Integrated Conceptual Model for Ecosystem Recovery

A TECHNICAL MEMORANDUM FOR THE PUGET SOUND PARTNERSHIP

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Introduction

Social Ecological Systems

Traditionally, natural resource management has focused almost exclusively on the natural environment, or biophysical condition of the ecosystem. Natural science conceptualizations and investigations were separated from those of the social sciences, as the two scientific fields developed independently and do not combine easily (Ostrom et al. 2009). The wellbeing of human communities is inextricably linked to both the health of the earth's biophysical environment and the health of humans living in the community (Yee et al. 2012); however, our understanding of how humans interact and benefit from nature has been limited. Although many have studied the human-nature interaction, the complexity of coupled systems has not been well understood (Liu et al. 2007).

More recently, ecological and social research has explored a more nuanced and comprehensive understanding of how humans experience and benefit from the natural environment's complex functions. This has required a shift in thinking to integrate, organize, and prioritize research within a systems context (Yee et al. 2012). All humanly used resources are embedded in complex, social-ecological systems (SESs) (Ostrom et al. 2009), and every ecosystem on earth is influenced by human action (Collins et al. 2011).

To reflect these dynamic systems, the scope of ecological management must expand to incorporate many scientific disciplines, as well as the pervasive human dimensions of environmental structure and change (Collins et al. 2011). To address the pressing and dynamic challenges of this era, the biophysical environment and natural resources used by humans are best understood and studied as elements of a SES (Liu et al. 2007). New approaches that integrate natural and social sciences are needed to better explore the outcomes of these human-nature interactions. An integrated systems framework has many potential roles in science, planning and management, including identifying key issues, visualizing interactions within the system, identifying research gaps, organizing information, developing analytical models and identifying indicators (Yee et al. 2012).

Ecosystems are comprised of many species that interact at varying rates and scales, from which patterns can emerge (Collins et al. 2011). SESs are comprised of multiple sub-systems and internal variables within these sub-systems at multiple levels, analogous to the self-organization of an organism's many parts; in a SES, subsystems such as a resource system (e.g. a coastal fishery), resource units (fish), users (fishermen), and governance systems are all relatively separable but interact to produce outcomes at the SES level, which feedback to affect those subsystems, their components, and other SESs (Ostrom et al. 2009). Human systems also self-organize, but can behave in unpredictable ways, as humans are able to act based on values and abstractions, and make decisions based on expectations of a future state (Collins et al. 2011). This unpredictability creates unexpected outcomes, which can have long term effects on SESs. (Liu et al. 2007). As we become aware of the emerging trends, dynamics, and feedbacks throughout these systems, we build our understanding of how our wellbeing is supported and sustained by natural systems and our interaction with them (Collins et al. 2011). The key to managing for continued sustainability is to effectively integrate environmental, economic, and societal needs, combining the specificity of science with the holistic nature of community decision-making (Yee et al. 2012).

Human Wellbeing and Ecosystem Management

Human wellbeing has been defined in a variety of ways. It is a multi-faceted concept that incorporates many aspects of our quality of life, including physical and mental health, economic stability and vitality, and cultural and spiritual practices (Biedenweg et al. 2014). Human wellbeing is subjective; it is shaped by people's values and perceptions. Human wellbeing depends on (but is not solely determined by) interactions within SESs; many aspects of our quality of life are shaped by the delivery of ecosystem goods and services.

Human wellbeing, or the delivery of goods and services to support human wellbeing, are commonly included among the goals and objectives of agencies and organizations charged with managing natural resources and biophysical systems (e.g., goals of the Puget Sound Partnership as described below; multiple-use sustained-yield policy of the U.S. Forest Service). Identifying measures of human wellbeing has become a growing trend in integrated ecosystem management (Bowen and Riley 2003). The explicit, integrated consideration of goals for human wellbeing and goals for ecosystem structure and function (Reiter et al. 2013) informed by an improved understanding of the relationship between human wellbeing and the biophysical elements of an SES will enhance the effectiveness of ecosystem management (Biedenweg et al. 2014).

The Puget Sound Partnership

The Puget Sound remains beautiful on the surface, however its current state reflects centuries of human pressure on the system – of its 16 major rivers, all have at least one salmon stock listed as threatened with extinction under the Endangered Species Act. Many other species are depleted, including the iconic Orca, which were listed as Endangered in 2005.

