Biennial Science Work Plan 2009-2011

Science Panel
Puget Sound Partnership
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1. Introduction

1.1 Objectives and scope of the Biennial Science Work Plan

This 2009-2011 Puget Sound Biennial Science Work Plan details the high-priority science activities required to: support the implementation of the Action Agenda; build capacity to revise and improve future Action Agendas; and enhance the Puget Sound Partnership's ability to lead the ecosystem protection and restoration effort. This Work Plan is intended to be nested within the overall context of a Puget Sound Strategic Science Program. The Puget Sound Partnership's Science Panel, with input and assistance from Partnership staff, prepared this Work Plan and is drafting a Strategic Science Plan to describe the underlying principles, structure and function of the Puget Sound science program. This Work Plan has by design a relatively short shelf life, being formally revised every second year. This initial plan covers the period from January 2009 through the end of June 2011; it includes the last six months of the 2007-09 state biennium and the entire 2009-11 state biennium. The Work Plan is the Science Panel's blueprint for near-term science actions to support ecosystem recovery, but the Science Panel may deviate from the Work Plan if the best available science and analysis suggest other actions during this biennial cycle. Because this is the initial Work Plan, it focuses not only on identifying gaps and opportunities, but also on building and sustaining the technical procedures, capacity, and tools required for the Partnership. The Science Panel anticipates subsequent Work Plans will center on prioritized research, observations, and analysis required to advance Puget Sound protection and restoration.

The objective of this Biennial Science Work Plan is to clearly articulate the essential steps required during 2009-2011 for the Puget Sound Partnership to coordinate, enhance, and communicate a rigorous, transparent science program in support of the Action Agenda. Specifically, the Science Panel recommends that during the next two years the Partnership:

1. Lead the enhanced analysis, integration, and interpretation of available information using the most advanced and rigorous tools, resulting in the best possible current understanding of the Puget Sound ecosystem (Section 2.1).
2. Support targeted studies, especially those that add valuable information to ongoing restoration and assessment projects, to improve the understanding of the ecosystem and the effectiveness of actions (Section 2.2).
3. Build the technical and institutional capacity to generate, analyze, and communicate information required to adaptively manage Puget Sound (Section 3.1).
4. Establish the organizational structure and procedures necessary for an efficient, transparent, adaptable, and sustainable science-based Puget Sound restoration and protection program (Section 3.2).

The Partnership's Action Agenda includes a number of science tasks or tasks with science-related elements. The Science Panel is committed to working with Partnership staff and leaders to ensure that these science-related issues, and any others that need to be addressed to advance protection, restoration, and pollution prevention, are aligned with and contribute to an integrated scientific program for the Puget Sound ecosystem.

The Partnership's Action Agenda outlines a number of important near-term actions for restoration, protection, and pollution control. With its focus on scientific investigations and science capacity-building for the next biennium, this Work Plan emphasizes areas of uncertainty and efforts to collect information to address uncertainties. The Science Panel appreciates the importance of acting now, in the face of uncertainty, and contends that scientific uncertainty is not a good reason to delay action, because there will always be uncertainty.

1.2 Building blocks and organizing framework

Strategic science for the Puget Sound Partnership will improve the science basis of ecosystem recovery efforts and facilitate learning and adaptation to improve management strategies over time. Therefore, the strategic value of this Work Plan depends on its contributions to improved approaches to answering the Partnership's organizing "four question" framework and to adaptive management. The Science Panel endorses the Integrated Ecosystem Assessment (IEA) as a cogent approach to systemically analyze and integrate ecological information for use in ecosystem approaches to management. These three starting points were used to identify key Partnership science needs for the 2009-11 biennium.

1.2.1 Biennial Science Work Plan activities support Action Agenda questions

Activities identified in this Work Plan will improve the science basis for the next Action Agenda by addressing prioritized uncertainties or information gaps. These science activities are explicitly linked to the four Action Agenda questions as follows:

Action Agenda Question	**Section of Biennial Science Work Plan**		
	2.1 Analyze existing and evolving information	**2.2 Conduct targeted investigations**	**3.1 Create and enhance science program elements**
(1) What is a healthy Puget Sound?	2.1.2 Phase 2 indicators development 2.1.4 Analysis of historical information to determine trends 2.1.5 Integrated ecosystem assessments addressing marine, nearshore, and terrestrial endpoints 2.1.6 Modeling of future scenarios	2.2.3 Stressors affecting pelagic food web and forage fish 2.2.4: Ecosystem services and socioeconomic indicators	3.1.2 Collaborative process modeling to develop further indicators, thresholds, and benchmarks; futures analysis 3.1.3 Emerging issues research

Action Agenda Question	**Section of Biennial Science Work Plan**		
	2.1 Analyze existing and evolving information	**2.2 Conduct targeted investigations**	**3.1 Create and enhance science program elements**
(2) What is the status of Puget Sound and what are the biggest threats to it?	2.1.1 Continue existing monitoring 2.1.5 Spatial analysis of status and threats/drivers for all action areas 2.1.6 Future scenarios modeling	2.2.2 Watershed-wide loading and effects of runoff 2.2.3 Stressors affecting pelagic food web and forage fish	3.1.1 Monitoring (status and trends) 3.1.2 Collaborative process modeling to develop further indicators, thresholds, and benchmarks; futures analysis
(3) What actions should be taken …? and (4) Where should we start?	2.1.2 Integrated ecosystem assessments addressing marine, nearshore, and terrestrial endpoints	2.2.1: Adaptive management for nearshore restoration 2.2.2: Watershed-wide loading and effects of runoff 2.2.3: Stressors affecting pelagic food web and forage fish	3.1.1 Monitoring (effectiveness) 3.1.2 Collaborative process modeling to develop further indicators, thresholds, and benchmarks; futures analysis

1.2.2 Adaptive management as the paradigm to execute science-based ecosystem protection and restoration

The Partnership uses adaptive management as a strategy to implement Puget Sound protection and restoration programs. At the core of adaptive management is a periodic cycle of actions, assessment, evaluation, and planning. This allows a program to move forward in the face of uncertainty, knowing that actions will be evaluated against goals and altered to optimize

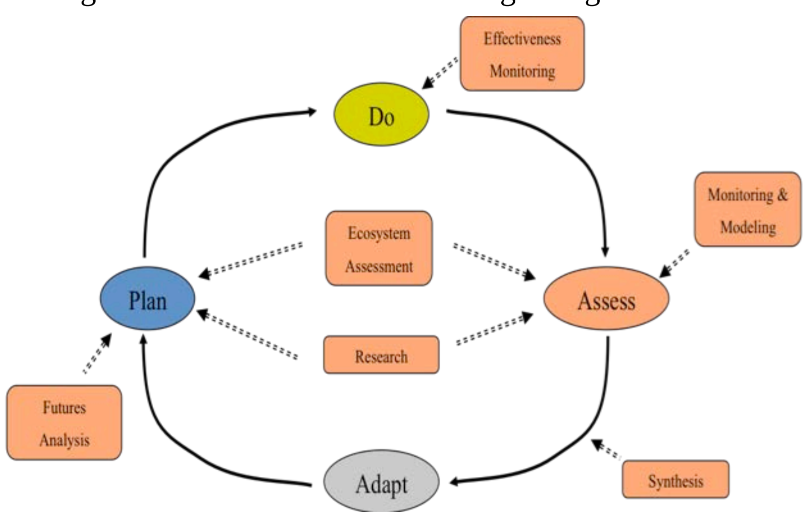

Figure 1. The adaptive management process used in the Action Agenda and Science Plan for the Puget Sound Partnership.

outcomes. Adaptive management is inherently data- and information-intensive, requiring that the correct information is generated and made available to decision-makers quickly. This requires an investment in infrastructure (people, organizations) and capacity (the ability to generate and analyze information) beyond that of traditional ecosystem management programs. But it results in greater, more immediate transparency and accountability. This Work Plan recognizes the data and information demands of adaptive management, and calls for the required investments by the Partnership.

