

# Preliminary Climate Change Assessment for the Puget Sound Partnership



*Prepared by*  
The University of Washington Climate Impacts Group

*In collaboration with*  
Puget Sound Partnership



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## FOREWORD

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Puget Sound is a complex ecosystem encompassing alpine areas, forests, wetlands, marine waters, shorelines, rivers, farmlands and cities. It supports a large part of Washington State's economy and provides vital recreational, cultural and other quality of life benefits. Multiple pressures, from land development, water pollution and climate change, all demand attention in order to achieve Washington State's goals for Puget Sound ecosystem recovery.

Climate change has, and will continue to have, important impacts on the region's resources, communities and ecosystems. Ocean acidification, warming temperatures, reduced snowpack, lower summer stream flows, and changing magnitude and frequency of extreme events will influence ecosystem recovery efforts, resource and other management activities on the land, and human health and well-being.

The Puget Sound Partnership (the Partnership) is the state agency lead on the region's collective effort to restore and protect Puget Sound. The Partnership is committed to undertaking a climate change assessment and resiliency strategy as outlined in the 2016 Action Agenda for Puget Sound. Building off the report *State of Knowledge: Climate Change in Puget Sound*<sup>1</sup>, the Partnership has begun efforts to understand the implications of climate change and ocean acidification on the Partnership's goals for recovery and long-term protection.

Adapting to climate change means taking action to prepare for, manage or reduce the adverse consequences of a changing climate and take advantage of opportunities to achieve desired future conditions. Understanding climate risks will improve the region's ability to plan for long-term change and extreme events, and adaptively manage as new science and information becomes available. The Partnership is part of the National Estuary Program, an EPA place-based program to protect and restore the water quality and ecological integrity of estuaries of national significance. This preliminary climate assessment is one of the initial steps to meeting the National Estuary Program requirements for risk-based assessment of climate change impacts and is meant to help inform future adaptation planning.

The Partnership intends that this preliminary assessment will inform and support future action in the collective efforts to recover and protect Puget Sound, including:

- Refine and improve how climate change is considered and reflected in future iterations of the Action Agenda and associated Near Term Actions.
- Consider climate change risks in new or updated Implementation Strategies to ensure that these plans for accelerating progress to ecosystem recovery targets are resilient to climate change and mitigate climate risk, where possible.

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<sup>1</sup> Mauger et al. 2015.

- Improve how climate change is considered and reflected in the Ecosystem Recovery Plans developed by Local Integrating Organizations, and in local salmon recovery chapter updates by Lead Entities.
- Advance climate-related science needs as outlined in the Puget Sound Science Work Plan.

For more information about these planning documents and approaches, please visit the Partnership's web pages at: [www.psp.wa.gov](http://www.psp.wa.gov).

Puget Sound ecosystem recovery efforts are ambitious in terms of their scope and complexity; climate change is one of many components that will need to be addressed. The Partnership will continue to pursue a diversity of entry points and partnerships required for a robust approach to planning and implementation as part of an overall strategy for climate adaptation in Puget Sound recovery.

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# 1 INTRODUCTION

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## 1.1 PROJECT OVERVIEW

The Puget Sound Partnership is the state agency leading the region's collective effort to restore and protect Puget Sound. The State Legislature charged the Partnership with achieving six overarching goals by 2020 related to water quantity and quality, species and habitats, and human health and quality of life. However, previous studies by the Partnership and others<sup>2</sup> indicate that climate change and ocean acidification threaten our ability to achieve these goals. To begin assessing the implications of climate change on Puget Sound recovery and long-term protection, the Partnership contracted with University of Washington's Climate Impacts Group to help the Partnership identify key climate concerns and provide a platform for moving toward a more resilient Puget Sound.

The purpose of this study is to develop and implement a preliminary assessment of the implications of changing climate and ocean conditions to Puget Sound Partnership's goals for ecosystem recovery and long-term protection. This preliminary climate assessment is intended to: support the development of climate adaptation planning that may be included in upcoming revisions of the Action Agenda and related plans, strategies and proposed actions for ecosystem recovery; assist in defining gaps in knowledge on important climate impacts in the Puget Sound Region; and articulate appropriate uses of the findings as well as opportunities for further refining climate risk assessment for Puget Sound.