In 2007, the Washington state legislature formed the Puget Sound Partnership (PSP) with a mission to restore Puget Sound by 2020, with the following six goals (PSP 2014):

- Healthy people are supported by a healthy Puget Sound
- Our quality of life is sustained by a healthy Puget Sound
- Species and the web of life thrive
- Habitat is protected and restored
- Rivers and streams flow at levels that support people, fish, and wildlife
- Marine and fresh waters are clean.

The first two goals identified by the legislature specifically call out human wellbeing aspects of the Puget Sound SES.

PSP utilizes an adaptive management and ecosystem-based approach to Puget Sound recovery. The PSP Leadership Council has adopted 21 Vital Signs (Figure 1; PSP 2014) to monitor progress toward recovery and additional indicators are being selected for both biophysical and human wellbeing domains to more comprehensively track and understand system dynamics.

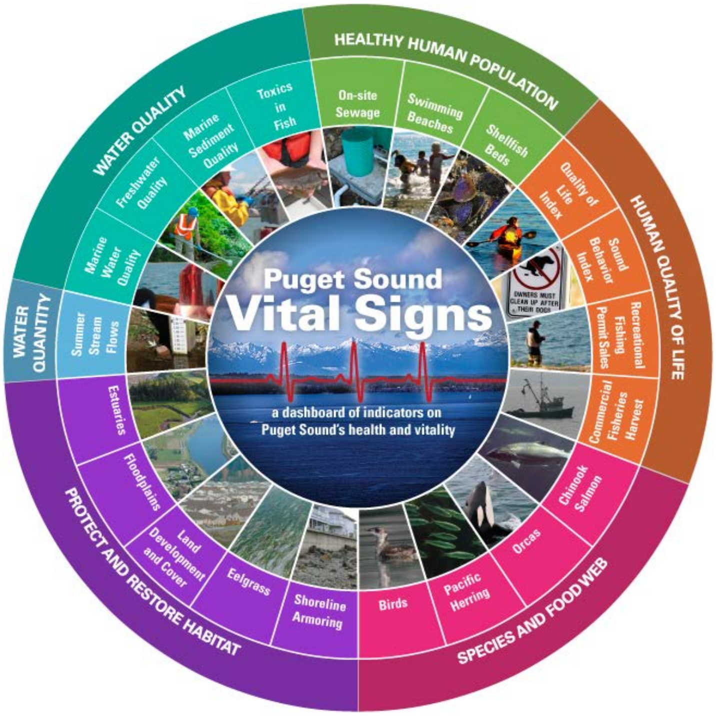

Figure 1: Puget Sound Partnership's Vital Signs Indicators

PSP's approach is guided by the *Open Standards for the Practice of Conservation* (*Open Standards*; CMP 2013), an open-source planning and performance management framework used by many conservation and restoration focused organizations around the world. PSP and its local salmon recovery planning partners map out their strategic actions using logic models (aka results chains or theories of change), to link actions to their intended outputs and outcomes. Local Integrating Organizations (LIOs) - the entities managing planning units comprised of one or a few watersheds - are also beginning to map out their recovery plans using results chains to document their assumptions.

Our understanding of how the ecosystem functions to produce those intended outcomes reflects evidence from direct experience, scientific hypotheses about system relationships, and assumptions. We especially rely on assumptions when we have incomplete information about the role of humans in the system, and how we engage and benefit from biophysical elements of the system.

Integrated Conceptual Model for Ecosystem Recovery

PSP's task of organizing and facilitating the recovery of Puget Sound requires a strong foundation of science-based theoretical application and nuanced understanding of the SES, integrating across biophysical and social components to achieve ecosystem outcomes related to the six goals introduced above.

Puget Sound consists of a complex SES that includes a rapidly growing population of over 4 million people across an area of 1.6 million acres of lands and waters, the overlapping jurisdictions of 12 counties, 15 tribal nations, and 115 cities, including both urban centers with large export terminals, and rural towns with strong heritages of fishing, timber, and agriculture, traditional resource uses, long held property and tribal treaty rights, and a region passionate for its outdoors.

The **Integrated Conceptual Model for Ecosystem Recovery** (Figure 2) provides a framework for understanding management and recovery of a system such as the Puget Sound SES. It is a simplified model that can be used to communicate and assess fundamental understandings of an SES, including the drivers and effects of recovery actions. This model serves as a top-level guide to the system and its components, expresses our underlying assumptions and hypotheses about key interactions and relationships within the system, and articulates a framework by which the entirety of the SES can be explored and system recovery can be evaluated.