The Partnership must learn from and act upon the results of activities taken to restore the Sound. The Action Agenda process begins with planning designed to address the most urgent and important needs as currently understood by the Leadership Council, Ecosystem Coordination Board, and the Science Panel. The 2008 Action Agenda is largely based upon work already under way, policy-driven initiatives, and projects aimed at coordinating efforts across jurisdictions and action areas (PSPAA 2008). As these actions are implemented, indicators and benchmarks will be assessed to determine if progress is being made toward the Partnership's goals for protection and restoration. In addition, scientific investigations will provide information about other attributes of the ecosystem. This assessment and continued learning about the ecosystem are critical for providing feedback to the next planning cycle and will inform the next iteration of the Action Agenda and Work Plan (PSPAA 2008).[1] The Partnership will need information about the implementation of actions to evaluate the effectiveness of the actions. The goal is that future iterations of the Action Agenda will include: greater specificity and science-basis for the Partnership's goals for a recovered ecosystem; tighter focus on top priority threats; improved scientific support for strategies and actions; and clear articulation of how strategies and actions will help achieve the goals and objectives defined by the Partnership.

During this biennium, the Science Panel will collaborate with the Leadership Council, the Ecosystem Coordination Board, and Partnership staff to evaluate the effectiveness of actions taken and to revise implementation strategies (including strategic priorities, policies, tactics and initiatives) and provide feedback to the program review cycle. As described in this Work Plan, the Science Panel will oversee the compilation and synthesis of available information about effectiveness of actions, ecosystem conditions and trends, and understanding about how the ecosystem is structured and functions. In particular, the Science Panel will work to establish clear linkages between pressure, state and response, especially identifying thresholds for key indicators of ecosystem health and understanding how people may respond to changing states and management responses. Applying social science principles to establish and articulate the human dimension aspects will allow the Partnership to more clearly link the restoration and protection actions to what people care about and the best science available.

1.2.3 Integrated Ecosystem Assessment as an organizing framework to analyze information

An Integrated Ecosystem Assessment (IEA) provides a framework to develop linkages among the threats/drivers (stressors), environmental goals, and social/economic goals (Levin et al., 2008). The IEA is an iterative and ongoing process that includes:

[1] The enabling legislation requires the Partnership to "revise the action agenda as needed, and revise the implementation strategies every two years using an adaptive management process informed by tracking actions and monitoring results in Puget Sound." (Washington State 2007, 90.71.310).

1) Refining ecosystem goals and objectives into more quantitative metrics, or the best set of ecological, social and economic ecosystem indicators. Thresholds associated with certain levels of ecosystem function are identified so they can serve as indicators and benchmarks against which restoration and protection activities are judged.
2) Conducting risk analyses to improve understanding of ecosystem status and to estimate how major drivers and threats affect the ecosystem. Developing qualitative and quantitative models that relate the most important drivers/stressors to outputs of ecosystem goods and services helps to identify the most imperiled parts of the system, and the likely causes of depressed status. Models of drivers, pressures, states, impacts, responses (DPSIR, EEA 2006, CEROI 2008) are the basis for a common understanding with policy makers and the public about how drivers (anthropogenic and natural) collectively affect current ecosystem states, and which drivers and pressures have the largest impact on indicators. Risk assessment and model development requires mining existing data to improve understanding of historical conditions and stressors and to predict future trajectories. Model development also reveals important scientific knowledge gaps that, with policy input, can become the basis of exploratory and directed research activities. Exploratory studies help identify and explain threats, conditions and impacts not routinely evaluated, and can help ensure that the Partnership can respond to newly emerging issues.
3) Developing and evaluating policy strategies for meeting ecosystem goals and objectives. Qualitative and quantitative models become the tools for predicting how policy decisions affect future ecosystem states (scenarios planning) based on a common set of assumptions. These scenarios can also address or highlight the most important set of scientific and socioeconomic (human well-being) uncertainties and effectively convey to policymakers what we know and do not know (Baker et al. 2004, Peterson et al. 2002).
4) Monitoring of ecosystem indicators and management effectiveness. Synthesis of this information is a key component of the assessment stage of adaptive management. In addition, information from monitoring will support updates and refinements of risk analyses and may also support re-evaluation of indicators, thresholds, and benchmarks.

The analyses and models developed during the IEA process identify conceptual and information gaps. This information may be used to both focus Puget Sound research efforts and improve ecosystem monitoring programs.

A Puget Sound IEA explicitly addresses the four main questions identified by the Partnership (see text box below).

Integrated Ecosystem Assessment provides a scientific framework to address the four main questions identified by the Puget Sound Partnership (PSP 2008a):

(1) *What is a healthy Puget Sound?* The IEA can highlight the indicators that most reflect changes in the functions of ecosystems and provide quantitative tools to forecast future conditions of the ecosystem, including human health and well-being;
(2) *What is the current status of Puget Sound? What are the biggest threats to it?* The risk assessment summarizes current ecosystem conditions or status and identifies quantitative relationships among the most important set of drivers and stressors, as well as the most at-risk ecosystem components (goods and services);
(3) *What actions must we take to move from where we are today toward a healthy Puget Sound?* The management strategy evaluation step facilitates the process of science-policy interactions to address those stressors now and into the future by providing estimates of the individual and cumulative effects of different strategies on ecosystem indicators; and
(4) *Where should we start?* The IEA's management strategy evaluation simulates different implementation scenarios that can support decisions about optimal packages and sequences of actions. The IEA will also assist in applying a monitoring and adaptive management framework that will feed information to subsequent iterations of the risk assessment and strategy evaluations so they can be adjusted as needed over time.

1.3 Outline of the Biennial Science Work Plan

The following sections call for the Partnership to support on parallel tracks two equally important sets of activities: Section 2 – continuing and expanding observations, analysis, critical evaluations, and synthesis of available Puget Sound information, while filling critical gaps with new investigations; and Section 3 – building the capacity and organizational structure, and establishing procedures required for an efficient, transparent, and adaptable science program.

2. Develop a better understanding of the Puget Sound ecosystem

The Puget Sound region enjoys a rich history of high quality science, including several recent efforts to comprehensively review and analyze the state of the ecosystem science (e.g., Ruckelshaus and McClure 2007; Gelfenbaum et al. 2006). These activities are a central underpinning of current and future Partnership efforts, and must be continued and expanded. In addition, the Partnership should identify and fill information gaps, especially where relatively modest Partnership investments in ongoing or planned programs would yield considerable "value added" benefits.

2.1 Analyze existing and evolving information with best available tools

Goal

Use historic and recently collected information to address key gaps in the scientific understanding of the Puget Sound ecosystem – how it has trended over time, how will it look in the future, and how actions affect the ecosystem.

Partnership needs

The Partnership needs the ability to use existing data and ongoing data streams to update and refine the scientific basis for ecosystem recovery. Studies are needed to analyze, synthesize and integrate available information to help address scientific aspects of the Partnership's four key questions. To most efficiently conduct this work, the Partnership needs to coordinate its analyses with others' projects. Section 3 provides additional detail about the Partnership's needs from monitoring and applied research and modeling of current and future conditions.

