Strategic Science Plan

February 2009 Science Panel Draft

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1. INTRODUCTION (from Tim and Frank)

1.1 Context and Recent History for Puget Sound

Ecosystem Decline

Puget Sound, like many coastal ecosystems worldwide, is showing symptoms of decline. Trends noted for coastal systems both globally and locally include increasing numbers of imperiled species, disrupted food webs, degraded habitat for many species, and increasing levels of toxic contaminants (Heinz Center, 2008, U.S. Commission on Ocean Policy 2004, Ruckelshaus and McClure, 2007,).

Healthy ecosystems are resilient, self sustaining systems that support human societies by providing goods and services in the form of energy, food, building materials, water purification, flood and erosion control, as well as spiritual enrichment, recreation, and aesthetic experiences (MA 2003). Human-caused stress on coastal environments such as Puget Sound can result in an ever-decreasing capacity to provide specific highly valued goods and services.

Ecosystem Level Response Needed

The general decline in coastal ecosystems has led to calls for natural resource conservation at a scale that encompasses the entire system, rather addressing components individually (Pew 2003, USCOP 2004, Leslie and McLeod, 2007). Ecosystem-based management is a strategy for integrating management activities across land, water, air, energy, and living resources in a manner that promotes conservation and sustainable use in an equitable way (United Nations Environment Program/Convention on Biological Diversity, 2000). At its core, ecosystem-based management requires an understanding of human behaviors and choices, and the implications of those choices on natural systems and the output of ecosystem goods and services. This

approach integrates the natural and social sciences, stakeholders, and public policy development to fulfill a common vision for the future of the ecosystem.

State of Washington Initiative/Goals

Novel strategies are required if ecosystem-based management is to succeed. Fragmented governmental jurisdictions, which traditionally manage diverse natural resources separately must give way to collaborative problem identification, ranking, and solving. Because the scientific knowledge base needed to support this collaboration is itself fragmented, a larger integration is needed than has ever before existed. Such integration would knit together specific, diverse components of the human community: state and federal agencies, local governments, tribes, non-governmental organizations, business, and the populace itself.

The Puget Sound Partnership (Partnership) is the State of Washington's attempt to initiate ecosystem-based management of Puget Sound. The Partnership's effort is intended to compliment and coordinate ongoing state, federal, tribal, local, nonprofit, and volunteer efforts to protect and restore the Puget Sound ecosystem. The Partnership is founded on four fundamental beliefs. The first is that Puget Sound Ecosystem is a national treasure and in many ways the life-blood of Washington State. The second is that the Puget Sound ecosystem is in serious decline and likely will worsen through time. The third recognizes that current activities to protect and restore Puget Sound ecosystem are fragmented, uncoordinated, and mostly ineffective at the ecosystem scale. The fourth belief—and impetus for creation of the Partnership—is that the Puget Sound ecosystem is worth saving.

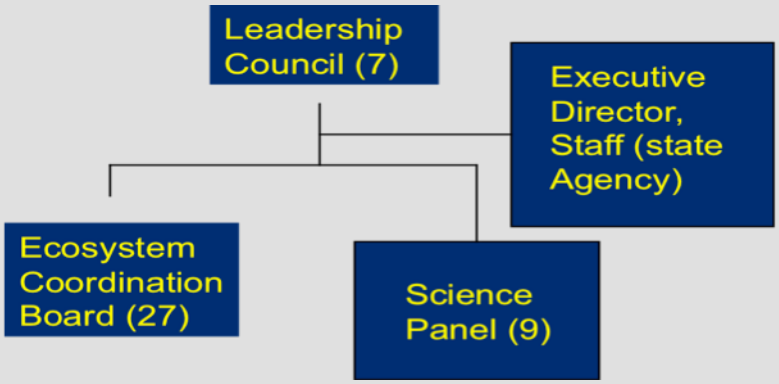
Previous efforts to coordinate protection and restoration efforts for Puget Sound have largely been aquatic in focus. Now, the Partnership has adopted the larger goal of maintaining and restoring the composition, structure, functions, and processes of natural and modified Puget Sound ecosystems for long-term sustainability. Common purpose to achieve this goal will be established through a collaboratively developed vision of desired future conditions that integrates ecological, socioeconomic, and institutional perspectives (Groom et al. 2006). The process has already resulted in a broadly vetted (albeit incomplete) scientific analysis of our current understanding of the Puget Sound ecosystem (Ruckelshaus and Mclure 2007), and a series of "Topic Forum" papers developed through a broad, collaborative, public process.

Puget Sound Partnership Goals and Structure (Text Box)

The Washington State Legislature created the Partnership (Engrossed Substitute Senate Bill, or ESSB 5372) to restore and protect Puget Sound by striving to meet the following goals by 2020:

1. A healthy human population supported by a healthy Puget Sound that is not threatened by changes in the ecosystem
2. A quality of human life that is sustained by a functioning Puget Sound ecosystem
3. Healthy and sustaining populations of native species in Puget Sound, including a robust food web
4. A healthy Puget Sound where freshwater, estuary, near shore, marine, and upland habitats are protected, restored, and sustained
5. An ecosystem that is supported by ground water levels as well as river and stream flow levels sufficient to sustain people, fish, and wildlife, and the natural functions of the environment
6. Fresh and marine waters and sediments of a sufficient quality so that the waters in the region are safe for drinking, swimming, shellfish harvest and consumption, and other human uses and enjoyment, and are not harmful to the native marine mammals, fish, birds, and shellfish of the region.

These goals are to be achieved through development and implantation of a plan, the *Action Agenda*. The *Action Agenda*, released December 1, 2008, is the roadmap to health for the Puget Sound. It identifies and ranks a broad suite of activities that fit into one or more of five *Action Agenda* priorities, which include: 1) protect intact ecosystems, 2) restore ecosystems, 3) prevent water pollution at its source, 4) prioritize actions in a coordinated system, and 5) build an accountability system. Importantly, the *Action Agenda* coordinates federal, state, local, tribal and private resources, and ensures that the Puget Sound community is proceeding cooperatively.



The organizational structure of the Partnership consists of three working committees staffed by the Puget Sound Partnership, an agency of the State of Washington. This Strategic Science Plan calls for engagement of the Science Panel with the broader science community (via both networking and formal working groups) and for collaboration with both policy makers and stakeholder representatives on the Leadership Council and Ecosystem Coordination Board.