The balanced design of this model distinguishes the two types of equally-important goals for recovery of the Puget Sound ecosystem – those related to human wellbeing and those related to biophysical condition – and articulates how other components of the ecosystem can affect achievement of those goals. For the Puget Sound system, we envision using the model to identify and describe specific tradeoffs, synergies and antagonisms related to various pathways by which recovery goals might be reached.

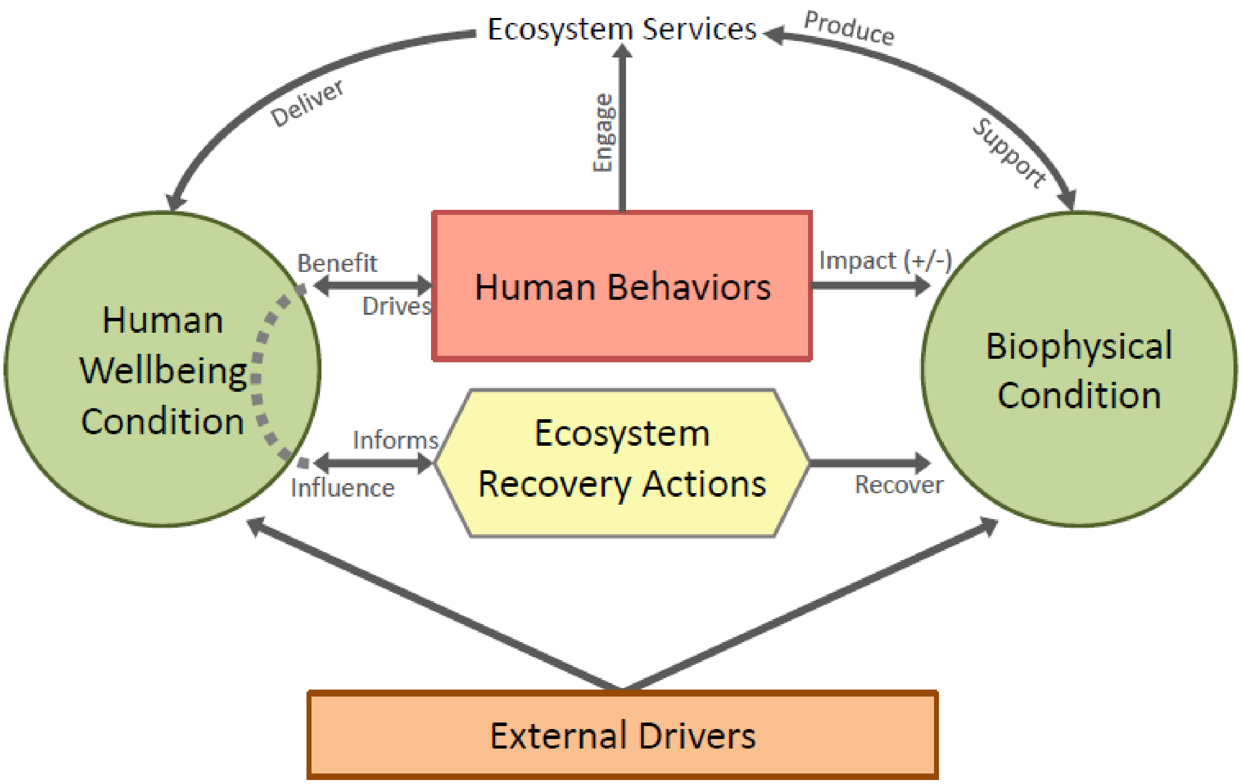

Figure 2: Integrated Conceptual Model for Ecosystem Recovery

This conceptual model can serve as a guiding tool in multiple ways, but its effectiveness relies on the availability of quantitative and qualitative information about the human and biophysical aspects of the system of interest. As more social science investment and more integration of social and biophysical science investigation occurs in the Puget Sound region, more information will be available to PSP and others to accurately explain each element's status and function, to describe flows and interactions among elements, and to predict outcomes of interventions in the system. Likewise, the conceptual model will support the identification of components and linkages where more and better information is needed to improve the planning and evaluation of recovery efforts. In the Puget Sound system, we envision applying this model to identify such research gaps and information needs.