2009-11 capacity & work program

2.1.1 Continue ongoing monitoring

Continue to collect and analyze information from ongoing monitoring efforts. State and federal agencies and local and tribal governments conduct status and trend and effectiveness monitoring programs related to many aspects of the Puget Sound ecosystem. These programs provide information that can help the Partnership characterize the state of the Sound and learn about the effectiveness of management actions in delivering expected benefits to the ecosystem.

Collect baseline indicator data on human uses of ecosystem services. Existing monitoring programs will be evaluated in this biennium and adaptations will be recommended for 2011-13 (see 3.1.1).

2.1.2 Use IEA framework to refine indicators, assess risks, and evaluate strategies, integrating marine, nearshore, and terrestrial efforts

2.1.2.1 Phase 2 indicator development

Inform indicator development through the IEA process described above and by funding Phase 2 indicator development. Because Phase 1 indicator development relied strictly on a retrospective analysis of previously existing indicators, Phase 2 will consider developing new ecosystem indicators while reviewing the suitability of "potential" and "proposed" indicators from the 2008 indicator evaluation. (O'Neill, Bravo, and Collier 2008). This two-pronged approach to identifying indicators reflects independent but complementary methods that will provide a robust process for final indicator identification. This will also include review of current preliminary human dimension indicators, integrated with Puget Sound ecosystem conditions within the context of the DPSIR framework, to identify relevant human-use indicators.

2.1.2.2 Evaluate current status and primary threats and drivers to indicators across the system

Synthesize information on status of ecosystem indicators and the relative magnitudes of drivers and pressures throughout the region to provide information for answering the second question posed in the Action Agenda: What is the current status of the Sound, and what are the major threats to its recovery?

To address key information gaps, this task will also include integrating and synthesizing historical information to examine changes in ecosystem conditions and threats. For example, assess biological communities and variability in the historical record (Lombard 2007). Steps might include: prioritize historical data records and assessment needs; reexamine existing data; and pinpoint knowledge needed to understand how ecosystem conditions, including human well-being, have changed in recent times.

2.1.2.3 Coordinate IEA efforts

Coordinate the National Oceanographic and Atmospheric Administration (NOAA) Northwest Fisheries Science Center IEA focused on identifying indicators and evaluating strategies focused on marine endpoints (Ruckelshaus et al. 2008) with the Biodiversity Council's Conservation Opportunity Framework (Washington Biodiversity Council 2007) and the Puget Sound Nearshore Ecosystem Restoration Partnership's General Investigation (PSNERP 2008, Simenstad et al. 2006, Gelfenbaum et al. 2006). This will help organize ongoing efforts around a common IEA framework, extend the identification of indicators and evaluation of strategies to terrestrial and nearshore endpoints, and ensure that outputs from one set of models (e.g., predicting land-use changes) can become inputs to other sets of models (e.g., changes in nearshore processes and marine food webs).

2.1.2.4 Explore potential future conditions through future scenarios modeling

Synthesize available information in the form of alternative future states of the ecosystem using results from the conceptual and quantitative modeling of marine, nearshore, and/or terrestrial portions of the system and by depicting likely outcomes under different scenarios. Visualizations of future scenarios will help show how the cumulative and interacting effects of changes in indicators will change the way the Puget Sound ecosystem functions and the benefits it provides. Studies should address high-priority needs and complement programs, projects, and efforts already under way in the region. This biennium's exploration of future scenarios can help to define "What is a healthy Puget Sound ecosystem" and will set the stage for using the future modeling to simulate management strategies.

2.2 Conduct priority scientific investigations

Goal

Design and implement studies to collect new data to address key gaps in scientific understanding of the Puget Sound ecosystem and how it is influenced by management actions.

Partnership needs

The Partnership needs scientific information to address key areas of uncertainty in the science basis for ecosystem recovery. This section identifies a few high-priority topics where new data collection would be useful in developing and demonstrating capabilities as well as providing important and urgently needed results. These topics were selected because they filled prominent gaps in knowledge (as identified in the Partnership's Topic Forum papers and a review of recent recommendations (Hall et al. 2008) and provided an opportunity to advance investigations that work across ecosystem issues of landscape ecology, contaminant loadings, food web structure and function, restoration science, and the integration of natural and social science. Studies of these topics should provide information to the Partnership's adaptive management cycle to identify opportunities and/or challenges for advancing the Action Agenda.

Through these studies the Partnership will contribute to the development of a robust capability for monitoring, modeling and other assessments, information management, and targeted research that can deliver information relevant to ecosystem recovery.

Implementation

Through the Science Panel (or a process developed by the Panel), the Partnership will competitively solicit, select, and fund studies on the four topics outlined below. The process for evaluating proposed studies will consider relevance to Action Agenda goals, issues raised in Topic Forum papers and their reviews, and other expressions of interest from the Partnership. Partnership staff will manage the processes for competing and awarding of contracts and will provide project oversight.

2.2.1 Topic 1: Adaptive management for nearshore restoration

Nearshore areas are critical Puget Sound environments supporting salmon, forage fish, shellfish, wetlands, tribal trust uses, and crucial hydrologic and geologic inputs to the larger Sound ecosystem.

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). Recent research on the role of large river deltas in supporting the ecosystem as a whole emphasizes the need for restoration of these systems. In fact, significant restoration actions are now planned or under way for several of the Sound's large deltas – for example the Skagit, Nisqually, Skokomish, and Elwha (USGS 2007a,b, PSNERP 2008b,c, Gordon 2008, WDFW 2006).

Because 33 percent of Puget Sound shorelines have some type of shoreline modification structure, nearshore habitat features formed and sustained by long-shore sediment transport and deposition are also important in Puget Sound restoration (Nearshore Habitat Program 2000, PSNERP 2008a).

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 (Washington Department of Natural Resources as cited in PSAT 2007).

The Puget Sound Partnership is committed to maintaining intact ecosystem processes, and to the use of science to support adaptive management over the course of restoration work generally. However, science to support restoration of large river deltas and marine shorelines generally has not been systematically planned or supported, and neither have studies been planned jointly with commitments by managers to assure good feedback in the adaptive management cycle (with a few exceptions, e.g., Skagit Systems Cooperative). Because most current science is pieced together with scant resources from multiple diverse agencies – where it happens at all – there is a need for development of restoration science clearly linked to management decision-making. These studies are conceived to develop joint planning with restoration managers to fulfill adaptive management in the restoration of Puget Sound's large river deltas. The work makes use of the fact that restoration has begun and will continue to happen at some deltas and along some segments of marine shoreline.

With its focus on the effectiveness of restoration, this topic provides scientific information directly relevant to one of the Action Agenda's four strategic priorities. This topic has been identified as a need in the research inventory (see Hall et al. 2008, Species, Biodiversity, and Food Webs section). In particular, there is a need to assess the effectiveness of restoration actions for salmon recovery.

Objectives of the project are:

- At one or more large river delta location(s) in Puget Sound and/or at one or more marine shoreline(s), work with managers to assure on-the-ground restoration actions are developed in an experimental design context, working with managers to assure outcomes of actions are both predicted and measured.
- Design and conduct restoration research to measure the results of restoration in such a way that collected data fulfills planning models, emphasizes ecological function, and feeds back to restoration decision-making.
- In addition to serving as the science link in adaptive management at the chosen site(s), this project should improve the understanding of the role of nearshore biology, physical processes, and functions in the wider Sound ecosystem in such as way to maximize the transferability of findings to other restoration actions in the Sound.

2.2.2 Topic 2: Watershed-wide pollutant loading and effects of surface water runoff

Conversion of forested, agricultural, and other areas to urban land uses increases the volume, intensity, and pollutant load of surface water runoff (PSP 2008b). The Puget Sound landscape will become increasingly urbanized with the projected arrival to the region of more than 1 million additional residents between 2005 and 2025 (Office of Financial Management cited in PSAT 2007).