The Puget Sound Science Panel

Although Puget Sound has a rich history of scientific endeavor, our science has never addressed ecosystem-scale management, protection, or restoration until now. The Partnership needs science because of the uncertainty inherent in undertaking such a challenging mission. Our understanding of Puget Sound is incomplete—which in and of itself is unremarkable. However, this uncertainty takes on new importance as humans increasingly impact the environment and affect the ability of the ecosystem to provide the full suite of goods and services. Addressing this uncertainty becomes critical when policy makers define broad restoration end points (as in the *Action Agenda*), but are uncertain how to more specifically define actions and progress to achieve those end points. While some policy decisions on the path to restoration can proceed despite relatively high scientific uncertainty, others will require additional scientific understanding before proceeding. Wisely, the Partnership is committed to building a constructive interplay between science and policy so that decisions account for uncertainly in an explicit way.

The central role of science in the Partnership was embodied in creation of the Puget Sound Science Panel (Panel), a nine member independent group of scientists. Panel members were chosen based on professional credentials, not the organization they represent. The Panel was created to assist the partnership in developing an ecosystem level strategic science program that: 1) addresses monitoring, modeling, data management, 2) identifies science gaps and recommends research priorities; 3) develops and provides oversight of a competitive peer-reviewed process for soliciting, strategically prioritizing, and funding research and modeling projects; 4) provide input to the executive director of the Partnership in developing action agendas; and 5) offer an ecosystem-wide perspective on the science work being conducted across the Puget Sound ecosystem. Overall, the Panel is responsible for ensuring that science is an integral and sustained part of evolving Partnership activities.

The Panel's mission is shaped by the enabling legislation of the Partnership; Section 1(2)a of ESSB 5372 states that the Partnership will "Define a strategic action agenda prioritizing necessary actions, both basin-wide and within specific areas, and creating an approach that addresses all of the complex connections among the land, water, web of species, and human needs. The action agenda will be based on science and include clear, measurable goals for the recovery of Puget Sound by 2020." Relying in part on Science Panel deliberation, the Partnership released the Puget Sound *Action Agenda* on December 1, 2008 (citation).

1.2 Why a Strategic Science Plan?

Purpose of the Plan

The purpose of this Strategic Science Plan is to provide the overall framework for development and coordination of the specific science activities needed to support protection and restoration of Puget Sound under the *Action Agenda*. Restoration will require our most capable scientists using the best scientific tools, engaged in a constant two-way conversation with public policy makers. We need a common, systematic, structured decision-making process to pull the pieces together. To succeed, this process needs to continually define, refine, and invigorate restoration in light of new knowledge.

Role of Science Defined by Adaptive Management

No matter how much science we carry out, we will never fully understand ahead of time how Puget Sound will respond to influences such as shoreline development, climate change, or—most critically—our own restoration actions. Snapshots of what we know, for example periodic State of the Sound reports, are needed to summarize and communicate progress. However, science can best help policy makers by deliberatively and continually discovering the causal links between restoration actions and actual measured outcomes in the ecosystem. That is, protection and restoration of Puget Sound is a continuous process through which we come to understand how the ecosystem is responding to change and then employ that understanding to make informed decisions about how to maintain important ecosystem goods and services consistent with the ecosystem's ability to provide those goods and services. Science and policy must perpetually interact to manage the risks of uncertainty.

Science Products of the Puget Sound Partnership (Text Box)

Guided by this Strategic Plan, several types of science products will be developed by the Partnership: [add brief descriptions]

State of the Sound

This plan

Biennial science plans

RFP Project Reports

Etc.

What would this science/policy interaction look like? The centerpiece of the connection between science and policy proposed in this Plan is *adaptive management*. Adaptive management involves the following elements, once restoration objectives have been identified and agreed upon (modified from Murray and Marmorek, 2004):

- exploring alternative actions to achieve restoration objectives;
- predicting outcomes explicitly (for example with process-based models);
- implementing one or more of these actions, recognized as somewhat experimental and therefore designed with evaluation in mind;
- measuring outcomes objectively with monitoring;
- adjusting the actions by comparing the measured outcomes to the predicted outcomes

Adaptive management is much easier to discuss than to practice, although many natural resource professionals erroneously believe they are already practicing adaptive management (Williams, et al., 2007). Adaptive management entails controlled risk-taking that challenges the status quo: "where science thrives on the unknown, politics if often paralyzed by it" (Gore, 1992). For example stakeholders of all stripes must openly confront unresolved uncertainties, change-resistant institutions must alter practices in fundamental ways, and policy makers may be faced with choosing between objective scientific findings and the desires of particular interest groups.

This is not to say these challenges are insurmountable; indeed adaptive management—if accepted by all participants as a guiding framework—may be the only available means by which scientists can be accountable to policymakers and policy makers can be accountable to the public for restoration results. It is therefore vitally important that participants understand what adaptive management is and is not (Van Cleve et al., 2004). This understanding should cut across all Partnership groups, in support of the scientific and policy rigor necessary for success. "A comparison of hypothesis-based predictions against evidence is an essential feature of scientific investigation, and a key reason why adaptive management is described as science-based." (Williams, et al., 2007).

The Puget Sound *Action Agenda* was a significant first step in establishing goals for the protection and restoration of Puget Sound. As these goals are better defined through collaborations within the Partnership to develop specific objectives, adaptive management will help us formalize the interface between science and policy. We need to understand Puget Sound well enough to predict the results of restoration. We need the ability to monitor outcomes of our actions to see if they work, and we need to be honest when they don't—honest enough to change the actions as a result. In this context the approach to science outlined here can support restoration solutions that are robust, but provisional and perpetually responsive to change (Healy, 2007).

Finally, substantial and very valuable scientific efforts are already underway in Puget Sound. Clearly, the one key component of developing an integrated, adaptive science program is identifying these efforts, determining what gaps are likely to be filled with ongoing work, and identifying how to best leverage cooperative scientific investigations. Among these efforts are: the Shared Strategy for salmon; Ecoregional Assessments (The Nature Conservancy and partners), the Puget Sound Nearshore Partnership; the Puget Sound Ambient Monitoring Program (PSAMP); the Forest and Fish Adaptive Management Program; and numerous programs of state, tribal, and federal agencies. The Panel and Partnership staff will identify past and current programs from which the Partnership can benefit and to which the Partnership could potentially add value. This theme of cooperating with the broader scientific community is consistent with the impetus for developing a Partnership in the first place, and is vital to providing the best science in a timely manner.