Development of Integrated Conceptual Model for Ecosystem Recovery

Both biophysical and social scientists were consulted in the model's development, as well as an exploration of the theoretical literature on SES models (Collins et al. 2011; Ostrom et al. 2009; Liu et al. 2007, Yee et al. 2012) and their application in other case studies (Biedenweg et al. 2013). The colors and shapes used for the new model's elements are consistent with those used in Miradi (the software used to support application of the *Open Standards*) results chains to improve partners' familiarity with the concepts.

The model was refined through multiple rounds of comment and revision from PSP's Science Panel, PSP's Social Science Committee members, and PSP's science program staff. The placement and direction of arrows, as well as their respective explanatory words to describe the relationship represented, were compared with many other SES models, both in the literature as well as regionally relevant projects by Puget Sound social scientists and ecologists.

The model also takes into consideration other causal chain planning frameworks, such as the Driver-Pressure-State-Impact-Response (DPSIR) framework commonly used in planning and policy-making (Smeets and Weterings 1999, EPA 2014). The DPSIR conceptual model can provide a scaffold and common language to conceptualize the system, but needs modification to integrate the core concepts of sustainability such as human wellbeing and equity, environmental risk factors, and the social and cultural aspects of environmental health into a single framework (Yee et al. 2012). Figure 3 shows how DPSIR elements are embedded within the new **Integrated Conceptual Model for Ecosystem Recovery**. Each element is present, and aligns with similar elements of the new framework. However, instead of a linear pathway, the new model moves those elements around to reflect SES theory describing the feedback relationship between human wellbeing and the biophysical environment, delivered via ecosystem services.

