoir on aquatic ecosystems. The study focused on the collection of water and sediment samples from the reservoir and surrounding areas and the analysis of their chemical composition and physical properties.

Study Results: The study results showed that the chemical composition of the water and sediment samples collected from the reservoir and surrounding areas was different from that of the adjacent watershed. The reservoir water contained higher levels of dissolved oxygen and lower levels of nutrients compared to the surrounding areas.


Journal Citation (if applicable): None
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<th>Ref</th>
<th>Ecosystem Component</th>
<th>Primary Pressure</th>
<th>Action Area</th>
<th>Study Title</th>
<th>Date</th>
<th>Author(s) or Study Contact</th>
<th>Supporting Agency</th>
<th>General Study Design/Methods</th>
<th>Study Results</th>
<th>Weblink</th>
<th>Journal Citation (if applicable)</th>
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<tr>
<td>C339</td>
<td>Terrestrial - Species &amp; Forest Blocks</td>
<td>Point Source Pollution</td>
<td>40</td>
<td>Measuring Mercury Trends in Freshwater Fish in Washington State; 2007 Sampling Results</td>
<td>2009</td>
<td>Furl, C. and C. Mewett</td>
<td>Washington Department of Ecology</td>
<td>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 38% 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 Constance contained a concentration of 1800 ppb. This sample was the highest mercury concentration recorded in a freshwater fish during the first three years of this long-term study.</td>
<td><a href="http://www.ecy.wa.gov/hbd/b/083507.html">http://www.ecy.wa.gov/hbd/b/083507.html</a></td>
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<tr>
<td>C389</td>
<td>Wetland - Habitats</td>
<td>Point Source Pollution</td>
<td>San Juan/Whatcom</td>
<td>Assessment of Sediment Toxicity near Point Foster (Bellingham Bay)</td>
<td>2008</td>
<td>Gries, T.</td>
<td>Washington Department of Ecology</td>
<td>Sediments were collected from 9 locations in September 2007 and tested using 5 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. Sulfide levels near Point Foster were not different from levels in other areas of Bellingham Bay.</td>
<td><a href="http://www.ecy.wa.gov/hbd/b/083514.html">http://www.ecy.wa.gov/hbd/b/083514.html</a></td>
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<td>C403</td>
<td>Terrestrial - Pollutants</td>
<td>Point Source Pollution</td>
<td>San Juan/Whatcom</td>
<td>Terrestrial - Point Source North Central Puget Sound</td>
<td>2009</td>
<td>Bremer, J., Wyde, J., Greenman, E., and Elliott, J.</td>
<td>US Geological Survey</td>
<td>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 noise, organic composition, and sulfide impacts to rainfed rice and clams. Three remediation alternatives were considered, and a scoring 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 the historical disturbance and to potentially contribute to an increase in nearshore diversity and productivity at this site.</td>
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<td><a href="http://pubs.usgs.gov/of/2009/1141/">http://pubs.usgs.gov/of/2009/1141/</a></td>
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<td>Matrix - Habitats</td>
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<td>Target monitoring towards identified management goals, objectives, and threats in an ecosystem context that will provide useful monitoring of issues/additional risks across IMMs.</td>
<td>21st Century Salmon and Steelhead Initiative (WDFW, 2008)</td>
<td>Requires Legislative Action; Implementation Lead: MPAWG</td>
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<td>Other Species &amp; Habitat</td>
<td>Ich</td>
<td>Support partners in identifying special habitat conditions and objectives necessary to reach and/or sustain existing goals</td>
<td>21st Century Salmon and Steelhead Initiative (WDFW, 2008)</td>
<td>Requires Legislative Action; Implementation Lead: MPAWG</td>
<td><a href="http://wdfw.wa.gov/publications/pub.php?id=00038">Weblink</a></td>
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<tr>
<td>Other Species &amp; Habitat</td>
<td>Ich</td>
<td>Protect habitat by providing additional technical assistance to effectively implement the Growth Management Act, Forest Juvenile Act, Shorelines Management Act and other state laws.</td>
<td>21st Century Salmon and Steelhead Initiative (WDFW, 2008)</td>
<td>Requires Legislative Action; Implementation Lead: MPAWG</td>
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<td>Other Species &amp; Habitat</td>
<td>Ich</td>
<td>Develop and implement management plans for WDFW lands with additional emphasis on habitat needs for salmon and steelhead.</td>
<td>21st Century Salmon and Steelhead Initiative (WDFW, 2008)</td>
<td>Requires Legislative Action; Implementation Lead: MPAWG</td>
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<td>Other Species &amp; Habitat</td>
<td>Ich</td>
<td>Water Workforce &amp; Commerce</td>
<td>Use existing programs to manage WMP water rights consistent with salmon and steelhead recovery.</td>
<td>21st Century Salmon and Steelhead Initiative (WDFW, 2008)</td>
<td>Requires Legislative Action; Implementation Lead: MPAWG</td>
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<td>Other Species &amp; Habitat</td>
<td>Ich</td>
<td>Sustainable Fishing &amp; Harvesting</td>
<td>Reduce the number of fishing days spanning in area and to appropriate use wild salmon and steelhead to build back to prior productivity and diversity of catch.</td>
<td>21st Century Salmon and Steelhead Initiative (WDFW, 2008)</td>
<td>Requires Legislative Action; Implementation Lead: MPAWG</td>
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<td>Other Species &amp; Habitat</td>
<td>Ich</td>
<td>Sustainable Fishing &amp; Harvesting</td>
<td>Ensure that hatchery facilities have safe salmon hatchery with passenger facilities, intake, screening, and collection control systems that comply with water quality regulations.</td>
<td>21st Century Salmon and Steelhead Initiative (WDFW, 2008)</td>
<td>Requires Legislative Action; Implementation Lead: MPAWG</td>
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<td>Other Species &amp; Habitat</td>
<td>Ich</td>
<td>Sustainable Fishing &amp; Harvesting</td>
<td>Create programs that cannot be modified to meet consumptive and by-catch objectives in cost-effective manner.</td>
<td>21st Century Salmon and Steelhead Initiative (WDFW, 2008)</td>
<td>Requires Legislative Action; Implementation Lead: MPAWG</td>
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<td>Other Species &amp; Habitat</td>
<td>Ich</td>
<td>Sustainable Fishing &amp; Harvesting</td>
<td>Expand selective fisheries to increase opportunities for recreational and commercial fishing on hatchery fish and reduce the harvest of wild salmon.</td>
<td>21st Century Salmon and Steelhead Initiative (WDFW, 2008)</td>
<td>Requires Legislative Action; Implementation Lead: MPAWG</td>
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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 to coordinate and prioritize needed actions and new investments. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be measured.