This project is motivated by findings of *The 2014 Puget Sound Pressures Assessment*<sup>3</sup> and the *State of Knowledge: Climate Change in Puget Sound*,<sup>4</sup> which indicate that achieving recovery and long-term protection of Puget Sound ecosystem is threatened by climate change and ocean acidification. This assessment also fulfills a commitment in the 2016 Action Agenda for the Puget Sound Partnership to conduct a vulnerability assessment by 2017 as a foundation for future resiliency planning.<sup>5</sup>

## 1.2 ASSESSMENT APPROACH

The central question for this assessment is:

***How will changing climate and ocean conditions projected for the 2050s affect the Puget Sound Partnership's ability to achieve Puget Sound recovery goals?***

The assessment combines published literature and data on climate change impacts with the knowledge and insights of experts on topics relevant to the Partnership's recovery goals. The approach was framed as a rapid vulnerability assessment given (1) the project's large geographical scope (the entire Puget Sound region, including marine, nearshore and terrestrial areas), (2) the breadth of topics encompassed in the Partnership's recovery goals, and (3) the brief time frame for conducting the assessment (March through June 2017).

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<sup>2</sup> For example, *The 2014 Puget Sound Pressures Assessment* (McManus et al. 2014) and *State of Knowledge: Climate Change in Puget Sound* (Mauger et al. 2015)

<sup>3</sup> McManus et al. 2014.

<sup>4</sup> Mauger et al. 2015.

<sup>5</sup> Puget Sound Partnership. 2016.



The chosen time horizon for assessing climate change impacts was the 2050s. This period was considered an appropriate middle ground for bridging the near-term focus of the Partnership’s legislatively established goals for 2020 and the point where projected climate change impacts (particularly increasing average annual temperature) start to emerge more consistently from the background noise of natural variability.<sup>6</sup>

The assessment is designed to sort Puget Sound recovery goals into high, medium, and low risk from climate change impacts and to provide a brief analysis of how climate conditions projected for the 2050s are anticipated to affect the Partnership’s ability to achieve the restoration goals and desired future conditions for Puget Sound. While this assessment focuses solely on the risks posed by climate change, the intent of the assessment is to provide a basis for adaptation planning in the future.

For the purposes of this assessment, the goals and desired future conditions for Puget Sound ecosystem recovery and long-term protection are represented by the Partnership’s established goals, Vital Signs, indicators and 2020 targets. These guide development of the Partnership’s strategies and actions that are collectively intended to restore and protect Puget Sound.

The Washington State legislature established the Partnership’s six goals in statute (RCW 90.71.300), which the Partnership simplifies in the Action Agenda as:<sup>7</sup>

- **Healthy Human Population.** Healthy people are supported by a healthy Puget Sound.
- **Human Quality of Life.** Our quality of life is sustained by a healthy Puget Sound.
- **Species and Food Web.** Puget Sound species and the web of life thrive.
- **Protect and Restore Habitat.** Puget Sound habitat is protected and restored.
- **Water Quantity.** Puget Sound rivers and streams flow at levels that support people, fish, and wildlife.
- **Water Quality.** Puget Sound marine and fresh waters are clean.

For each goal, there are one or more associated Vital Signs, which provide a mechanism to measure progress toward the goal and to describe desired future conditions. For example, the Healthy Human Population Goal has six Vital Signs: Onsite Sewage; Shellfish Beds; Outdoor Activities; Local Foods; Air Quality; and Drinking Water (See Figure 1).

Each Vital Sign is represented by one or more indicators, which are designed to be specific and measurable. For example, the Local Foods Vital Sign has two indicators: Locally Harvestable Foods; and Recreational Shellfish Beds. Some Vital Signs do not have a specific Indicator established yet.



**Figure 1:** Puget Sound goals and associated Vital Signs. The Healthy Human Population Goal and associated Vital Signs are circled in red.

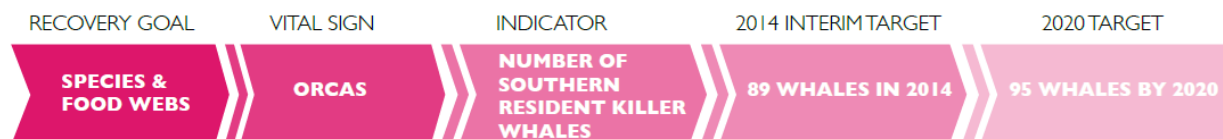
<sup>6</sup> More specifically, by the 2050s (2040-2069), average annual temperature in the Puget Sound region is projected to be warmer than the warmest year observed between 1950-1999 (Mauger et al. 2015).

<sup>7</sup> Puget Sound Partnership. 2016.



For many of the indicators, the Partnership has adopted 2020 ecosystem recovery targets. These are “science-informed statements of desired future conditions for each Vital Sign indicator.” Together, the Vital Sign indicators and recovery targets can show how the ecosystem is improving or declining relative to baseline conditions and the desired future conditions across the six recovery goals.<sup>8</sup>

As an example, the 2016 Action Agenda provides the following illustration using orcas from the Species and Food Webs Goal.