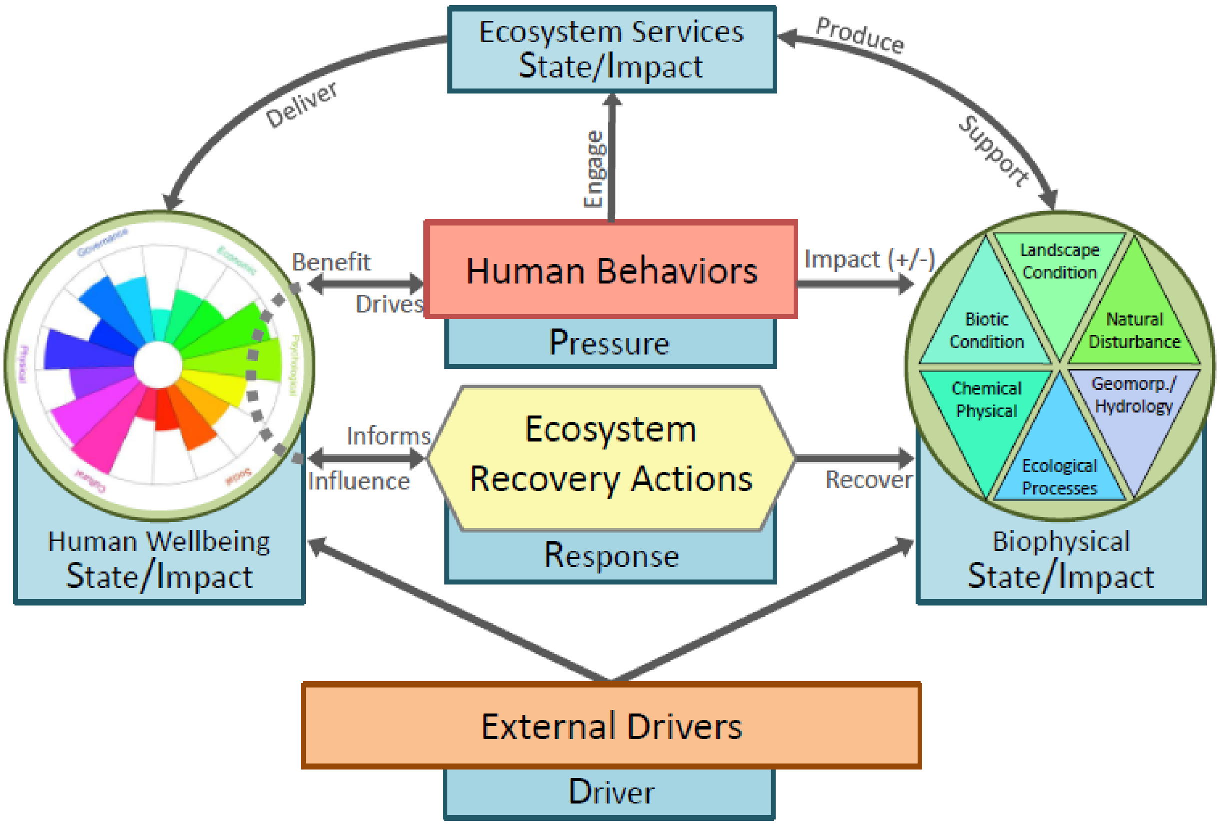

Figure 3: Integrated Conceptual Model for Ecosystem Recovery with DPSIR Framework. The Driver-Pressure-State-Impact-Response (DPSIR) framework is embedded within the new conceptual model (blue boxes). The Essential Ecosystem Attributes (EPA 2002) are shown within the biophysical condition (colored wedges), as well as the domains of human wellbeing (colored wedges; Biedenweg et al. 2014)

Model Description

The conceptual model provides a framework to link the biophysical and human wellbeing components of the SES. The human wellbeing and biophysical conditions of the system are shown as green circles on either side of the model, with multiple pathways linking the two to illustrate the complex ways in which humans and the biophysical environment interact. For example, biophysical conditions produce ecosystem services, and when people engage these services via our behaviors, we complete the pathway by which they deliver benefit to our human wellbeing.

Definitions of each element and their relationships are detailed below.

Human Wellbeing Condition – The human wellbeing condition of the SES reflects our quality of life related to, or affected by, natural resources. Human wellbeing is subjectively determined but can be described by characterization of six domains: physical, psychological, economic, governance, social, cultural (Biedenweg et al. 2014). Attributes and indicators that further define each of the six domains for a given SES are identified by the individuals and institutions that are part of the SES. An effort is currently underway to develop an improved set of human wellbeing Vital Signs and indicators using this framework (Biedenweg, 2014)

Biophysical Condition – A variety of frameworks are available to characterize and assess the biophysical condition of an SES. PSP's approach has been to recognize and articulate biophysical conditions for three domains – Marine/Nearshore, Freshwater, and Terrestrial (Levin et al. 2011) – and to characterize essential ecological attributes – landscape condition, biotic condition, natural disturbance, geomorphology/hydrology, ecological processes, chemical/physical (EPA 2002) – for each of these domains. PSP's Vital Sign indicators can be mapped to these attributes.

Ecosystem Services – The Millennium Ecosystem Assessment defines ecosystem services as the benefits people obtain from ecosystems, including provisioning services such as food and water; regulating services such as regulation of floods, droughts, land degradation and disease; supporting services such as soil formation and nutrient cycling; and cultural services, such as recreational, spiritual, and other non-material benefits (MEA 2005). Some of these services are self-sustaining for the biophysical environment as well (Figure 4(E)), such as the supporting and regulating services. Our wellbeing benefits when humans engage with the supply of ecosystem services through our activities and behaviors (Figure 4(F)) described below.