Uses and Organization of this Plan

This Strategic Science Plan defines how the Partnership will engage in the Puget Sound science enterprise to implement the Action Agenda. It supports the role of science in supporting public policy development and the adaptive implementation of policy decisions. It seeks to assure that the broader science community is engaged, the process is transparent to the public, that Puget Sound science is robust, responsive to external review, and receives permanent stable support. the Strategic Science Plan supports development of tools by which the Partnership measures, and is accountable for, progress toward Puget Sound recovery as defined in the Action Agenda. (http://www.psp.wa.gov/aa_what.php).

More specifically, this document is intended to provide foundational guidance to the development of the Biennial Science Work Plan on a two year state budget cycle. We envision the Biennial Science Plan (BSP) as a funding plan to implement the Stategic Science plan's vision as it applies to the *Action Agenda*. The BSP will address the most pressing scientific information gaps and most critical scientific capacities needs. Science needs will change as more is learned about Puget Sound, and as we come to better understand the Puget Sound ecosystem. Similarly, scientific questions driving monitoring, research and modeling may change in response to improved understanding or as we respond to early restoration outcomes and changing information needs of policy makers. Continual learning is a healthy aspect of the Partnership's commitment to adaptive management, and each BSP will reflect the understanding gained as we proceed.

Within this plan, we first provide a brief summary of the Puget Sound ecosystem itself (Section xx), emphasizing features that make Puget Sound unique, tracing several of the trends that indicate the system is in decline. This is the real world context for our policy, science and on-

the-ground actions. These characteristics are elaborated in more detail in several previous publications, cited in this Plan.

Next (Section xx) we explicate several important assumptions and principles agreed upon by the Panel that will guide implementation of science under the plan. This provides for transparency in the thinking behind our science, since unspoken but differing assumptions about the role of science within the Puget Sound community could make the job of protection and restoration much more difficult.

[brief section descriptions the other sections follow here after they are drafted]

2. DESCRIPTION OF PUGET SOUND CHARACTERISTICS AND TRENDS [from John, Trina, Jan]

System approach for Puget Sound: To address the mission and goals of the PSP, an ecosystem-wide framework has been adopted. However, to take a system approach, we must emphasize the unique natural attributes of the Puget Sound as a system that distinguish it from other estuaries and estuarine systems in the nation.

2.1 Marine and nearshore

Puget Sound is the second largest estuary in the United States, having 3,790 kilometers of shoreline. It is the only urbanized fjord in the nation. The average depth of the Puget Sound is 140 meters with a maximum depth of 280 meters. The bottom of the Sound consists of a series of valleys and ridges which act to disrupt the movement of water and help it mix. The watershed of the Puget Sound is approximately 42,800 square kilometers with over ten thousand rivers and streams. The majority of surface water (80%) flowing into Puget Sound comes from the following major river drainages: Cedar/Lake Washington canal, Duwamish/Green, Elwha, Nisqually, Nooksack, Puyallup, Skagit, Skokomish, Snohomish, and Stillaguamish (http://www.uwfishcollection.org/fishkey/aboutps.html).

Puget Sound nearshore habitat is steep-sided and narrow. Some implications of this structure are that there is only a narrow fringe of nearshore habitat that supports many species at some point in their life cycle. Because this habitat is restricted, there is less leeway regarding destruction of nearshore habitat. Removing or degrading a portion of the nearshore habitat in

Puget Sound does not have the same proportional effect on the living system as in a shallow, flat estuary.

Puget Sound is deep, with strong tides, with bathymetric sills that result in retentive circulation. Salt water from the nearby Pacific Ocean mixes with fresh water runoff from the surrounding watershed. The denser salt water sinks deeper and moves toward the land, while fresh water forms a surface layer that moves towards the ocean (http://www.uwfishcollection.org/fishkey/aboutps.html). The implications of these conditions are that inputs to Puget Sound persist for a long time. Therefore, long-lasting effects that can be de-coupled from source elimination. Puget Sound biota have a high degree of residency which makes the Sound highly productive, but also highly retentive of contaminants.

Climate effects, like ENSO, droughts, upwelling/down welling, have a demonstrated and particularly strong effect on Puget Sound. While climate has a strong influence on Puget Sound, there is a need to recognize the cumulative and diversified effects which come from global influence on three sources of influence: ocean conditions, watershed conditions, and local weather. Because variability due to climate forcing is strong it is extremely important to preserve resiliency, redundancy and representative diversity to assure ecosystem sustainability. This is even more profound in light of uncertain effects from climate change.

2.2 Watershed and landscape

The watershed of the Puget Sound Basin varies across the five PSP action areas. It ranges from predominately rural lands with some forestry, agriculture, conservancy lands, a few small towns and moderate human shoreline use in the San Juan Islands to major and extensive towns along the Puget Sound shorelines and estuaries in South Central Puget Sound where there is heavy shoreline use. Terrestrial habitats throughout the Sound are dominated by fir-hemlock-cedar forest with significant patches of madrone forest, grasslands, scrub-shrub, and rock outcrops. At higher elevations there are glaciers, hemlock and mixed conifer forests. Hemlock and Douglas fir forests line higher elevation streams, becoming riparian woodlands and shrub lands along larger rivers in the lowlands. Fresh water habitats range from small, intermittent streams and lakes to major river systems such as the Duwamish/Green, Puyallup-White, Cedar and Sammamish.

The land cover of Puget Sound today exhibits a dramatic human presence. Although an historical account of change in land cover across the entire Puget Sound basin is not yet available, the dramatic changes show clearly the rapid effects of urbanization (Alberti et al, 2003). Between 1991 and 1999 alone, 1% of the total area in the Central Puget Sound region has been newly developed, and the area designated as forest land decreased by a total of 55% during the same period. Overall, forest cover decreased 8.5 percent between 1991 and 1999.