C-3

Inventory of Scientific Study Recommendations

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<td>Marine - Species &amp; Food Webs</td>
<td>Unsustainable Fishing &amp; Harvesting</td>
<td>Improve fishery management to ensure that impacts are well understood and accurately assessed.</td>
<td>21st Century Salmon and Steelhead Initiative (WDFW, 2008)</td>
<td>21st Century Salmon and Steelhead Initiative (WDFW, 2008)</td>
<td><a href="http://www.wdfw.wa.gov/fisheries/21st-century-salmon-and-steelhead-initiative/publications.html">Website</a></td>
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<tr>
<td>C-3</td>
<td>Marine - Species &amp; Food Webs</td>
<td>Unsustainable Fishing &amp; Harvesting</td>
<td>Work with our tribal co-managers in each watershed to develop joint state/tribal hatchery and harvest management. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be measured.</td>
<td>21st Century Salmon and Steelhead Initiative (WDFW, 2008)</td>
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<td>C-3</td>
<td>Marine - Species &amp; Food Webs</td>
<td>Unsustainable Fishing &amp; Harvesting</td>
<td>Monitor numbers of juvenile fish that migrate to marine areas and adult fish that return to fresh water to determine effectiveness of conservation and recovery actions.</td>
<td>21st Century Salmon and Steelhead Initiative (WDFW, 2008)</td>
<td><a href="http://www.wdfw.wa.gov/fisheries/21st-century-salmon-and-steelhead-initiative/publications.html">Website</a></td>
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<td>C-3</td>
<td>Marine - Species &amp; Food Webs</td>
<td>Unsustainable Fishing &amp; Harvesting</td>
<td>Communicate progress on status of salmon and steelhead populations and implementation of hatchery and harvest management. The framework is a matrix of measurable outcomes critical for healthy salmon and healthy fisheries, against which salmon-related strategies can be measured.</td>
<td>21st Century Salmon and Steelhead Initiative (WDFW, 2008)</td>
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<td>Residential - Natural Park &amp; Blvd</td>
<td>Unsustainable Fishing &amp; Harvesting</td>
<td>Clearly identify fishery management objectives, recover the status of wild salmon and steelhead, and adjust harvest rates to better protect at-risk stocks.</td>
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<td>Build models to simulate the effects of climate change on salmon and steelhead populations.</td>
<td>21st Century Salmon and Steelhead Initiative (WDFW, 2008)</td>
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<td>Climate Change</td>
<td>Identify and/or provide accessible input on high priority research needs that would improve our understanding of climate impacts and responses of natural and human systems.</td>
<td>Preparing for a Changing Climate: Washington State's Integrated Climate Change Response Strategy - DRAFT October 2011</td>
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<td>Climate Change</td>
<td>Knowledge needed for implementation requires rigorous scientific investigation at various scales, for example, at each site, PCB sites, working with NOAA, DFO, COAs and others.</td>
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<td>Social Conditions</td>
<td>Using historical and modern evidence developed by the climate change information community to aid in planning to better express future scenarios for climate-ready water utilities and flood resilient authorities.</td>
<td>Preparing for a Changing Climate: Washington State's Integrated Climate Change Response Strategy - DRAFT October 2011</td>
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<td>Needs for data, information, and resources that would facilitate understanding of the socioeconomic and human dimensions of climate change demand an effective strategy for linking climate information to their social use.</td>
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APPENDIX D: SUMMARY OF STATE MONITORING PROGRAMS
High Salmon Fisheries Monitoring