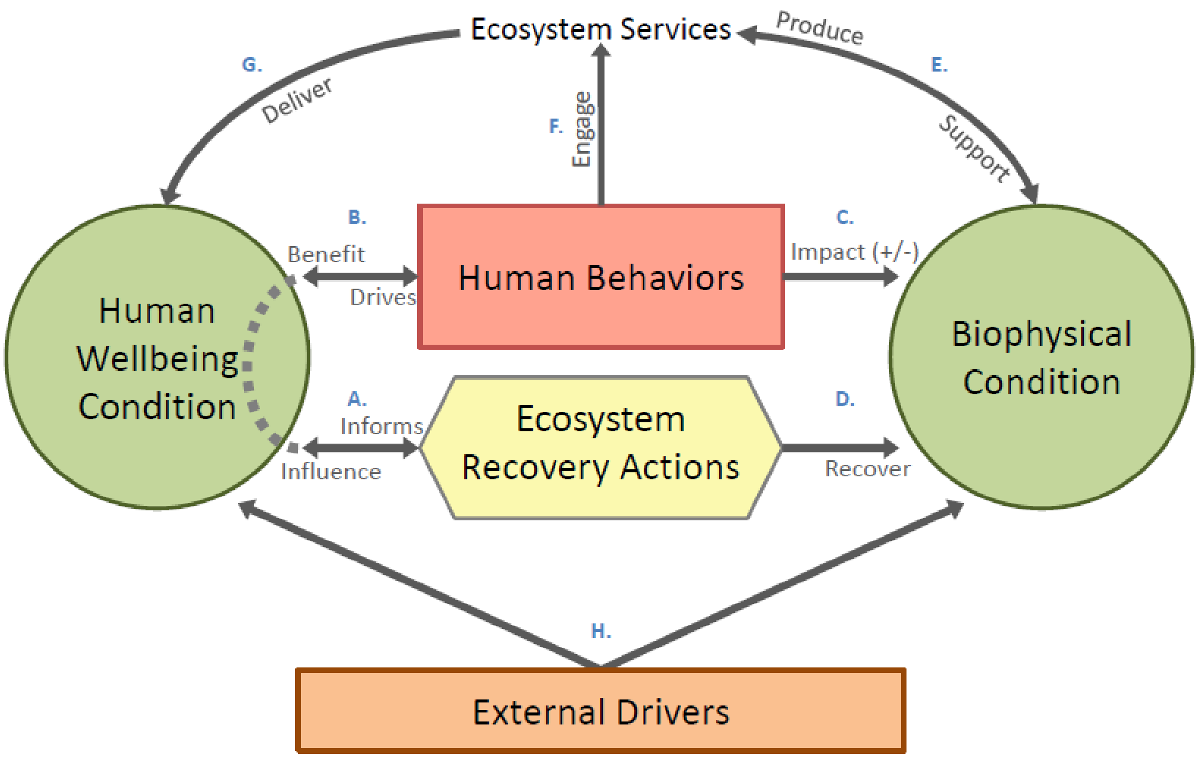

Figure 4: Integrated Conceptual Model for Ecosystem Recovery with relationships labelled by letter.

Human Behaviors: This element encompasses all of the ways in which humans engage with and experience the environment – such as resource extraction, recreation, creation and maintenance of a built environment, transportation, agriculture, subsistence activities, and so on. Some of these behaviors inherently involve a tradeoff between a direct benefit to human wellbeing and a negative impact on biophysical conditions (Figure 4(B & C)). Other behaviors can have a positive impact on the environment and human wellbeing.

The two-way arrow (Figure 4(B)) between human wellbeing and human behaviors illustrates that while values shape our actions, our actions are often intended to benefit wellbeing, whether their impact on the biophysical condition is positive or negative, or whether ecosystem services are generated.

Ecosystem Recovery Actions: This element encompasses the direct ways we improve the environment via conservation and restoration projects (Figure 4(D)), as well as the indirect route to achieve ecosystem outcomes (Figure 4(A)). This includes environmental policies and planning, management strategies, outreach and communications, sustainability and stewardship programs, and many other examples of how humans respond, via individuals or institutions, to the changing ecosystem condition.

The dotted line from ecosystem recovery actions *through* human wellbeing to human behaviors (Figure 4(A to B)) illustrates the pathway through which management and policy responses drive behavior change, whether in individuals or institutions. By changing perceptions and incentives, people and practices change. Likewise, our human wellbeing reflects our values, which in turn informs our strategic ecosystem recovery actions (Figure 4(B to A)).

External Drivers include both natural and social factors outside the scope of recovery actions, but which impact the condition of human wellbeing and the biophysical system. External drivers include processes outside the SES such as natural disasters, national and international economic and political conditions, and globalization.

Applying the Integrated Conceptual Model for Ecosystem Recovery

The Integrated Conceptual Model for Ecosystem Recovery provides a framework for an ecosystem-based approach to recovery planning that builds on best available natural and social science. It can be used to identify where information is needed to improve understanding of the system, and to evaluate management tradeoffs. A number of PSP's existing programs and projects can be mapped to the conceptual model to demonstrate their potential contribution to achieving desired outcomes, and identify approaches for their evaluation. For example, Figure 5 shows that PSP's current emphasis is weighted toward the biophysical condition and monitoring the human impact on biophysical conditions. A more balanced set of initiatives would be needed to understand how humans benefit from the environment, how human wellbeing shapes human behavior, and the role of ecosystem services in contributing to human wellbeing.