Highly developed land (i.e., land with greater than 75 percent impervious cover) increased by more than 6% of total area in the region and moderately developed land (i.e. between 15 and 75% impervious cover) increased by almost 8%. The most intense development occurred with the Urban Growth Boundary as defined by the State Growth Management Act, where forest cover has declined by 11.1%. Almost half of the land conversion to development has occurred in the Seattle Metro area (Alberti et al, 2003).

2.3 Humans/economy

The Puget Sound Basin reflects significant ethnic and racial diversity including a rich Native American or tribal heritage as illustrated by the numerous tribes that live and work in the region. People from all around the world are drawn to the area because of the relatively high quality of life (e.g., the Puget Sound Basin is unique in that that there is high connectivity at local and regional levels and residents have lower monthly energy bills than the national average, and there is a wide range of job opportunities). The lands and water of Puget Sound provide an array of ecosystem goods and services that humans enjoy such as commercial, recreational and tribal fisheries, local wastewater treatment, wildlife viewing, hiking and other recreational opportunities, and transportation. The Puget Sound is also at the heart of the State of Washington's prosperity. Geographical location gives the Puget Sound region the advantage of serving as the major North American gateway for trade with Pacific Rim countries. Together the ports of Seattle and Tacoma are number two in the nation for container traffic. The diversified economy creates economic stability. The area has one of the largest shellfish producing regions in the U.S. and at the same time is the world center for software development and information technology. The Puget Sound Basin includes five of the top 10 fastest growing counties in the state of Washington. As many as 1.4 million new residents are expected to move into the region by 2025.

3. PRINCIPLES GUIDING SCIENCE FOR PUGET SOUND

Practicing science in an adaptive management framework will require that scientists, policy makers, managers, and stakeholders reach common understanding about the assumptions, driving forces, and limitations that influence chances for successful protection and restoration. Too often, participants in large scale restoration programs agree on broad language, but later discover that they were actually working from different definitions, frames of reference, or beliefs about roles. If the assumptions underlying a science program are hidden, assumed, or undeclared, consensus on restoration is difficult. During development of the *Action Agenda*, much progress was made by the Partnership toward developing a necessary common frame of

reference. The discussion below is aimed at enlarging this common frame of reference regarding the major drivers, assumptions, and basic themes and principles that shape the science need of Puget Sound.

The human population in Puget Sound basin will increase substantially by 2020 and beyond, adding some two million residents within the next 20 years (Ruckleshaus and McClure, 2007). Restoring Puget Sound will increase in complexity and difficulty through time because of the increasing intensity of human activities. People will continue to build homes along the shore, build roads and other infrastructure, and at the same time recreate in its waters and consume food from the near-shore zone. Land and water use, release of pollutants, shoreline modifications, and other results of population increase will be major drivers of ecosystem change.

Climate change will affect Puget Sound in ways that are both predictable and unpredictable, affecting the way we think about restoration (Ruckleshaus and McClure, 2007). For example, sea levels will rise and the seasonal timing and amount of stream and river inflow will change (Mote et al., 2005), propagating other changes throughout the ecosystem. Human infrastructure, natural habitats and living resources such as spawning salmon will be influenced by these changes; local species extinctions will be more likely; invasive species (including perhaps disease microbes) will be more likely to find newly suitable habitats.

Our ability to define an ecological baseline will diminish as population growth, climate change, and other drivers fundamentally change the ecosystem. Conditions in Puget Sound will no longer fluctuate within a definable envelope of historical variability (Milly et al., 2008); rather the entire system will likely be transformed through new states at a rate comparable to our maximal rate of scientific learning (Healy, 2007). In a setting of moving baselines, the traditional view of restoration—that is restoration to a set of historically defined conditions—may no longer be valid.

Ecosystem structure, function, and processes are critical to restoration but are not well understood aspects of Puget Sound. The Partnership is committed to protecting individual resources (say, salmon), but also committed to protecting supporting ecological functions that support the ecosystem with minimal human maintenance. Such functions might include production of forage fish within the food web, and related natural structures such as spawning beaches needed by the forage fish. In this example the critical structure is the beach, its function is provision of spawning habitat for surf smelt, and the critical process is natural beach nourishment. In practice, research on the ecological processes integral to healthy system functioning is therefore needed to develop models supporting adaptive management, and to appropriately design needed

science elements such as monitoring (Williams et al., 2007; National Research Council, 1990).

Amplifying these themes, certain ancillary principles emerge from the collective experiences of scientists and natural resource managers—some working in specific coastal ecosystems other than Puget Sound. Some of these principles are listed below, as further support in shaping this science strategy. A particularly good discussion can be found in Van Cleve, et al. (2004).

Expect Surprises. Science will inevitably yield counter-intuitive knowledge crucial to the success of restoration. For example, the science program of the Galveston Bay National Estuary Program reversed previous conventional wisdom for 4 of the 17 major restoration needs identified for the ecosystem (Shipley and Kiesling, 1994). In Puget Sound, recent new science addressing Hood Canal oxygen depletion has fundamentally changed our understanding of the role of nutrients (Paulson et al., 2006) and therefore the range of possible restoration actions. Not accounting for scientific revelations such as these in the management arena signals a potential disconnect in the science-policy partnership needed for effective restoration.

The precautionary principle. "Erring on the side of caution" is a much-discussed tenet of natural resource conservation. For any specific activity affecting Puget Sound, the precautionary principle would lay the burden of proof—determining whether the activity is consistent with restoration goals—on those proposing or carrying out the activity rather than on resource managers. In the context of ecosystem restoration science, the precautionary principle is an admission of, and a means to account for, scientific uncertainty about influences of various ecological drivers. Knowledge is always incomplete, and science can never prove, only disprove. Regarding mitigation, for example, Thom et al. (2005) recommend: "Admit uncertainties and overcompensate in design of projects for unavoidable damages."

Benchmarks are not immutable. Effective planning necessarily incorporates goals, actions to achieve those goals, indicators to measure response, and benchmarks to gauge progress (predefined, desired indicator response levels). Uncertainty, however, requires that the process of restoration be continually experimental to some degree. Use of benchmarks to gauge progress and to support accountability must also recognize that these benchmarks will likely need to change as surprises about the ecosystem are revealed by science.