The assessment began with a “kick-off” webinar to inform key staff, partners, and advisors about the assessment and to gain input on the proposed approach and on experts to engage in the process. Assessment leaders then convened two workshops with participants selected for their specific knowledge and insights. The first focused on the Vital Signs under the Water Quantity and Water Quality goals. The second focused on Vital Signs under the Protect and Restore Habitat goal and the Species and Food Webs goal. Because scheduling a third workshop proved difficult, assessment leaders opted to convene a series of web-based conference calls to address the remaining Vital Signs under the Healthy Human Population goal and the Human Quality of Life goal. For each convening, participants received background materials on the Partnership’s goals, Vital Signs, indicators, and targets. They also received a summary of climate change impacts drawn from the report *State of Knowledge: Climate Change in Puget Sound*.<sup>9</sup>

Following the workshops and calls, notes were compiled, results were assessed, and a draft document was produced. Those who participated in the workshops, calls and “kick-off” webinar were given the opportunity to review sections of the draft. Those comments were incorporated into the final report.

The approach for this assessment generally follows the steps outlined in EPA’s 2014 publication *Being Prepared for Climate Change: A Workbook for Developing Risk-Based Adaptation Plans*.<sup>10</sup>

“The Workbook uses the risk management process in an international standard (ISO 31000—Risk Management), and tailors it to respond to the practices and norms of the climate change community. Specifically, the ISO methodology (which is conceived as a start-to-finish application of a risk management process) was modified to accommodate a two-part process consisting of (1) a stand-alone vulnerability assessment, followed (either immediately or after a period of time) by (2) an action plan. When faced with many discrete risks, managers can benefit from a process that will help them prioritize those that should receive attention, and decide on how to mitigate them.”<sup>11</sup>

<sup>8</sup> Puget Sound Partnership. 2016.

<sup>9</sup> Mauger et al. 2015.

<sup>10</sup> Environmental Protection Agency. 2014.

<sup>11</sup> Environmental Protection Agency. 2014.

According to the EPA Workbook, “In the context of climate change, a risk is the possibility that a given climate change stressor will affect your organization’s ability to meet its goals.” Risk is a function of the *likelihood* of a climate change impact occurring and the *consequence* if it did occur.<sup>12</sup>

To assess risks to Puget Sound recovery goals (as represented by the desired future conditions of each Vital Sign), workshop and conference call participants were asked to evaluate the following questions:

1. What is the **likelihood** that climate change will negatively affect the Vital Sign by 2050?
2. Assuming climate impacts occur at the magnitude projected for 2050, what is the **Consequence** to our ability to achieve the desired future conditions associated with the Vital Sign?

Each question could be rated low, medium, or high. The ratings for likelihood and consequence of each Vital Sign were then placed on a matrix to identify the risk ranking (Figure 2). Vital Signs in the red zone are at high risk because they have a medium to high probability of being negatively affected by climate change impacts by 2050 and the consequences are expected to moderately or significantly impede our ability to achieve desired future conditions. Vital Signs in the green zone are at low risk because they are unlikely to negatively affect the Vital Sign by 2050, and even if they did, the consequences would be low to moderate. Vital Signs in the yellow zone are at moderate risk.

**Figure 2. Risk Assessment Matrix**  
(Adapted from EPA Workbook)

Likelihood of Climate Impact Occurrence	<b>High</b>			<b>High Risk</b>
	<b>Medium</b>		<b>Moderate Risk</b>	
	<b>Low</b>	<b>Low Risk</b>		
		Low	Medium	High
	Consequence of Impacts to Desired Future Conditions of Vital Sign			

The risk rankings help sort Vital Signs into high, medium and low risk from climate change impacts. However, an important component of the assessment is the reasoning provided by participants for their ratings. Notes from the discussions were captured and are summarized for each Vital Sign. This information should prove useful as the Partnership develops strategies and actions for reducing the likelihood and consequences of climate change impacts.

<sup>12</sup> Environmental Protection Agency. 2014.

### 1.3 ABOUT THIS REPORT

This report provides a preliminary assessment of how changing climate and ocean conditions are expected to affect the Partnership's ability to achieve Puget Sound recovery goals. Following this introduction, the report presents a brief summary of climate change impacts, drawing from *State of Knowledge: Climate Change in Puget Sound*.<sup>13</sup> The report then assesses the climate-related risks for each of the Partnership's Vital Signs based on information provided by experts during assessment workshops and calls. This section describes the attributes and current condition of each Vital Sign and rates the likelihood of climate change impact and the consequences if those impacts occur. The results of the assessment are then summarized and next steps are suggested regarding use of this information for planning and strategy development, filling gaps in knowledge and continuing to assess climate risks.

This preliminary assessment represents a valuable step towards evaluating the effects of climate change on the Partnership's goals, Vital Signs, indicators, and targets. While reading this report, there are a number of considerations to keep in mind.