- **Program**: Stock ID and Fish Age Structure
  - **Sport Harvest catch Record card**: DFW Tracks sport catch in the smaller
  - **Stock Identification and Genetics Monitoring**: DFW Estimates abundance and trends
  - **Wildlife Status and Trends (CMER)**: DFW Tracks catch allocations between Puget Sound salmon by species, month, and river.

- **Wildlife Status and Trends**
  - **Wildlife**
    - **Biotoxin monitoring**: DFW Tracks catch allocations between Puget Sound salmon by species, month, and river.
    - **Shellfish Growing Area Marine Monitoring**: DFW Tracks catch allocations between Puget Sound salmon by species, month, and river.

- **Puget Sound Salmon Harvest Assessments**
  - **Puget Sound Herring Stock monitoring**: DFW Tracks catch allocations between Puget Sound salmon by species, month, and river.
  - **Biotoxin monitoring**: DFW Tracks catch allocations between Puget Sound salmon by species, month, and river.

- **Limiting Factors Analysis**
  - **WCC Provided initial assessment of Forest-Fish forest practice rule changes in rivers and streams of the state.**
  - **Riparian vegetation, freshwater habitat**: DFW Tracks catch allocations between Puget Sound salmon by species, month, and river.

- **Testing the effectiveness of Forest-Fish forest practice rule changes in rivers and streams of the state.**
  - **Riparian vegetation, freshwater habitat**: DFW Tracks catch allocations between Puget Sound salmon by species, month, and river.
  - **Riparian vegetation, freshwater habitat**: DFW Tracks catch allocations between Puget Sound salmon by species, month, and river.

- **Fish forest practice rule changes in rivers and streams of the state.**
  - **Riparian vegetation, freshwater habitat**: DFW Tracks catch allocations between Puget Sound salmon by species, month, and river.
  - **Riparian vegetation, freshwater habitat**: DFW Tracks catch allocations between Puget Sound salmon by species, month, and river.

- **Biotoxin monitoring**: DFW Tracks catch allocations between Puget Sound salmon by species, month, and river.
  - **Shellfish Puget Sound, Washington**: DFW Tracks catch allocations between Puget Sound salmon by species, month, and river.
  - **Shellfish Puget Sound, Washington**: DFW Tracks catch allocations between Puget Sound salmon by species, month, and river.

- **Forestry Forest practice rule changes in rivers and streams of the state.**
  - **Riparian vegetation, freshwater habitat**: DFW Tracks catch allocations between Puget Sound salmon by species, month, and river.
  - **Riparian vegetation, freshwater habitat**: DFW Tracks catch allocations between Puget Sound salmon by species, month, and river.

- **Puget Sound Fisheries Monitoring**: DFW Tracks catch allocations between Puget Sound salmon by species, month, and river.

- **Shellfish Puget Sound, Washington**: DFW Tracks catch allocations between Puget Sound salmon by species, month, and river.

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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 eliminate pollution from centralized wastewater 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 from 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 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)
- Landfill Assessments, Closure, and Remediation – Port Angeles Landfill Sediment Characterization – Ecological (Vegetation and Benthic)
• 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


• 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 NOx and Sox?
- 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

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<th># of Responses</th>
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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 been 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. Macroinvertebrate 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 sand lance, 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.

**Sand lance.** Though genetic analyses have recently indicated that surf smelt in Puget Sound are a single, panmictic population, no genetic work has been done for sand lance. Recent genetic work in the Bering Sea and southeast Alaska has documented two new species of sand lance and it is possible there is more than one species in Washington. Additionally, it is possible that even a single species of sand lance 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,

F-7
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 oceanographic 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 nutrients (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 sediment 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-I BI 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 not 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 enterococci 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 disrupters, 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](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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