Science as common ground. Differing, often divisive beliefs about the ecosystem and its restoration can emerge when knowledge is incomplete. Science can help unify viewpoints by filling in some of the gaps. For this to happen, scientists must convert

data into relevant information, translate complex ideas for a broad audience, work at a scale relevant to practical action, and have a ready answer to the question "so what?" about the findings of their work (Shipley and Kiesling, 1994; Van Cleve et al., 2004). "Agreement on the facts" is a good foundation for action. Scientist can also come to consensus despite uncertainty that cannot be *quickly* remedied with new data (e.g. as occurred through the work of the Intergovernmental Panel on Climate Change). Thus the lack of knowledge about some ecosystem dynamics can be addressed via concerted effort to document the common ground among experts, as opposed to allowing this disagreement to play itself out in the literature or in public.

Integration of science disciplines. As a particularly dynamic, complex ecosystem, Puget Sound requires an approach that is inherently interdisciplinary and multi-scalar. Collaboration and cross-disciplinary thinking to solve problems in a basin-wide context are particularly important. The entire science talent pool in the region needs to be tapped to address all elements of restoration including marine, lowlands and basin-wide influences. This approach brings to the table many different scientific disciplines: hydrology, marine biology, geomorphology, socioeconomics, terrestrial ecology, and many others.

Four types of information needs. *Research* is needed to fulfill fundamental knowledge gaps relevant to restoration (particularly regarding ecosystem processes); *monitoring* tracks the effectiveness of restoration actions, and at a regional indicator scale, tracks the overall status and trends of the ecosystem; *modeling* helps reconcile competing hypotheses and hidden assumptions, predicts consequences of alternative actions, and supports risk analyses, *information management* supports continuity, consistency, and accessibility of data and information, and supports unforeseen future analysis needs.

Integrating natural and social sciences. Restoration in an ecosystem management context must address the interdependence between human and ecological systems across space and time. For restoration efforts to be successful, simply adding people to ecological models may not be sufficient. Studying coupled human-natural systems requires us to recognize the effects of humans on the environment (how human stressors influence ecosystem processes) *and effects of environmental change and management responses on human behavior, as well as human activities and well-being*. Broadly speaking, human well-being is "produced" by the combination of two types of inputs; ecosystem capital, goods, and services; and human-built capital goods and services. Humans may serve as both agents of positive and negative change to the environment.

The Limits of Science. Scientists should not be asked what should be done to achieve restoration, but rather to help narrow the possible range of actions by predicting their consequences. Decision makers, as keepers of societal values, should consider social, economic, and legal issues in addition to scientific input in choosing actions and setting their priority (Van Cleve et al., 2004). Furthermore, funding will be insufficient for research and monitoring to be undertaken for every restoration action. The challenge will be to design restoration and science strategically so that science best informs policy across a wide range of scales—up to and including the entire ecosystem.

Do Not Delay. Scientific uncertainty is not a good reason to delay action, since there will always be uncertainty. The risk of doing nothing outweighs the risk of taking actions without complete knowledge, at least for certain restoration applications. Under adaptive management, taking action in the face of uncertainty provides science with the experiment it needs to better inform future action.

4. SCIENTIFIC INFORMATION REQUIRED TO ACHIEVE THE SIX PS PARTNERSHIP GOALS (6-9 pages, Lead: Jan; 2nd Joel)

IV.A-F.1. Evaluation of the adequacy* of current scientific information and/or new research/analyses needed to achieve the goal

a. Priority observations are required to describe the current situation

b. Priority tools required to guide policy to meet this goal by 2020

IV.A-F.2. Evaluation of the adequacy* of science-policy linkage information and strategies

a. Priority tools required to assess the efficacy of these policies

IV.A-F.3. Evaluation of where most effectiveness is to be gained (an indication of prioritization)

5. FOUNDATIONS OF A RIGOROUS, DURABLE, AND RESPONSIVE PUGET SOUND SCIENCE PROGRAM (4-6 pgs - Lead: Joel, 2nd Trina, and John; staff Mary)

5.1 Analysis:

V.A.1. How is the Puget Sound ecosystem, including social and economic systems, structured and how does it work?

a. Why this question is important to PSP goals:

b. What is required:

c. Current state of capacity to address this question:

d. Roadblocks and opportunities:

V.A.2. How has the Puget Sound ecosystem and social and economic systems changed and what will it look like in 2020?

a. Why this question is important to PSP goals:

b. What is required:

c. Current state of capacity to address this question:

d. Roadblocks and opportunities:

V.A.3. What are the individual and cumulative effects of actions?

a. Why this question is important to PSP goals:

b. What is required:

c. Current state of capacity to address this question:

d. Roadblocks and opportunities:

5.2 Required Capacity and Competency (1-2 pages, Lead: Joel, 2nd Trina; Staff: Scott and Ken).

The Puget Sound Science Program should maintain a balanced portfolio that includes:

V.B.1. Integration, synthesis, and application of existing information

V.B.2. Observations of current status and trends

V.B.3. Exploration of ecosystem structure and function

V.B.4. Exploration of social and economic systems

V.B.5. Ecosystem-scale prediction

V.B.6. Anticipatory science (getting ahead of the curve)

V.B.7. Development of new tools including decision tools and integrated ecosystem/economic systems models

V.B.8. A healthy scientific community in Puget Sound also requires investments in:

a. Training/education

b. Infrastructure

c. Communication (conferences, publications, outreach)

5.3 Peer Review (from Guy)

Peer review is a fundamental tenet of good science. Independent peer review is the accepted tool for rigorous, impartial evaluation of scholarly manuscripts, research proposals, complex institutional research programs, academic faculty and federal agency science staff promotions and most other decisions affecting how science is conducted and used to address human needs and problems. Peer review has become a cornerstone of most science and engineering research and funding agencies. For instance, the Ecological Society of America (ESA)[1] has described peer review as "…is an integral component of scientific research and publishing. It allows the scientific community to maintain quality control of research through the review of research proposals, journal manuscripts and other reports. Academic peer review, although far

[1] Ecological Society of America (ESA) Public Affairs Office briefing to the US Congress, ESA Bulletin 86(1), January 2005; see: http://www.esapubs.org/bulletin/current/current.htm

from perfect, is the best tool scientists have to ensure high standards for their professional work."