A variety of local, state, and federal programs attempt to reduce ecosystem harm from stormwater runoff and manage patterns of land use. The Puget Sound Partnership is committed to these programs and to the use of science to adaptively manage stormwater and land use.

Work on this topic would address key questions about land use and stormwater at the scale of watershed systems that are approximately 100 square miles in size. These studies would contribute to an ongoing, disciplined, and transparent analysis of potential benefits and impacts of alternative approaches for managing stormwater and land use. These studies, and the ongoing analysis, would provide a key scientific basis for integrated land use and water resources planning as recommended by the Puget Sound Partnership (PSP 2008b).

The objective(s) of studies within this topic will be to address the following questions or issues:

- The effects of stormwater on receiving waters, habitat, biota, or human health in a watershed: what size, location, or other variable makes a particular stormwater discharge more or less likely to cause harm?

- The ability of watershed-scale application of low impact development in an area of new development to effectively maintain the hydrologic regime in a stream.

- The extent to which retrofits reverse past harm. Hypothesized benefits of retrofitting a watershed that might be evaluated include:

    - restore hydrologic equilibrium to an urban stream that is not returned to its historic condition; or

    - reduce loading of toxics to surface waters in an urban watershed; and

    - reduce loading of nutrients and pathogens to surface waters in a suburban or rural watershed.

- The effectiveness of watershed-scale combinations of stormwater management actions (techniques) at reducing harm and the conditions under which findings are likely to be transferable to other watersheds.

The Puget Sound Topic Forum papers (PSP 2008b) and research inventory both identified stormwater runoff and pollution sources as key areas in need of study (Hall et al. 2008).

2.2.3 Topic 3: Stressors affecting the Puget Sound pelagic food web and forage fish restoration

Because Pacific herring, sand lance, and surf smelt occupy a key position in the Puget Sound food web, important ecosystem processes and populations of valued species in the Sound may be controlled directly or indirectly by ecological processes involving forage fish – both up and down the food chain. The open-water food web provides ecological life-support for valued species in the Sound such as salmon, and forage fish are a valued economic resource themselves. Certain populations of forage fish (e.g. Cherry Point herring) have shown steep declines with no clear cause. New stressors are apparently affecting these fish and the food web generally, and these stressors must be accounted for in ecosystem restoration. Stressors include: changing species compositions of prey, competitors, or predators; loss of forage fish-spawning habitat; invasive species; and novel diseases – with climate change and human population impacts as likely drivers behind some of the change (Penttila 2007).

To support restoration, new science is needed to identify stressors within the food web, their effects on forage fish, and the indirect implications for critical ecosystem processes and populations of valued species ranging from algae to orcas. The Puget Sound Topic Forum papers (PSP 2008f) and research inventory both identified food webs and increased marine species knowledge as key areas in need of study (Hall et al. 2008).

Objectives of this project are to:

- Use existing databases on the Puget Sound food web and new research to fill critical knowledge gaps, and characterize the structure and dynamics of the Sound's pelagic trophic ecology.
- Identify stressors affecting forage fish, significant trends, and food web influences on the population dynamics of valued Sound species, in the context of climate change.
- From the outset, develop these studies to inform modeling of food web structure and processes, for use in developing and evaluating Sound-wide restoration actions.

2.2.4 Topic 4: Ecosystem services and socioeconomic indicators

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 restoration goals, the Partnership must measure the progress and effectiveness of restoration not only in terms of ecosystem health, but also in terms of the impacts of restoration on people. Numerous studies have been conducted to estimate the value of marine ecosystems (Pendleton 2008), including studies of the economic value 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, where environmental value studies are shedding new light on the value of ecosystem services in Puget Sound basin (Batker et al. 2008).

The Science Panel encourages use of conceptual models such as DPSIR to provide a conceptual framework for understanding how people and the environment interact. Theoretically, it can serve as a guide for collecting data to model and predict how changes in human behavior affect the environment **and** how environmental changes in turn affect humans and their behavior. To that end, progress has been made in collecting data to characterize changes in the state of the ecosystem. Ecological data are collected in Puget Sound to measure levels of nutrients, bacterial contamination, and a number of other elements characterize the ecosystem. However, no significant investments have been made in development of measures of human response and activity in Puget Sound, and how human activities change as the condition of the ecosystem changes.

Objectives of this project are to:

- Provide specific guidance on how to analyze chosen indicators to show the impact of ecosystem change or restoration on human uses.
- Estimate monetary values of priority indicators of ecosystem service uses using relevant economic models.
- Develop empirical study to demonstrate the effect of policy action and ecosystem change on human uses – using indicator data on human uses, climate conditions and other socioeconomic factors – to determine how much ecosystem restoration and enhancement affect human uses of articulated ecosystem services. As a first step, using information from existing modeling of ecosystem services being conducted in the Puget Sound Basin, conduct statistical analyses to explore the direction and magnitude of relationships between human use and environmental indicators.

2.3 Synthesize, integrate, and communicate the current best answers to the four questions

Goal

Integrate and synthesize findings from scientific investigations for reporting in Partnership's 2009 State of the Sound and 2010 Puget Sound Science Update.

Partnership needs

The capacity to integrate and synthesize information will be needed to communicate a scientific understanding of the Puget Sound ecosystem to the Partnership, its stakeholders and citizens. A clear understanding of the assessments being conducted by contributing agencies and organizations will help leverage the Partnership's assessment needs. Successfully completing this work will require coordination among participating groups, sharing of data and information, and interpreting the results and findings collaboratively. A dedicated professional staff capable of communicating the status, progress, and uncertainties associated with the State of the Sound ("report card") and the Puget Sound Science Update (compendium of Puget Sound science) will be needed to produce these reports on a regular schedule (State of Washington 2007). Additionally, the findings and synthesis products should be peer-reviewed and the technical data and information on which they are based should be publicly available.

2009-11 capacity & work program

2.3.1 2009 State of the Sound

The State of the Sound report includes findings from the ecosystem monitoring program, especially on the status and trends of ecosystem indicators, as well as the Partnership's reporting on a number of aspects of implementation of the Action Agenda.[2]

[2] The State of the Sound is to include reporting on: progress in implementing the Action Agenda; accomplishments in the use of state funds for action agenda implementation; actions by implementing entities that are inconsistent with the Action Agenda and steps taken to remedy the inconsistency; comments by the Science Panel on progress in implementing the plan; citizen concerns provided to the Partnership and the disposition of those concerns; expenditures of funds to state agencies for the implementation of programs affecting the protection and recovery of

The science program contribution of findings from the monitoring program would be accomplished by: (1) integrating and synthesizing information from historic and ongoing investigations to characterize the condition of the Puget Sound ecosystem; (2) commissioning peer review of findings and synthesis products; and (3) delivering peer-reviewed findings and synthesis products to the Partnership's executive director and the Leadership Council for production by November 1, 2009. The Science Panel will oversee contractor and/or Partnership staff work to accomplish these tasks.

2.3.2 2010 Puget Sound Science Update

The Science Panel, with assistance from Partnership staff, is required to produce a Puget Sound Science Update in April 2010 (to be updated as needed thereafter). State statute mandates that the update: (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.

To accomplish this assignment, the Panel and Partnership staff will oversee an effort to: integrate and synthesize information from historic and ongoing investigations to prepare the science update; commission peer review; and submit a peer-reviewed update to the executive director by April 2010. In the early months of 2009, the Science Panel will discuss what content to develop for the science update and how to get broad input and vetting for developing the report.