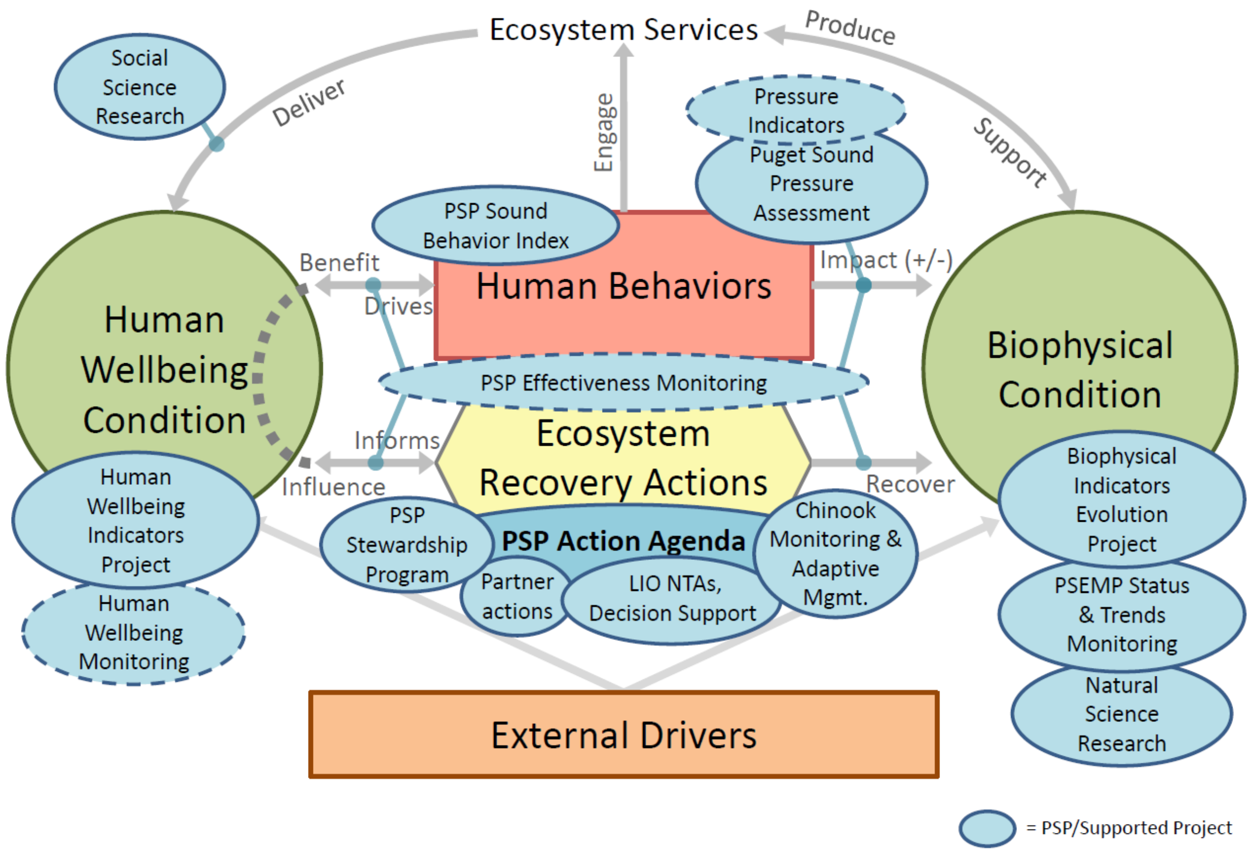

Figure 5: Integrated Conceptual Model for Ecosystem Recovery + PSP Projects and Programs. PSP programs and projects (blue ovals) are mapped to the conceptual model to illustrate where management, research and planning efforts are focused, and which components of the SES require more attention. The blue ovals with dotted outlines indicate projects that are in development.

PSP's Vital Signs are mapped on the conceptual model in Figure 6, showing where Partnership monitoring and reporting is focused. This demonstration again shows that significant emphasis is currently given to monitoring the biophysical condition and human behaviors and actions; relatively little emphasis is placed on monitoring human wellbeing at this time.

The model can be used to guide decision-making processes and to illustrate the underlying assumptions about recovery efforts and associated ecosystem outcomes. Specific recovery actions can be mapped to the model to identify the SES relationships addressed that are important to the action's success, or to identify where relationships may have been overlooked or underemphasized. These modeling exercises will become more plausible and informative once the quality and availability of both biophysical and social data improve in the region.

Mapping PSP programs and Vital Signs on the SES conceptual model helps to elucidate important gaps in PSP's institutional knowledge and recovery efforts. The addition of indicators to measure human behaviors and their impact on the system will become an important piece of information in the EBM approach. The Puget Sound Pressures Assessment (PSPA; PSP, 2014) provides an evaluation of key biophysical vulnerabilities from human behaviors; the results of the PSPA could be used to identify some of the pressure indicators for the Puget Sound SES. Likewise, measuring and monitoring of ecosystem services is another information gap in PSP's recovery efforts. This is an emerging field that will provide valuable information toward improving our understanding of the link between the biophysical and human wellbeing conditions of the SES.