Peer Review Components

Restoration and preservation of Puget Sound ecosystems as developed under PSP will involve extensive assessment of scientific direction and priorities, and scrutiny of background science and restoration performance; all of these aspects demand some level and type of peer review. Peer review under PSP should: (1) ensure that the "best available science[2]" is pursued; (2) avoid potential conflicts of interest and minimize the influence of other, subjective factors, such as funding source. There are four fundamental types of peer review: (1) research proposal ranking and selection; (2) technical report and other product review; (3) strategic science approach review; and (4) program review.

Decisions of Selection or Ranking. Any decision based on scientific and technical merit, such as evaluation of research proposals, should be based in peer review. Through peer review, the difficult decisions about research funding allocation and dissemination of results can be objectively based on scientific validity, originality, and importance and relevance.

Product Review. The second internal need for formalized peer review is to ensure the scientific credibility of PSP products, such as guidance documents, technical reports and data/metadata. Optimally, peer review is characterized by:

Effectiveness—an effective process for peer review is essential to promote integrity

Competence—reviewers should have the expertise to provide an authoritative review

Usefulness—procedures for reviews will be followed in a timely fashion and that reviewers' comments will be constructive

Security—confidence that the peer review process minimizes the risks of bias and that reviewers will not take unfair advantage of privileged information

Scientific Strategy and Direction. Peer review is also a critically important aspect of program guidance, contributing to pivotal decisions and advising on strategic directions. Such guidance typically involves a body (formal committee or panel) of experts from outside the region, who are completely disassociated with the program but familiar with the ecosystems and scientific concepts required to address the regional issues. Such peer review can serve internal direction

[2] See US federal and other institutional/legal definitions; Lessons Learned document (PSNERP-NST 2005) also provides detailed definition.

in (1) an *advisory* role or can (2) provide critical *review* of program progress and performance. In addition, these roles may be exercised *internally* (operating as an explicit component of the organizational structure) as the Science Panel now performs or *externally* (operating outside of the organizational structure, reporting to an over-seeing or independent body).

There are some significant differences in the internal advisory vs. external review roles:

Internal advisory bodies do not always examine the fine detail aspects of a program, but more the program's fundamental goals and objectives, the strategic approach to addressing them and the organization structure and decision-making process. When applied most effectively, advisors are involved early in the program and meet periodically to review the program at critical stages, in an adaptive mode. Reporting is often brief and often the most critical exchange is verbal review with the program staff. They often report directly to a program's technical staff, but copy their advice to management levels.

External review bodies typically evaluate a program nearing its completion, or at least late in its maturity. The primary goal is often to assess whether or not the program has met its goals and objectives, and to provide pivotal evaluation for the decision of whether or not to continue a program. Such review panels or committees may stipulate their own approach to assessing the program, independent of the program or its sponsor.

Programmatic Structure. Designing the structure of a complex restoration program, such as the PSP, is a difficult task with seemingly endless alternatives to integrating and balancing science, management, governance and evaluation (VanCleve *et al*. 2004). Peer review, often associated with comparable tasks under Scientific Strategy and Direction (above), can also be utilized to help advise on and shape program structure to maximize the implementation of "best science".

The Science Panel Proposes PSP Peer Review

The integrity and effectiveness of scientific investigations associated with PSP require peer review, preferably in the multiple programmatic levels described above. The PSP Science Panel presently performs the functions of providing Scientific Strategy and Direction and recommends that PSP establish peer review at two additional levels:

- Proposal and Product Review (Internal)
- Program Review (External)

Research Proposal and Product Review would provide the periodic review required for proposals and products from and to PSP. These would be based on an internal review process conducted by anonymous, independent experts not associated with the program. To prevent real or perceived conflict of interest, reviewers would be limited to individuals not related to

any on-going PSP research or other direct or contractual activities. The reviewers and their disciplines would vary depending upon the topic of the review, but their expertise should overlap extensively with the proposal or product topic. Review of PSP products (e.g., reports, manuscripts, datasets) would typically be based on mail/e-mail exchanges. Proposal reviews would likely involve a combination of mail/e-mail review and panel meetings. Review participants would be volunteers (as is often the case for proposal and manuscript review) or be compensated on a review-by-review basis.

One specific example to improve the quality of science that is used by decision makers is to adapt the *Puget Sound Update* to become a document that is more similar to the International Panel for Climate Change (IPCC) Assessment Reports that come out every 5 years or so. The IPCC utilize a structured process involving a small working group of authors for each major section that writes from an outline that is given to them by the IPCC, and then there are several rounds of intensive peer-review before the document is finalized. Criteria for data or analyses that can be included are set in advance, and it is not limited to peer-reviewed journal articles (e.g., assessment data and evaluations can be included, as long as they meet peer review standards.) Such a peer review process for the *Update* would elevate the quality of the document, and broaden its scope to include priority science reporting needs defined by PSP. It also would contribute to a significant change in the scientific and policy communities (e.g., provide ease of access for major scientific conclusions and synthesis of most current science; elevate science quality by filtering it through rigorous peer review process, etc.)

Program Review would require a less frequent (e.g., annual?) assessment than that provided by the Science Panel but would address the broader goals and purposes of the PSP on the scale of a NRC review but with continued involvement rather than a one-time review. It would be composed of both national (or international?) and regional experts, including representatives of scientific and technical expertise, social scientists and stakeholders. Optimally, members would have some experience in large, ecosystem-scale restoration in other regions (as might be represented by key individuals involved in the case study programs reviewed in Van Cleve *et al.* 2003). While their background should be science based, their perspective should be programmatic, e.g., to ensure that science is most effectively deployed and managed toward the goals of the PSP. They would report principally to the PSP Leadership Council. Participants would be compensated on an on-going contractual basis for each review period.

6. IMPLEMENTATION (12-16 + 1 pages – Lead John, 2nd Joel and Jan)

(NB. May be merged with section IV, if appropriate)

VI.A Integration of information and efforts. (1 page, Lead: Joel, 2nd Jan; Staff: Scott and Mary)

In the following sections specific foundational elements are addressed to convey important aspects pertinent to each. However, success requires a seamless and integrated program such that data are available to all, that monitoring is supported by research, that research is supported by availability of monitoring data, that numerical models are integrated into assessments, and that conceptual models are used to convey information and understanding.

Also discuss integration of existing necessary resources and efforts under the Partnership and under a common, unified vision.