The ratings for likelihood of impact and consequence of impact are qualitative and subjective. They are based on the expertise of those who participated in the workshops and calls. While participants were chosen for their knowledge and insights, those who were able to participate may not represent the full range of knowledge for each Vital Sign. Additional input will help ensure that each Vital Sign's assessment reflects the full range of potential impacts and other considerations important for characterizing the potential risk of climate change to a Vital Sign.

The availability of research and knowledge related to climate change impacts varies widely among the Vital Signs. While most of the physical climate drivers are well studied, many of the expected biological and human system responses remain speculative. Vital Signs with low confidence ratings point to topics that would benefit from more study or additional expertise.

The structure of the Vital Signs themselves posed challenges for the assessment. Some Vital Signs are not yet defined, some lack indicators or targets, and some have indicators that are incomplete measures of the topic. In addition, most Vital Signs were defined without consideration of climate change impacts. Participants identified numerous opportunities to improve or enhance Vital Sign descriptions and these notes were collected by Partnership staff for future consideration.

Many Vital Signs lump multiple diverse topics together, some of which are expected to be affected by climate change while others might not. Thus, some attributes of a Vital Sign might be rated as high likelihood of impact or high consequence of impact while other attributes might be rated as low likelihood or consequence. When determining the risk ranking for a Vital Sign with multiple attributes, the Vital Sign was accorded the rating for the highest rated attribute. This partially explains why many of the Vital Signs were ranked as high risk.

The approach to rating likelihood and consequence evolved during the course of the assessment. In the first workshop (focusing on Water Quantity and Water Quality Goals), participants were asked to rate the consequence of climate impacts on the goal. This proved challenging due to the breadth of the goal statement. In subsequent sessions, participants were asked to rate the consequence to achieving the

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<sup>13</sup> Mauger et al. 2015.

desired future conditions for the Vital Sign. The results presented in the assessment reflect the ratings given by participants for each session.

In assessing climate change impacts, participants were instructed to assume that current policies and management approaches remain constant and that no additional adaptation occurs. This was intended to remove the uncertainty of potential human responses and isolate the climate change impacts on the Vital Signs.

## 2 BRIEF CLIMATE SUMMARY

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In 2015, Climate Impacts Group at University of Washington published *State of Knowledge: Climate Change in Puget Sound*.<sup>14</sup> This report provides the most comprehensive and up-to-date assessment of climate change impacts for the Puget Sound region. Readers seeking peer-reviewed climate change data and information on impacts are encouraged to consult the State of Knowledge report. To provide context for the findings presented in this preliminary climate assessment, **excerpts from the State of Knowledge Report's Executive Summary are presented below.**

### **Projected changes in several key physical drivers. (Box ES-1)<sup>15</sup>**

- **Average annual temperature:** By the 2050s (2040-2069), the average year in the Puget Sound region is projected to be +4.2°F (range: +2.9 to +5.4°F) warmer under a low greenhouse gas scenario and +5.5°F (range: +4.3 to +7.1°F) warmer under a high greenhouse gas scenario (RCP 4.5 and 8.5, respectively), relative to 1970-1999.
- **Heavy Rainfall:** By the 2080s (2070-2099), the wettest days (99th percentile or 24-hour precipitation totals) in the Pacific Northwest are projected to increase by +22% (range: +5% to +34%) for a high greenhouse gas scenario (RCP 8.5), relative to 1970-1999.
- **Declining Spring Snowpack:** By the 2040s (2030-2059), the average year in the Puget Sound region is projected to have -23% (range: -34 to -6%) less April 1<sup>st</sup> snowpack under a low greenhouse gas scenario (B1), and -29% (range: -47 to -4%) under a moderate greenhouse gas scenario (A1B), relative to 1970-1999.
- **Sea Level Rise:** By 2050, relative sea level in Seattle is projected to rise by +6.5 inches (range: -1 to +19 inches) for a moderate, low, and high greenhouse gas scenario (A1B, B1, and A1FI, respectively), compared to 2000. Sea level rise at other locations may differ by up to 8 inches by 2050, due to different rates of uplift or subsidence.
- **Higher Storm Surge Reach.** Although storm surge is not projected to increase, sea level rise will cause the same events to have a greater impact. In Olympia, a +6 inch rise in sea level (the middle projection for 2050 is +9 inches) would cause the 100-year surge event to become a 1-in-18 year event.

### **Puget Sound Land Areas**

*From the mountaintops to the shorelines of Puget Sound, these climate changes will cause changes in the region's water cycle, natural resources, and ecosystems.*

- **Snowpack and Streamflow:** Warming will cause a greater proportion of winter precipitation to fall as rain rather than snow. Snowpack is projected to decline, causing the spring peak in streamflow to occur earlier in the year. Winter streamflow is projected to increase in snow-influenced watersheds, while most locations are projected to experience a decline in summer streamflow.
- **Landslides and Sediment Transport:** Changes in rainfall, snowpack, and streamflow may lead to an increase in landslide risk, erosion, and sediment transport in fall, winter, and spring, while reducing the rates of these processes in summer. Quantitative projections of the likely changes in sediment transport and landslides are limited, in part because it is challenging to distinguish

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<sup>14</sup> Mauger et al. 2015.