3. Build capacity for conducting and coordinating strategic science for ecosystem recovery

3.1 Create and enhance the elements of a sustained science program

An important component of the science program is to develop integrated, focused, and balanced capacities for monitoring, research, modeling, and data management. These elements of a sustained science program should be focused on informing the Action Agenda and providing the scientific support for the Partnership's adaptive management program.

3.1.1 Integrated, sustained ecosystem monitoring and applied research

Goal

Sustain social and natural scientific investigations that develop information to allow the Partnership and its stakeholders to understand the Puget Sound ecosystem, evaluate progress toward ecosystem recovery goals, and to assess the effectiveness of strategies and actions. During the next two years, complete an analysis of ongoing programs and recommend improvements so that an enhanced monitoring and research program could be implemented during the 2011-13 biennium.

Puget Sound; funds provided to the Partnership; and recommendations as to how future state expenditures for all entities, including the Partnership, could better match the priorities of the Action Agenda.

Partnership needs

To understand the ecosystem and to revise implementation strategies based on an adaptive management approach, the Partnership needs information about: (1) status and trends of ecosystem conditions, impacts to important ecosystem goods and services, and factors that affect ecosystem conditions; (2) effectiveness of strategies, programs, and projects; and (3) cause and effect linkages for issues involving high risks and difficult tradeoffs. To provide this information, the Partnership will rely on investigations that integrate across land, water, air and physical, chemical and biological elements, as well as social, cultural, and economic systems.

The Partnership will use ecosystem indicators and evidence of cause-and-effect relationships to evaluate progress toward the six ecosystem recovery goals – human health, human well-being, species and biodiversity, habitat protection and land use, water quality, and water quantity. Ongoing status and trends monitoring provide some of these indicators; new monitoring capacity may be required to provide information for additional indicators, especially indicators of pollution loading and other factors that affect ecosystem condition. In addition, monitoring and applied research must be in part exploratory to detect previously unknown threats.

Investigations of whether management programs and projects achieve their expected outcomes will allow the Partnership to evaluate strategies and actions and to find out whether the reasons for selecting strategies and actions appear to be correct or should be adjusted. Existing capacity provides some information about program and project effectiveness. New monitoring and research capacity most likely will be required to provide information about programs and projects that are not currently evaluated.

2009-11 capacity & work program

In the two-year period addressed by this plan, the Partnership will transition to a coordinated ecosystem monitoring and targeted research program for Puget Sound. This program will collect, store, and analyze information about all parts of the Puget Sound in a way that accounts for the effects of human actions on the ecosystem and the benefits human derive from an enhanced state of the environment. The Science Panel and Partnership staff will:

3.1.1.1 Support ongoing efforts to improve ecosystem monitoring in Puget Sound regions

Support and facilitate improved coordination among existing monitoring and assessment efforts, especially those of the Puget Sound Monitoring Consortium's stormwater work group and the Washington Forum on Monitoring Salmon Recovery and Watershed Health.

3.1.1.2 Develop and implement a coordinated regional monitoring program to meet the needs of the Puget Sound Partnership

Develop key assessment questions. Convene a monitoring and assessment work group that makes recommendations to the Science Panel for assessment questions to be addressed by sustained monitoring and research programs. This work group will use Science Panel-endorsed criteria to prioritize the greatest needs for targeted research, effectiveness studies, and status and trends monitoring that should be addressed by sustained, integrated scientific investigations.

Characterize and evaluate current monitoring. Convene (via Science Panel invitation) key scientists from agencies, universities, and tribes into topic-specific technical working groups to characterize and evaluate ongoing monitoring.

Design studies and arrange implementation logistics for a coordinated program. Commission technical working groups (convened above) to recommend ways to improve the scientific quality of information from sustained monitoring and research efforts (e.g., through improved study design, adopting or enhancing conceptual models, selection of variables and indicators, development of monitoring protocols). Facilitate community review and evaluation of options for coordinated monitoring and research, using the Puget Sound Monitoring Consortium to engage stakeholders and convene interest-based focus groups.

To evaluate progress toward the Partnership's goals, recommend enhancements to status and trends monitoring by developing and evaluating different scenarios for where, when, and how to improve and/or expand monitoring of ecosystem conditions, drivers, and pressures. Recommendations can include assessments that are necessary to determine baseline conditions as well as new monitoring of emerging issues.

Recommend programs for investigating the effectiveness of restoration and protection. Recommendations can include developing programs for sustained, integrated approaches to learn from and improve the effectiveness of ecosystem restoration and protection actions in the Puget Sound region.

These activities would be coordinated by Partnership staff with oversight from Science Panel members and would require some additional funding for work group logistics and facilitation.

3.1.2 Invest in capacity for modeling current and future ecosystem impacts

<u>Goal</u>

In two years, the Partnership and collaborators will successfully initiate a process to develop a family of analysis tools that can be used to predict important ecological, economic, and social consequences of alternative future scenarios for the Puget Sound ecosystem. Scenario planning involves process models using quantitative and qualitative information to develop concrete pictures of the future and to reduce the uncertainty associated with projecting future states. Such information can then be used to engage the public in developing more resilient conservation policies (Peterson et al. 2002; Maier et al., 2007). Typically this information is most useful for planning purposes when it is in the form of spatially explicit models (which should emerge from the other science tasks in this plan). Such models are used to simulate ecosystem outcomes from a series of potential actions phrased in terms of policy alternatives (Baker et al. 2004).

<u>Partnership needs</u>

The Partnership needs the ability to evaluate the consequences of various actions (or inaction) and the means of assessing the effectiveness of management scenarios and adaptive alternatives in meeting stated goals and objectives. Scenario planning involves two major steps:

(1) using existing information to create a set of models that can illustrate how drivers/stressors (e.g., human population size, land-use, climate) translate to ecosystem impacts and how management strategies translate to changes in ecosystem service benefits and human well-being; and (2) informing the public about how changes in human behavior related to drivers can affect (future) tradeoffs in ecosystem goods and services.

During the next two years, the Partnership should focus on completing step one: identifying and modeling the most important subset of driver-pressure-state-impact-response (DPSIR) chains that affect the Partnership's ability to reach its goals. Because these models will invariably involve expert opinion, this work should be carried out by teams of local experts in the scientific community under the guidance of Partnership staff, and then undergo peer review by outside experts. As discussed in Section 2.1.2, the process of model construction should include the identification of monitoring indicators, ecosystem thresholds or breakpoints, and information gaps, in addition to quantifying uncertainty (Manno et al. 2006). As discussed in Section 2.1.2, the impacts of major threats and drivers on indicators and the effects of strategies also will be included in model development. Quantifying uncertainty should in turn lead to identification of critical research needs that could be addressed based on the relative importance of the DPSIR chain and the need for greater certainty in defining policy choices. Because *future* scenario planning requires predicting the future state of some driver/pressure and indicators, alternative futures scenarios typically include predicting human population change and the resultant change in land use as a staring point. The Puget Sound Nearshore Partnership is funding work to predict changes in human population and land-use change for the Puget Sound ecosystem that can form the basis of other Partnership's work (PSNERP 2008). The Partnership's work should also be informed by and complement futures analyses by: the University of Washington's Climate Impacts Group (CIG) and Puget Sound Regional Synthesis Model (PRISM 2008) program; the USGS's Puget Sound Ecosystem Portfolio Model; local watershed restoration projects funded by the USEPA (2008); recovery planning tools developed for Puget Sound region salmon recovery (RC0 2007); food web and watershed models being developed by NOAA; and marine modeling approaches developed by members of the Puget Sound marine environmental modeling consortium (PSMEM-C 2008).