VI.B. Monitoring (from Ken before Nov 2008 SP meeting)

Monitoring is the measurement of environmental characteristics over time to 1) assess whether management actions (including regulatory policies and environmental laws) have been implemented; 2) determine the value and temporal or spatial trend of indicators of the state of the ecological system; and 3) to assess if management actions are having the desired effect (Suter 1993, Noon 2003). In the framework of ecosystem monitoring, these components are known as *implementation* monitoring, *status and trend monitoring*, and *effectiveness* monitoring (Noss and Cooperrider 1994, Busch and Trexler 2003 and articles therein), although different scientific subdisciplines sometimes use other terms. Monitoring, therefore, provides the information to make better decisions.

The Puget Sound Partnership and Strategic Science Plan is the overarching framework for collaborating and coordinating the diverse ecosystem monitoring efforts for the six Puget Sound Partnership ecosystem goals. This is not a plan for single, comprehensive monitoring

program. In contrast, the Puget Sound Partnership and Science Panel recognize and encourage ecosystem monitoring by many different entities in the Puget Sound at different geographic scales. This includes existing programs and new programs that will fill gaps in our knowledge. The characteristics that are necessary for these efforts to be as useful and cost-effective as possible have been described in numerous publications (e.g. ISP 2000, Busch and Trexler 2003 and articles therein, Thom et al. 2007). In advancing the Partnership goals, the Science Panel sees eight elements that require collaboration and coordination as part of the Science Plan.

1. **Assessment Objectives**. The different monitoring efforts need to be part of a clearly defined hierarchy of objectives and assessment questions related to the six Partnership goals. Objectives also need to represent an informative balance of implementation, status and trends, and effectiveness monitoring. Coordinating and reviewing the development of these objectives is a major goal of the Science Panel.
2. **Statistical Designs.** Because we cannot monitoring everywhere or all the time, most status and trend monitoring will be based on choices of locations, times, and frequencies to make measurements. Using appropriate, coordinated, rigorous statistical sampling or experimental designs increases confidence in the results and allows the data to be combined with other similar data. Likewise, designing effectiveness monitoring depends on developing good conceptual models. Developing the capacity to coordinate assessment objectives, which inform the design, and to generate and review appropriate statistical designs is an important element of the Science Plan.
3. **Variables and Indicators.** The environmental characteristics (or variables) that are measured need to be relevant and applicable to the environmental or institutional endpoint, responsive to changes, and reliability and efficiently measurable. In addition, they need to be useful in developing indicators that can be used to accurately and easily communicate monitoring results. Developing and evaluating appropriate indicators of attributes of ecosystem state or function from measurements on multiple biological, physical, or chemical variables is not simple. The Science Panel is required by legislation to identify appropriate indicators of the health of the Puget Sound. The Science Panel also recommends benchmarks (values of indicators to use to assess progress). The intent of the Science Plan is to begin with review and selection of variables and indicators based on existing monitoring efforts and then refine and add to these as more complete and coordinated ecosystem monitoring develops.
4. **Monitoring and Sampling Protocols.** Standardized sampling and data collection protocols are necessary to reduce measurement errors and to allow replication. Indicators that will be aggregated across different scales or monitoring objectives need to be based on variables that are standardized at the lowest possible scale. Encouraging collaborative, standardized monitoring protocols is an important element of the Science Plan.
5. **Data Quality.** One of the most damaging ways to discredit monitoring results is to attack the quality of the data. An important element of the Science Plan is to promote

quality controls that ensure the integrity and validity of monitoring data for the Puget Sound. A key part of the Science Plan is developing and documenting descriptions of program organizations (data flow and database management), data quality assurance objectives, data transfer protocols, data reduction and validation, and quality assurance audits and corrections.

6. **Sharing Data.** The Puget Sound Partnership is a state agency built around collaborative efforts by other state agencies, federal agencies, Indian tribes, local governments, businesses, and non-governmental organization to recover the Puget Sound. Sharing data is vital if scientific information is to have an important role in all the decisions that affect the status of Puget Sound. (See Section V.E. Data Information and Management). With successful collaboration and coordination on elements 1-5 (above) and advances in information technology, it is possible to overcome the logistical and institutional constraints that existed even a decade ago.
7. **Analysis and Reporting.** If monitoring is to contribute to better decisions to protect and restore the Puget Sound, then the data need to be analyzed and reported in ways that are useful. A key part of the Science Plan is to report on the status of the ecosystem and its components, progress towards the Puget Sound Partnership benchmarks and goals, and evaluations of the effectiveness of management actions. Strategically this means targeting audiences at different levels of scientific sophistication and reporting in different venues, ranging from peer-review scientific journals and conferences to newsletters and magazines. In keeping with a broad-based, interdisciplinary collaborative approach and because the Science Panel does not have the capacity to do all analyses that possible or desired, analysis and reporting will be done by many different groups. The Science Panel, however, can provide or facilitate independent reviews and interpretation of these.
8. **Adequate Funding.** Funding agencies often hesitate to support long-term ecological monitoring because of the perceptions that the results are not very useful, that monitoring takes money away from on-the-ground restoration or protection efforts, and that monitoring projects are implemented without a sense of priorities. Successfully implementing the above elements of the Science Plan addresses these perceptions by focusing on clearly identified objectives that are important for management, coordination that promotes the most cost-effective use of the data, and reporting on indicators that provides direct, understandable feedback to the public and organization responsible for the Puget Sound on state of the ecosystem and its components. These same elements provide the framework assessing the scientific priorities for recommending monitoring to decision makers for funding.

VI.C. Modeling

VI.D. Research

VI.E. Data Management Capabilities Needed to Support the Puget Sound Partnership Science Program

7. SCIENCE EDUCATION AND OUTREACH PLAN (from Trina)

7.1 Background

The goal of restoring and protecting Puget Sound requires a community effort of citizens, governments, tribes, scientists and business working cooperatively to prioritize projects, leverage resources and develop a cohesive plan that will hold people and organizations accountable. Technological advancement, leadership in the sciences, and effective conservation and management of coastal and marine resources are not the only vital components necessary to restoring the health of Puget Sound. Equally important is an informed and empowered society. Success of a healthy Puget Sound among this diverse group of stakeholders will require an outreach and education strategy that optimizes gathering and dissemination of information and effective communication.