<sup>15</sup> Mauger et al. 2015.

climate change effects from non-climatic factors such as development patterns and forest management.

- **Flooding:** Both the extent and the frequency of flooding is projected to increase. Heavy rain events are projected to intensify, increasing flood risk in all Puget Sound watersheds. Continued sea level rise will extend the reach of storm surge, putting coastal areas at greater risk of inundation. In snow-accumulating watersheds, winter flood risk will increase as the snowline recedes, shifting precipitation from rain to snow.
- **Salmon:** Warmer streams, ocean acidification, lower summer streamflows, and higher winter streamflows are projected to negatively affect salmon. The persistence of cold water “refugia” within rivers and the diversity among salmon populations will be critical in helping salmon populations adapt to future climate conditions.
- **Timing of Biological Events:** The timing of many biological events (e.g., leaf emergence in spring, plankton blooms in lakes, spawning runs for salmon) can be altered by warming. Because each species will respond differently, climate change may cause important biological interactions to become unsynchronized.
- **Species Distributions:** Many species will exhibit changes in their geographic ranges, with some species experiencing expansion, while others experience contraction or migration. For example, declining snowpack is expected to lead to a decline in montane meadows as forests expand into higher elevation habitats. Range shifts will vary among species, and will be affected by non-climatic factors such as development and management patterns.
- **Forests:** Over the long-term, climate change is expected to alter the distribution and abundance of some tree species in the Puget Sound region. Growth of Douglas-fir and other species in relatively warm lower-elevation forests (where growth is currently limited by summer water availability) may decrease. In contrast, growth of cold-climate, high-elevation species such as mountain hemlock (where growth is currently limited by mountain snowpack) may increase. Increases in the risk of large wildfires and altered ranges and timing of insects and fungal pathogens will affect the vigor, growth, and distribution of forest species in the Puget Sound region.
- **Agriculture:** Warming is expected to increase the length of the growing season. Along with higher temperatures, increases in atmospheric CO<sub>2</sub> concentrations could increase the production of some crops. However, increases in heat stress, decreases in summer water availability, increases in flood risk, and changes in the range and timing of pests may negatively affect crops and livestock.

### **Puget Sound’s Marine Waters**

*Climate change will affect the saltwater habitats of Puget Sound, driving changes in its currents, chemistry, and ecosystems.*

- **Coastal Habitats:** Sea level rise is projected to expand the area of some tidal wetlands in Puget Sound but reduce the area of others, as water depths increase and new areas become submerged. For example, the area covered by salt marsh is projected to increase, while tidal freshwater marsh area is projected to decrease. Rising seas will also accelerate the eroding effect of waves and surge, causing unprotected beaches and bluffs to recede more rapidly.
- **Harmful Algal Blooms:** Warmer water temperatures, both in the North Pacific Ocean and in Puget Sound, will likely make harmful algae blooms more frequent and severe, and will extend the season when they can occur. Ocean acidification may increase the toxicity of some harmful algal blooms.



- **Marine Ecosystems:** A combination of climate-related stressors will affect marine organisms and habitats, including warmer water temperatures, loss of coastal habitat due to sea level rise, ocean acidification, and changes in water quality and freshwater inputs. Some species, like salmon and shellfish, are likely to be negatively affected by these changes; other species, such as eelgrass, may benefit.
- **Circulation in the Ocean and in Puget Sound:** Future changes in the circulation of Puget Sound and the near-shore Pacific Ocean are unclear. Changes in the timing and amount of river flows may affect the ability of Puget Sound's surface and deep waters to mix. Ocean upwelling may change, but projections are not conclusive. Short-term variability in upwelling (ranging from seasons to decades) will likely be more important than long-term changes related to global warming throughout the 21st century.

## People

*The Puget Sound region is home to a growing population and a rich diversity of cultural, institutional, and economic resources, many of which will be affected by climate change.*

- **Tribes:** Rooted in place, tribes are particularly vulnerable to climate change. Puget Sound's tribal communities face a wide range of climate-related risks, including sea level rise, more frequent and larger floods, impacts on culturally-important species such as salmon and shellfish, a greater risk of wildfires, and changes in the forest, coastal, and marine ecosystems on which they rely.
- **Built Environment:** The developed areas of Puget Sound and the transportation, drinking water, wastewater, and energy systems that serve the region's population will face an increasing risk of a variety of extreme weather events (e.g., heat waves, flooding, wildfire). Consequences include flooding of low-lying infrastructure, damage to energy transmission, and higher maintenance costs for many transportation and other elements of the built environment.
- **Human Health:** More frequent heat waves and more frequent and intense flooding may harm human health directly. Warming may also exacerbate health risks from poor air quality and allergens. Climate change can indirectly affect human health through its impacts on water supplies, wildfire risk, and the ways in which diseases are spread. Risks are often greatest for the elderly, children, those with existing chronic health conditions, individuals with greater exposure to outside conditions, and those with limited access to health resources.