As a starting point, this work could assemble existing information and models that predict changes in stream hydrology, stormwater inputs, freshwater loadings of toxics, pathogens, and nutrients, and terrestrial biodiversity associated with human land use and global climate change. The linkages with the marine food web component also need to be better informed. One important aspect of this work is the need to address the spatial scale at which these processes are appropriately modeled and addressed by policy. The need for this work is supported by recommendations in the Puget Sound Partnership Topic Forum papers (PSP 2008b, c, d, e, f) and the research inventory (Hall et al. 2008).

The Partnership would be well served by peer networks of ecosystem modelers who evaluate and discuss model compatibility and evaluation of tools and applications. The Puget Sound Marine Environmental Modeling Consortium (PSMEM-C 2008) is an example of such a peer network.

2009-11 capacity & work program

3.1.2.1 Participate in modeling/assessment work groups

To advance modeling expertise and coordinate monitoring requirements, the Science Panel and Partnership staff will participate in modeling working groups such as: PSMEM-C; Hood Canal Dissolved Oxygen Program's Integrated Assessment and Modeling (HCDOP 2008); Sinclair-Dyes watershed and marine modeling (ENVVEST 2006); PSNERP and USGS's Puget Sound Ecosystem Portfolio Model,; toxic loading study (WDOE 2008a); Puget Sound-wide dissolved-oxygen modeling project (WDOE 2008b); and other modeling programs.

3.1.2.2 Develop capability for modeling of future scenarios and predicting ecosystem effects of management strategies

Develop a long-term plan for future scenario modeling, identifying the goals and milestones for this work, and describing the roles and relationships of collaborators in carrying forward increments of this work. Partnership staff will coordinate efforts to define the requirements, functions, and assets for modeling in support of the Puget Sound Partnership. Modeling should include the capacity for modeling biogeochemical and physical processes, social and economic systems, as well as decision support models and tools.

3.1.3 Invest in capacity for emerging issues research

Goal

In two years, the Science Panel will have established capacity to conduct research to fill knowledge in gaps in ecosystem processes not addressed in 3.1.2 and to explore emerging trends critical to protection and restoration of the Puget Sound ecosystem.

Partnership needs

In implementing the Partnership's commitment to adaptive management, science practices such as monitoring and model development will highlight knowledge gaps. Often, these gaps reflect inadequate understanding of ecosystem processes; in other cases new drivers such as climate change require novel science efforts at the cutting edge of research. Such research will be necessary for proactive management of critical ecosystem processes, structures and functions. Results of research that explore new topics or better define links between critical ecosystem components are ultimately critical, as knowledge of the ecosystem – through modeling to support adaptive management – translates into better design of management actions. Responsive to this need, the Partnership looks to the Science Panel to define an element of the science program, and lead in identifying emerging issues research priorities for the Puget Sound ecosystem.

2009-11 capacity & work program

3.1.3.1 Identify emerging research needs

Identify urgent emerging targeted research priorities through active Science Panel interaction with science community, Partnership staff, and the Leadership Council.

3.1.3.2 Develop and issue a Request For Proposals (RFP) reflecting emerging research needs, commensurate with available funding.

At the direction of the Science Panel, Partnership staff will manage the processes for competing and awarding contracts. Partnership staff will also provide project oversight.

3.1.4 Support education, training, and outreach

Goal

In two years, the Science Panel will have worked in collaboration with the other education, training and outreach capacities of the Puget Sound Partnership and its partners to: promote scientific rigor in communication products; present scientific knowledge to the public and students; and promote and facilitate training for the next generation of scientists capable of addressing complex challenges facing Puget Sound.

Partnership needs

The Partnership needs the people who use and affect the land and waters of Puget Sound with sufficient knowledge of the ecosystem to better understand the implications of their actions and the trade-offs in ecosystem functions, goods, and services. An informed population may result in behavior that improves the quality of the Puget Sound system. Specific roles for the Science Panel are to: (1) advocate for science and science training for students and educators; (2) encourage the Partnership to select a science outreach coordinator to translate science for a range of audiences, and to provide natural and social science perspectives when identifying behavioral changes to be targeted in the Partnership's communication campaign; (3) develop resources to provide advice and scientific content to educational programs (K-12, higher education, etc.); (4) assist and advise Partnership education staff to integrate Puget Sound environmental education into Washington science standards; and 5) advocate for fellowship and internship programs that foster the training of the next generation of Puget Sound scientists.

2009-11 capacity & work program

3.1.4.1 Develop a science education, training and outreach assistance framework

The Science Panel will serve as advocates (e.g., lectures, ambassadors of science education) for science and science training in Washington. For example, the panel will help create a framework where scientific experts provide training and offer technical assistance to existing educational and outreach network resources. This assistance would be aimed at improving the accuracy and quality and quantity of science messaging on Puget Sound throughout the region. The Science Panel will coordinate with Partnership staff to offer advice and content to educational organizations.

3.1.4.2 Provide access to scientific expertise and translation of scientific content

Scientifically qualified Partnership staff (e.g., natural and social scientists) will address day-to-day questions to the Partnership on natural and social science issues or topics and serve as liaisons to the Science Panel to: provide access to scientific information on selected topics; provide contacts for scientific experts; and highlight when there is high scientific uncertainty on a topic and offer access to a balanced input. The Panel will advise and assist the Partnership's chief scientists, science coordinators, and other staff in the translation of scientific content for public outreach materials.

3.1.4.3 Explore opportunities for Puget Sound intern and fellowship programs

The Science Panel recommends the establishment of fellowship and internship programs. The fellowship program would fund graduate and post-doctoral researchers conducting research relevant to the Partnership's goals. The internship program would fund interns to work within institutions (state, federal, tribal, local, NGO, academic), providing cross-fertilization among institutions and opportunities for professional enrichment for a wide spectrum of interns (ranging from recent high school graduates through mid- and late-career scientists). Fellows and interns would be selected to work on research and analyses of relevance, applying to the Partnership via a competitive process. In the next two years, the Panel will work with Partnership staff to explore the opportunities for these programs.

3.1.5 Data management and communication

The Partnership and its stakeholders need access to data from current and historic monitoring, assessments, and research studies so they can integrate and synthesize information about the condition of the Puget Sound ecosystem. Many organizations, including federal, state, and local agencies, tribes, educational and research institutions, private organizations, and citizen monitoring groups are involved in collecting data on the Puget Sound. Furthermore, the Partnership itself will need to collect administrative and project-related data to evaluate the effectiveness of actions and policies implemented as part of the Action Agenda. This information varies from highly quantitative data, such as analytical chemistry results, to qualitative information such as observations reported by volunteers. The types of data formats may range from high-resolution, multi-spectral imaging data to hand-written field notes recorded in a logbook. All these data have the potential to provide important contributions to understanding the ecological condition and quality of the Puget Sound – especially if they can be integrated and made available to support site-specific to regional scale analyses. Data uses include everything from long-term trend analysis to real-time decision support. Therefore a data management system must be developed that is: flexible; capable of accessing data from various organizations and agencies; proficient at cataloging and archiving critical data and information to document Partnership activities; and accessible to a wide-user community consisting of managers, researchers, stakeholders, and the general public.

The Partnership and some of its partners have begun efforts to develop an information management architecture in which the Partnership can function as the center of distributed system of data exchange nodes (RCO 2007b). The Science Panel envisions an architecture that provides functions for users to discover, access and visualize data that are maintained in dispersed information management systems (e.g., similar to that being developed for the Northwest Association of Networked Ocean Observing System, NANOOS 2008). The data management system utilized by the Partnership should take advantage of the existing data repositories and clearing houses already established within the Puget Sound region and work to provide connectivity that would foster and enhance a collaborative user network capable of responding to a wide variety of information needs.