The PSP needs to empower people that affect the land and waters of Puget Sound with sufficient scientific knowledge of the ecosystem. Promotion of this knowledge by an informed population may result in behavior that improves the quality of the Puget Sound system. Specific roles for the SP are to: 1) to advocate for science and science training for students and educators: 2) encourage the PSP to select a chief scientist or science coordinator to provide translation of science content to outreach messages for a range of audiences, and vet Partnership work to identify a list of behavioral changes with a science underpinning that the communications campaign will promote, 3) develop resources to provide advice and scientific content to educational programs (K-12, higher education, etc.), 4) assist and advice PSP educational staff to integrate PS environmental education into WA science standards and 5)

advocate for Fellowship and Internship programs that foster the training of the next generation of Puget Sound scientists. (UPDATE THIS PARAGRAPH AS OTHER BULLETS ARE ADDED BELOW)

A number of recent national and regional efforts, including the Puget Sound Conservation and Recovery Plan, the Oceans and Human Health Act and the work of the U.S. Commission on Ocean Policy have emphasized the importance of outreach and education. Targeted, high-quality outreach and education efforts will enable the Partnership to:

- Better fulfill its responsibilities to provide the scientific basis to meet Partnership's stewardship role by 1) ensuring resource managers have the scientific information they need to conserve and manage living resources and their habitat, 2) by listening to and understanding the values of stakeholder groups and community members, 3) by helping to create a well-informed public that understands the Puget Sound ecosystem.
- Ensure a dynamic, diverse, and interdisciplinary workforce with competencies critical to advancing ecosystem research, both now and in the future.

7.2 Purpose

This plan summarizes the priorities and approach of the Puget Sound Partnership (PSP) Science Panel's education and outreach efforts. The purpose of this plan is to provide a document that helps coordinate and focus the Science Panel's outreach and education efforts both now and in the future.

7.3 Definitions

People define outreach and education in many different ways. In the context of this plan, **outreach** is considered to be any information, activity, or program that is designed to reach out and learn about the perspectives, objectives and value sof stakeholder groups and community members, translate scientific knowledge, build awareness, develop relationships, or inspire individuals to pursue further learning opportunities, while **education** is considered to be any information, activity, or program that is designed to increase learning. Importantly, learning encompasses both knowledge and skills development.

Education is often divided into formal or informal education. In **formal education**, learning takes place as part of a structured educational system where students are required to demonstrate proficiency in the process of reaching an end goal. In contrast, with **informal education**, learning takes place outside of a structured educational system, and is the choice of an individual. Informal education can take place in a variety of

settings (e.g., a museum or park), and while participants may not be required to demonstrate proficiency, all informal education activities and programs have clearly defined objectives.

Education, and in particular informal education, and outreach are often confused. While the distinction between education and outreach can be blurry, and outreach and education activities are often linked, from our perspective what distinguishes education from outreach is the goal or intent of the activity or program that is undertaken. With **outreach** the goal or intent is to learn about stakeholder and community values and objectives and provide specific scientific information, to inspire audiences or to raise awareness of or interest in NOAA, science, or a specific topic area. With **education**, however, the goal or intent is to go beyond awareness, appreciation, and exposure to increase learning in specific areas.

7.4 Goals and Approach

The approach of the PSP Science Panel's outreach and education efforts include the following:

1. The SP will serve as advocates (e.g., lectures, ambassadors of science education) for science and science training in Washington State. For example, create a framework where scientific experts would provide training and offer technical assistance to existing educational and outreach network resources that vastly improves the accuracy and quality and quantity of science messaging on Puget Sound throughout the region. The SP will serve as a resource to offer advice and content to educational organizations, in coordination with the PSP and their partners
2. The SP recommends the PSP establish a natural and social science position (e.g., chief scientists) that works with the PSP staff regarding any day-to-day questions on natural and social scientific issues or topics. The chief scientists will serve as liaisons to the SP to provide access to scientific information on selected topics, to provide contacts for scientific experts, and to highlight when there is high scientific uncertainty on a topic and offer access to a balanced input.
3. Serve as a resource to offer advice and content to K-12 (and beyond) educational organizations. This will be coordinated with the PSP and major educational groups in Washington such as NAME, E3, Salish, and COSEE and various universities and educational institutions.
4. The SP will advice and assist the PSP's chief scientists or science coordinators in the translation of natural and social scientific content for public outreach materials.

5. The SP supports the establishment of Fellowship and Internship Programs. The Fellowship Program would fund graduate and post-doctoral researchers and the Internship Program would fund interns (high school, 0-5 years past a Bachelors or Masters degree) to work within institutions (state, federal, tribal, local, NGO, academic). Fellows and interns would be selected to work on research and analyses of relevance and application to the PSP via a competitive process with evaluation of proposed work and presentation of results to the PSP for their use. In the next two years, the SP will work with PSP staff to explore the opportunities for these programs.
6. Help identify and support a citizen science coordinator who would:

    - Work to make connections between monitoring or data-collection needs (from agencies and others) and willing and able citizen groups
    - Coordinate and implement training opportunities
    - Help identify gaps and opportunities in Puget Sound wide citizen science effort
    - Help make existing appropriate data available for use (data bank).

7. Catalogue, evaluate and assess current science education programs and work
8. towards better quality and consistency of programs
9. Help with creating effective assessment and evaluation strategies for existing education and outreach efforts.
10. Conduct research on the link between education and outreach efforts and the health of the environment it is trying to affect.

Mary's note: Reporting *should be mentioned as part of education and outreach. Re-iteration of using PS Update as the primary summary report (or whatever we decide) as stated in peer review section. Need to frame chapters by PSP leadership; scientists write them to the best of our ability, get it peer reviewed. The 'best available info' is archived and used until next iteration. The scientific 'state of understanding' can be used in education and outreach…in addition to more detailed and smaller-scope results to be shared at PSGB conference, web sites with annotated bibliographies, etc*

7.5 Conclusion

To achieve these goals, future outreach and education activities on eight primary areas are warranted: media relations, public & internal events, publications, the internet, formal education, informal education, professional development, and research and career opportunities. Examples of priority activities in the Science Plan in these focal areas over the next 3 to 5 years include: working to improve Washington State science education in partnership with specific institutions; working with school districts and local

non-profit organizations to provide professional development for middle and high school teachers in statistics and scientific inquiry: developing fellowships and traineeships to develop and strengthen science workforce.

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