## 3 CLIMATE RISKS TO VITAL SIGNS

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In the following pages, the expected effects of climate change are described for each Vital Sign. The Vital Signs are organized by their respective goal, and each discussion begins with a description of the Vital Sign's attributes and its current condition as presented on the Puget Sound Partnership's Vital Signs website (<http://www.psp.wa.gov/vitalsigns>). Workshop and call participants' ratings are then presented for climate-related risk, likelihood of climate impact, consequence of impacts to the desired future conditions and confidence in the likelihood and consequence ratings. A summary of the rationale for these ratings, as reported by workshop and call participants, completes each Vital Sign description.

### 3.1 WATER QUANTITY GOAL

The Water Quantity Goal was established by the legislature as:

**Water Quantity Goal:** An ecosystem that is supported by groundwater levels as well as river and streamflow levels sufficient to sustain people, fish, and wildlife, and the natural functions of the environment. (RCW 90.71.300)

This goal has one Vital Sign (in bold) and one associated indicator:

- **Summer Stream Flows:** Summer Low Flows

#### 3.1.1 Summer Stream Flows Vital Sign

##### *Vital Sign Attributes and Current Status*

This Vital Sign focuses on large and small rivers and small, low-gradient streams. To assess climate change impacts on summer stream flows, workshop participants evaluated the following attributes of this Vital Sign:

- Minimum 30-day average water flow
- Long-term trends of annual summer low flow levels

According to the Puget Sound Partnership's progress summary for the Water Quantity Vital Sign, the Summer Low Flows Indicator is "getting better." Nine of the twelve rivers monitored are increasing flows or showing no trend. Of the remaining three rivers with decreasing trends, the Deschutes River near Rainier is weakly decreasing, while Issaquah Creek and North Fork Stillaguamish are strongly decreasing.<sup>16</sup>

##### *Assessment Findings*

Risk		Rating	Confidence
High	<i>Likelihood of Impact</i>	High	High
	<i>Consequence</i>	Medium, but high in some locations	Medium

Workshop participants rated this Vital Sign as high risk for the following reasons. Summer streamflow is likely to decline due to the projected shift to rain-dominated systems, reduced snow pack and earlier spring snow melt and lower summer precipitation. Higher air temperatures and greater residence time

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<sup>16</sup> [http://www.psp.wa.gov/vitalsigns/summer\\_stream\\_flows\\_indicator1.php](http://www.psp.wa.gov/vitalsigns/summer_stream_flows_indicator1.php). Accessed June 19, 2017.

of water in streams may lead to higher water temperatures and increased evaporative losses. Bank erosion is expected to increase due to higher peak flows in winter, and this may contribute to declines in above-river bed low flows in sections where erosion widens the river. Domestic and agricultural summer water use is likely to increase as demand increases in response to higher temperatures. This is expected to lead to increased competition for summer water and increased groundwater use, both of which could diminish summer low flows and affect groundwater discharge. However, in lowland areas, groundwater is expected to maintain summer streamflows at or near current conditions as long as drought does not significantly reduce aquifer levels. In areas where groundwater storage is limited, such as Orcas Island or upper elevations where only thin unconsolidated aquifers are present, meeting summer low flow targets is expected to become increasingly difficult and many streams that are currently perennial are likely to go seasonally dry.

## 3.2 WATER QUALITY GOAL

The Water Quality Goal was established by the legislature as:

**Water Quality Goal:** 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. (RCW 90.71.300)

This goal has four Vital Signs (in bold) and eleven associated indicators:

- **Freshwater Quality:** Water Quality Index; Benthic Index of Biotic Integrity; Freshwater impairments
- **Marine Water Quality:** Marine Water Condition Index; Dissolved Oxygen in Marine Waters
- **Marine Sediment Quality:** Sediment Quality Triad Index; Sediment Chemistry Index; Percent of Chemical Measurements Exceeding SQS
- **Toxics in Fish:** English Sole Contaminants and Disease (PCBs, PBDES, PAHs); Pacific Herring Contaminants (PCBs, PBDES, PAHs); Salmon Contaminants (PCBs, PBDES)