3.1.5.1 Establish information management working group

Establish a multi-agency working group to coordinate data management activities, identify opportunities and obstacles for data management, and develop a data management implementation plan for the Partnership.

3.1.5.2 Develop information management detailed work plan

Complete an assessment of Partnership's business needs for information access and management. For example, describe Partnership's needs and interests in flows of information from monitoring on indicators for State of Sound reporting.

3.1.5.3 Participate in information management working group

Science Panel and Partnership staff will participate in the information management working group and coordinate with data management initiatives being conducted as part of modeling and monitoring working groups addressing information management issues.

3.1.5.4 Develop data exchange for key data sets

Develop data exchange capabilities for key information flow needs and perform other foundational work to build regional data management capabilities.

3.1.5.5 Implement information exchange network

Develop a process to make indicators and other assessment information available and accessible to a wide-user community consisting of managers, researchers, stakeholders, and the general public.

3.2 Organization and procedures

Goal

During the next two years, the Science Panel, working with the Partnership's Leadership Council, executive director, and staff, will establish the necessary organizational structure and processes required to support the Puget Sound Partnership's science commitment.

Partnership needs

The Puget Sound Partnership has a commitment to natural and social science as an underpinning to ecosystem restoration and protection. This commitment emphasizes protection and restoration of ecosystem structure, functions, and processes, as well as the use of adaptive management as a guiding framework for improving management actions through time (Washington State 2007). A meaningful science program must therefore address several kinds of science activities, each of which must target high-priority needs, acquire and process data quickly and efficiently, communicate findings clearly to decision-makers, and make use of the capacities available in the region. The Partnership looks to the Science Panel to lead this effort, while actively engaging the larger scientific community.

More specifically, the Partnership needs decision processes for identifying science priorities and to select and fund targeted research – tapping the considerable scientific talent in the region and beyond. The Partnership needs efficiently managed peer review for both proposals and findings of Partnership sponsored science. Throughout, there must be assurance that science is collaborative, interdisciplinary, and strategically connected to the highest priority needs for ecosystem protection and restoration.

2009-11 capacity & work program

With support from Partnership staff, the Partnership will:

3.2.1 The Strategic Science Plan

Complete the Strategic Science Plan. Prepare a public review draft of the Strategic Science Plan and obtain input from the regional science community on the proposed design and emphases of a strategic science program for the Partnership. This outreach effort could also be used to obtain input on priorities and sequencing of activities presented in this Biennial Science Work Plan. Revise the plans to respond to community input.

3.2.2 RFP process

Develop a process for soliciting science efforts via competitive RFPs. Open communication with the Partnership's leaders and staff will assure that RFPs are responsive to ecosystem recovery policy needs and address the full spectrum of needed knowledge. Specific procedures will be developed to ensure a fair and open process to award grants for projects identified in this Work Plan (e.g., see investigations listed in section 2.2) and future Biennial Science Work Plans, including: peer review of proposals; competitive selection of projects; and awards and management of science funds.

This action would include a determination of the best mix of directed (non-competed) and RFP (competed) funding mechanisms, based on the particular science needs and the capabilities and programs of Puget Sound organizations currently conducting science.

3.2.3 Peer review of materials forming the science basis for Partnership decisions

Establish procedures for timely peer review of technical materials used by the Partnership to make decisions, set priorities, and update and implement the Action Agenda.

3.2.4 External program peer review process

Establish review processes for periodic external review of the overall science program, utilizing highly respected scientists external to the program. This process might be coordinated with the Washington State Academy of Sciences' "assessment of basin-wide restoration progress," due December 1, 2010, subject to available funding.

3.2.5 Puget Sound Partnership-sponsored science

Oversee Partnership-sponsored science conducted in 2009-11 to ensure relevance to ecosystem recovery efforts and Partnership adaptive management.

Identify key needs for the 2011-2013 biennium based on an evaluation of science activities of the region, including the Georgia Basin.

3.2.6 Working groups

Develop working groups to support implementation of the above, and extend participation of the larger science community. The nature of these groups – whether for peer review, collaboration on themes, or development of communities of practice – will be determined through consultation with the Partnership's leaders.

3.2.7 Coordinate agency science programs and initiatives

Coordinate with science programs of state and federal agencies to better align with Partnership interests and contribute to Partnership science program needs. The Science Panel has not decided on roles of the Panel, Partnership staff, and/or independent consultants or work groups in conducting these evaluations.

4. Summary

This Biennial Science Work Plan is a roadmap for describing the scientific capacities, goals, objectives, and tasks to be implemented during the 2009-2011 biennium to move the Partnership closer to its goals. This Work Plan identifies the initial work needed to launch the strategic science program and achieve short-term, high-priority objectives identified by the Science Panel as critical to the implementation of the Action Agenda (PSPAA 2008). The plan outlines the science capacity needed to manage the Puget Sound ecosystem, including: supporting the development of an Integrated Ecosystem Assessment framework; and initiating an integrated and sustained ecosystem monitoring, modeling and research program. The Work Plan identifies high-priority scientific investigations critical to the Partnership's ability to launch an effective strategic science program and Action Agenda. While the research areas encompass only a small fraction of our information gaps, the Science Panel believes these initiatives can help establish early science connections that will be needed on a larger scale to achieve 2020 Partnership goals.

The Work Plan also covers the development of the infrastructure needed to support the Puget Sound Partnership strategic science program, including the development of advisory, peer, and client groups, as well as the development of open, transparent, and responsive processes to select, manage, and review Partnership science projects. The Work Plan also recommends: investing in modeling and predictive tools needed to support adaptive management and planning for future outcomes; identifying research needs for emerging issues; and investing in the education and training of the Puget Sound science and management community. The State of the Sound synthesis and adaptive management work will require effective management of data and information to synthesize and report on the status of the ecosystem, as well as the effectiveness of actions, programs, and policies implemented to protect and restore the Sound.

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Glossary

adaptive management	"… is a structured, iterative process of optimal decision making in the face of uncertainty, with an aim to reducing uncertainty over time via system monitoring." http://en.wikipedia.org/wiki/Adaptive_management
anthropogenic	Caused by humans (Ruckelshaus and McClure 2007).
attribute	Term used to describe potential indicators of each threat/driver category (Ruckelshaus et al. 2008).
benchmark	"… measurable interim milestones or achievements established to demonstrate progress towards a goal, objective, or outcome." (ESSB 5372, Sec 2(3) (cited in Ruckelshaus et al. 2008).
cause and effect monitoring	Also known as validation monitoring, intensive monitoring, research, or cumulative effects monitoring. This is the most comprehensive and thus expensive type of scientific monitoring endeavor. At its core, cause-and-effect monitoring attempts to elucidate enough of a DPSI(R) chain from driver through Impact (or Response depending on the model structure) that we begin to understand the system or validate the most important parts of a conceptual models. This type of monitoring is typically done at smaller spatial and temporal scales because of cost and because increasing spatial and temporal scale increases the complexity of the system and thus the ability to tease apart true cause and effect relationships.
data stream	A time sequenced series of similar data files (ARM 2008).
DPSIR	Conceptual model reflecting the drivers (D), pressures (P), states (S), impacts (I), and responses (R) of factors effecting valued components of the ecosystem (Dennison et al. 2007).
drivers	Driving forces are underlying factors influencing a variety of relevant variables. Examples: the number of cars per inhabitant; total industrial production; GDP (Ruckelshaus et al. 2008).
ecosystem	In this document ecosystem includes, unless otherwise noted, environmental, social, cultural, and economic systems.
ecosystem services	Are environmental provisioning, regulating, habitat forming, and informational functions which "… include products like clean drinking water and processes such as the decomposition of wastes." http://en.wikipedia.org/wiki/Ecosystem_services
effectiveness monitoring	Also known as prescription or performance monitoring. Effectiveness monitoring (EM) asks: Are specific actions or activities resulting in predictable outcomes. In a DPSIR framework, EM often translates into measuring changes in one particular element (i.e., Driver or Pressure) and measuring the resultant element in that same model chain i.e., Pressure or State, respectively. For example, a new regulation could be implemented that removes 75% of copper in stormwater. Whereas compliance monitoring might ask the question, who has implemented the program, effectiveness monitoring (EM) would measure copper concentrations in the water. This type of monitoring typically does not include the question of how biota might respond to these reductions because answering both questions simultaneously (is there a reduction in copper and