The **Integrated Conceptual Model for Ecosystem Recovery** provides a guide for an EBM approach that is rooted in science, and holistic in its consideration of all SES components. The generalized illustration of the SES acts as a starting point, a guide to fill in the blanks with the most relevant and localized information available to explore ecosystem recovery efforts to achieve goals for human wellbeing and biophysical conditions.

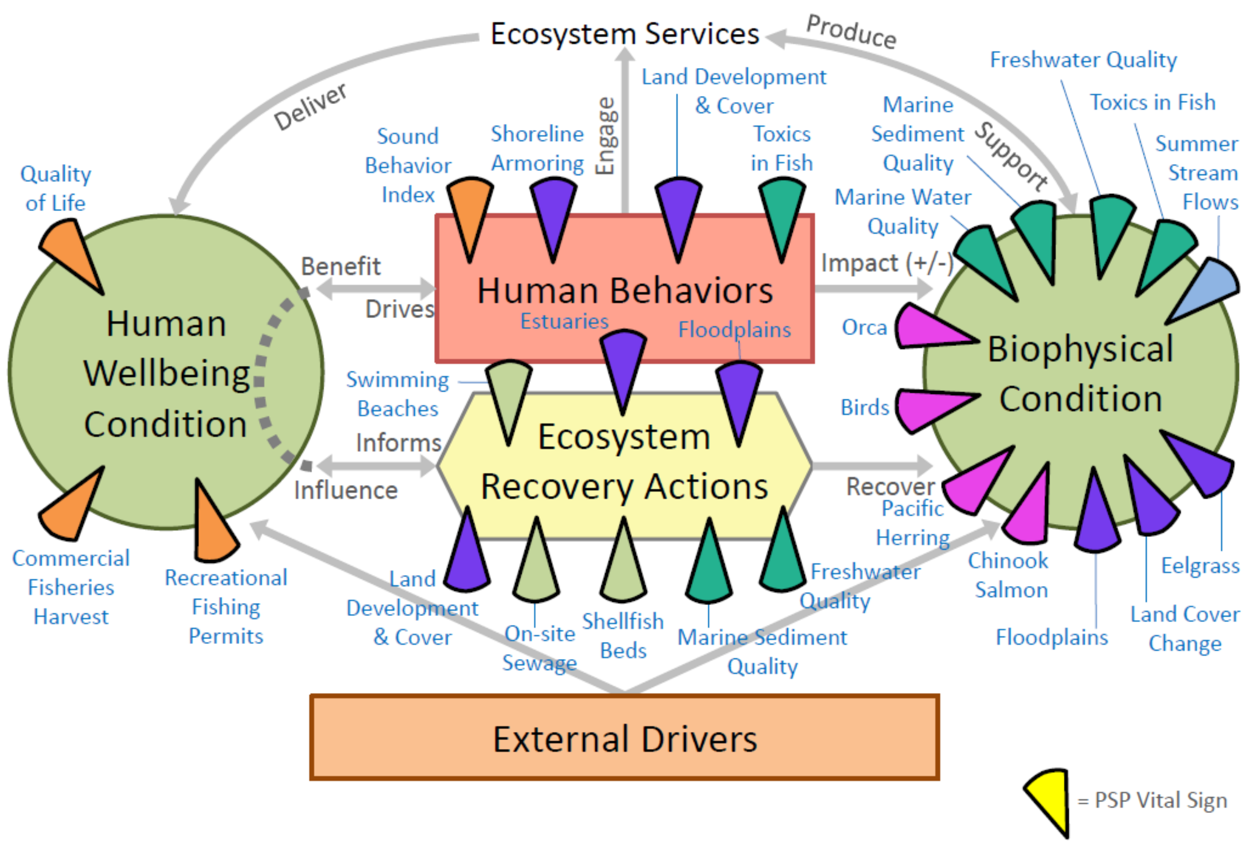

Figure 6: Integrated Ecosystem Recovery Conceptual Model + PSP Vital Signs. The 21 Vital Signs were mapped to the conceptual model to illustrate where PSP monitoring and reporting efforts are focused. The colors of the Vital Sign wedges relate to colors of the six goals represented in the PSP Vital Sign Wheel (Figure 1).

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