### 3.2.1 Freshwater Quality Vital Sign

#### *Vital Sign Attributes and Current Status*

This Vital Sign focuses on rivers, streams, lakes and ponds and has three indicators: (1) Water Quality Index, (2) Benthic Index of Biotic Integrity, and (3) Freshwater Impairments. Some attributes are addressed in multiple indicators. To simplify this, workshop participants evaluated the following integrated list of attributes for this Vital Sign:

- Dissolved oxygen
- pH
- Temperature
- Fecal coliform bacteria
- Nitrogen
- Phosphorus
- Suspended sediment
- Turbidity

- The diversity and relative abundance of the benthic (bottom dwelling) macroinvertebrates such as mayfly larvae, stonefly larvae, caddisfly larvae, worms, beetles, snails, dragonfly larvae, and many others

According to the Puget Sound Partnership’s progress summaries for the Freshwater Quality Vital Sign:

- The Water Quality Index Indicator is “Not Changing.” Only 39 percent of monitored stations were at or above the target value of 80, on average, between 2011 and 2015. This result is lower compared to the baseline reference established for the 2005 – 2009 period (52 percent), but the difference is not significant. Six river systems—Deschutes, Nisqually, Green, Cedar, Samish and Skokomish rivers— had some improvements, but not enough to significantly sway the overall scores.<sup>17</sup>
- The Freshwater Impairments Indicator has “No Data” or not enough data are available to make a conclusion about progress.<sup>18</sup>
- The Benthic Index of Biotic Integrity (B-IBI) Indicator shows “Mixed Results.” Overall, biological condition at some sites is declining, improving at others, and not changing at most.<sup>19</sup>

### Assessment Findings

Risk		Rating	Confidence
High	<i>Likelihood of Impact</i>	High	High
	<i>Consequence</i>	High	Low to Medium

Workshop participants rated this Vital Sign as high risk for the following reasons. Warmer stream temperatures are expected to affect fish, benthos and impairment listings for water temperature. More intense heavy rain events are expected to cause flow pulses that wash benthic organisms downstream and increase sedimentation, turbidity, and runoff of nitrogen, phosphorus, and fecal coliform bacteria. Reduced summer low flows are expected to increase stream temperatures and concentrations of toxics, nutrients and other pollutants. However, impacts will vary considerably by location depending on the current functional health of the system (healthy, marginal or impaired). Healthier systems have a higher ability to withstand these changes and groundwater may moderate the temperature increases in some locations.

### 3.2.2 Marine Water Quality Vital Sign

#### *Vital Sign Attributes and Current Status*

The Marine Water Quality Vital Sign focuses on embayments and marine open waters (where sediment surface is below the euphotic zone). The Vital Sign has two indicators: (1) Marine Water Condition Index, and (2) Dissolved Oxygen in Marine Waters. Some attributes are addressed in both indicators. To simplify this, workshop participants evaluated the following integrated list of attributes for this Vital Sign:

- Temperature
- Salinity
- Nutrient balance
- Algae biomass

<sup>17</sup> [http://www.psp.wa.gov/vitalsigns/fresh\\_water\\_quality\\_indicator1.php](http://www.psp.wa.gov/vitalsigns/fresh_water_quality_indicator1.php). Accessed June 22, 2017.

<sup>18</sup> [http://www.psp.wa.gov/vitalsigns/fresh\\_water\\_quality\\_indicator2.php](http://www.psp.wa.gov/vitalsigns/fresh_water_quality_indicator2.php). Accessed June 22, 2017.

<sup>19</sup> [http://www.psp.wa.gov/vitalsigns/fresh\\_water\\_quality\\_indicator3.php](http://www.psp.wa.gov/vitalsigns/fresh_water_quality_indicator3.php). Accessed June 22, 2017.

- Dissolved oxygen
- Human-related contributions of nitrogen

According to the Puget Sound Partnership’s progress summary for the Marine Water Quality Vital Sign:

- The Marine Water Condition Index Indicator is “Getting Worse.” Over the long-term, Marine Water Condition Index scores have generally declined. In 2015, water was exceptionally warm in Puget Sound due to a large-scale temperature anomaly in the North East Pacific (the “Blob”). As a result, index scores for the entire region declined below baseline conditions. Some regions are not faring well: index scores in Bellingham Bay, Sinclair Inlet, and Oakland Bay have declined continuously relative to the baseline starting in 1999, and Budd Inlet has followed a similar trend over the last decade.<sup>20</sup>
- The Dissolved Oxygen in Marine Waters Indicator is rated as “No Data.” However, the progress summary further states that modeled oxygen depletion resulting from human-related inputs to Puget Sound is not within the target value of 0.2 mg/L for significant portions of the Puget Sound. In local areas, including South Sound inlets and Skagit Bay, the magnitude of oxygen depletion caused by nutrient inputs from humans is much larger than the target value of 0.2 mg/L.<sup>21</sup>