	how is this reduction affecting biota) may compromise the ability to answer either question alone. In other words, scientists are likely to design the studies that answer those two questions very differently. EM does not provide strong cause and effect relationships when dealing with the response of biota, relative to validation monitoring, because by definition, EM does not control for other potential factors that can confound biological responses. EM is best suited to track specific management actions in the Action Agenda for which we need targeted feedback.
ENVVEST	Puget Sound Naval Shipyard & Intermediate Maintenance Facility Project ENVironmental InVESTment http://www.ecy.wa.gov/programs/wq/tmdl/sinclair-dyes_inlets/sinclair_cd/read_me.htm
HCDOP	Hood Canal Dissolved Oxygen Project, Integrated Assessment and Modeling. http://www.hoodcanal.washington.edu/
indicator	"… a physical, biological, or chemical measurement, statistic, or value that provides a proximate gauge, or evidence of, the state or condition of Puget Sound. ." (ESSB 5372, Sec 2(5)) this could also include a number of social and economic measurements (Ruckelshaus and McClure 2007).
IEA	Integrated Ecosystem Assessment
IM	Information Management
impact	Impact indicators describe the ultimate effects of changes of state. Example: the percentage of children suffering from lead-induced health problems; the mortality due to noise-induced heart attacks; the number of people starving due to climate change-induced crop losses (Ruckelshaus et al. 2008).
implementation monitoring	The simplest type of monitoring. It asks: Are you doing what you said you would do with respect to specific management actions or activities. This type of monitoring can include charactering regulatory processes (e.g., what proportion of counties completed GMA planning by June of 2008) to characterizing physical activities (what proportion of new bulkheads are established above the ordinary high water mark). Compliance monitoring is one type of implementation monitoring.
linkage	A quantitative relationship between two or more components of a DPSIR framework. Put another way, thresholds are functional relationships describing how change in one component of a DPSIR framework (i.e. the level or amount of some state or process) results in a significant change in another component (Ruckelshaus et al. 2008).
metadata	Is "information or data about the data." Metadata typically refers to information about primary data, which is usually numerical, or information describing aspects of the primary data. Such information could include instrument site information, environmental conditions under which the data were acquired, and any other data needed to understand the primary data (ARM 2008). See also What is Metadata? (USEPA 2008)
monitoring	Data collection to answer a question about the ecosystem, management actions, or relationships among them. See entries for implementation, status and trend, effectiveness, and cause-and-effect monitoring.

NANOOS	Northwest Association of Networked Ocean Observing Systems, 2008. Pacific Northwest Estuaries and Shores. http://www.ccalmr.ogi.edu/nanoos/about.php
NOAA	National Oceanographic and Atmospheric Administration
nutrient	Chemical elements and compounds found in the environment that plants and animals use to survive and grow. In water quality investigations, the major nutrients of interest are forms of nitrogen and phosphorus. High concentrations of nutrients in water bodies can cause eutrophication and hypoxia (Ruckelshaus and McClure 2007).
NWFSC	Northwest Fisheries Science Center
pathogen	Any disease-producing agent, especially virus, bacteria, or fungi (Ruckelshaus and McClure 2007).
peer review	"… the process of subjecting an author's scholarly work, research or ideas to the scrutiny of others who are experts in the same field." http://en.wikipedia.org/wiki/Peer_review
pelagic	That part of the ocean that comprises the water column; open water (Ruckelshaus and McClure 2007).
pressures	Pressure indicators describe the variables that directly cause (or may cause) environmental problems. Examples: toxic emissions, CO 2 emissions, noise etc. caused by road traffic; the parking space required by cars; the amount of waste produced by scrap cars (Ruckelshaus et al. 2008).
PSAT	Puget Sound Action Team. 2007. 2007 Puget Sound Update: Ninth Report of the Puget Sound Ambient Monitoring Program. Puget Sound Action Team. Olympia, Washington. 260 pp. http://www.psp.wa.gov/downloads/SOS07/2007_PS_Update.pdf
PSMEM-C	Puget Sound Marine Environmental Modeling Consortium 2008. http://www.psmem.org
PSNERP	Puget Sound Nearshore Ecosystem Restoration Partnership 2008a. http://www.pugetsoundnearshore.org/
PSP	Puget Sound Partnership http://www.psp.wa.gov Avoid this form where there is potential for confusion with paralytic shellfish poison (routinely abbreviated as PSP).
quality assured data	Typically the final form of data to be submitted to the data system. This includes data stream description documentation, fully calibrated data in commonly used geophysical units, quality flagged data files and all ancillary data (metadata) needed by a future user of the data stream to make full sense of it (ARM 2008).
RCO	Recreation and Conservation Office http://www.rco.wa.gov/rcfb/default.asp
response	Response indicators demonstrate the efforts of society (i.e. politicians, decision-makers) to solve the problems. Examples: the percentage of cars with catalytic converters; maximum allowed noise levels for cars; the price level of gasoline; the revenue coming from pollution levies; the budget spent for solar energy research (Ruckelshaus et al. 2008).
RFP	Request For Proposal
state	State indicators show the current condition of the environment. Examples: the concentration of lead in urban areas; the noise levels near main roads; the global mean temperature (Ruckelshaus et al. 2008).

status and trends monitoring	Also may be referred to as extensive, ambient, or indicator monitoring. This type of monitoring asks: How is an environmental element (indicator) changing through time and/or space. Status and trend (S&T) is usually collected over big areas and/or long time frames and could include collecting data on any of the elements that make up a Driver, Pressure, State, Impact, Response model) (DPSIR). This type of monitoring usually does not collect enough elements of a particular DPSIR chain to inform cause (Driver, Pressure or State) and effect (Impact or Response) although cause and effect is sometime inferred from the data model itself or considered relatively unnecessary because we understand these links from other scientific work on the topic. The link between cause and effect is weak in this type of monitoring especially as temporal and spatial scales increase because the relationship between elements in DPSIR model can change in different environments. S&T monitoring could include measuring ocean acidification throughout Puget Sound but would not inform us what acidification is doing to ecosystem structure, function, or processes. In its simplest form, this type of monitoring is just measuring a single indicator without information on why the indicator may be changing. The Partnership typically reserves the word **indicator** for this type of monitoring.
threats	Threat (vs. Driver): A threat is a driver that is related to human activities, as opposed to a driver, which is natural (Ruckelshaus and McClure 2007).
threshold	A level or amount of some state or process below or above which something changes, becomes significant, or will require a management action (Ruckelshaus et al. 2008).
trophic level	A group of organisms that occupy the same position in a food chain (Ruckelshaus and McClure 2007).
USGS	United State Geological Survey
WDFW	Washington State Department of Fish and Wildlife
WDOE	Washington State Department of Ecology

Other glossaries are available at:
http://www.st.nmfs.gov/st4/documents/FishGlossary.pdf
http://www.ecy.wa.gov/programs/sea/swces/products/glossary.htm
http://www.epa.gov/glossary/