*Assessment Findings*

Risk		Rating	Confidence
<b>High</b>	<i>Likelihood of Impact</i>	High	Mixed: <ul style="list-style-type: none"> <li>• High for temperature, ocean acidification and runoff.</li> <li>• Low for winds, dissolved oxygen and circulation.</li> </ul>
	<i>Consequence</i>	High	Mixed: <ul style="list-style-type: none"> <li>• High for temperature</li> <li>• Low for eutrophication, circulation, residence time; anything that has to do with pelagic food web beyond temperature; upwelling due to possible change in winds; species migration effects.</li> </ul>

Workshop participants rated this Vital Sign as high risk for the following reasons. More intense heavy rain events are expected to increase runoff and contribute to more pollutant and nutrient runoff (such as nitrogen) into Puget Sound. Harmful algal blooms are expected to increase in frequency and extent as air and marine water temperatures increase. Puget Sound marine waters are expected to become more acidic, and harmful algal blooms may become more toxic with increasing ocean acidification (although

<sup>20</sup> [http://www.psp.wa.gov/vitalsigns/marine\\_water\\_quality\\_indicator1.php](http://www.psp.wa.gov/vitalsigns/marine_water_quality_indicator1.php). Accessed May 26, 2017.

<sup>21</sup> [http://www.psp.wa.gov/vitalsigns/marine\\_water\\_quality\\_indicator2.php](http://www.psp.wa.gov/vitalsigns/marine_water_quality_indicator2.php). Accessed May 26, 2017.

ocean acidification is not currently an attribute for this Vital Sign). Water quality is sensitive to nitrogen, which can contribute to eutrophication, but biological interactions and connectivity to the ocean can mask these effects. Increased residence time of water in Puget Sound could amplify the effects of nutrients and pollutants on water quality, however the effects of climate change on circulation and residence time are uncertain.

### 3.2.3 Marine Sediment Quality Vital Sign

#### *Vital Sign Attributes and Current Status*

The Marine Sediment Quality Vital Sign focuses on embayments and marine open waters (where sediment surface is below the euphotic zone) and has three indicators: (1) Sediment Quality Triad Index, (2) Sediment Chemistry Index, and (3) Percent of Chemical Measurements Exceeding Sediment Quality Standards. Some attributes are addressed in multiple indicators. To simplify this, workshop participants evaluated climate change impacts on the following integrated list of attributes for this Vital Sign:

- Chemical contamination, as described in the Sediment Chemistry Index (SCI)
- Sediment Quality Standards (SQS)
- Toxicity of the sediments to marine life
- Diversity of the benthos
- Metals
- Polychlorinated biphenyls (PCBs)
- Polynuclear aromatic hydrocarbons (PAHs)
- Polybrominated diphenyl ethers (PBDEs – flame retardants)
- Chlorinated pesticides
- Phthalates
- Some solvents
- Various other pollutants

According to the Puget Sound Partnership’s progress summary for the Marine Sediment Quality Vital Sign:

- The Sediment Quality Triad Index Indicator shows “Mixed Results.” While five of eight regions and four of six urban bays currently have mean SQTI scores that statistically meet the target value of 81, three regions and two bays do not meet the target value. Where scores declined, it is primarily due to declines in the number and types of benthic invertebrates.<sup>22</sup>
- The Sediment Chemistry Index Indicator is “Not Changing.” Overall, sediments in Puget Sound have been and continue to be in generally good condition with regard to the measured set of chemicals, except in Elliott Bay near Seattle.<sup>23</sup>
- The Percent of Chemical Measurements Exceeding Sediment Quality Standards Indicator is “Getting Better.” Although the target is not fully met across all of Puget Sound, recent improvements suggest progress toward the 2020 target.<sup>24</sup>

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<sup>22</sup> Mauger, et al. 2015.

<sup>23</sup> [http://www.psp.wa.gov/vitalsigns/marine\\_sediment\\_quality\\_indicator1.php](http://www.psp.wa.gov/vitalsigns/marine_sediment_quality_indicator1.php). Accessed June 22, 2017.

<sup>24</sup> [http://www.psp.wa.gov/vitalsigns/marine\\_sediment\\_quality\\_indicator2.php](http://www.psp.wa.gov/vitalsigns/marine_sediment_quality_indicator2.php). Accessed June 22, 2017.



## Assessment Findings

Risk		Rating	Confidence
High	<i>Likelihood of Impact</i>	High	Medium to High
	<i>Consequence</i>	Medium to High	Low

Workshop participants rated this Vital Sign as high risk for the following reasons. Toxics are likely to increase in Puget Sound due to more intense heavy rain events, which are likely to increase runoff, sediment loading and burial of toxics, especially from the built environment. More extreme precipitation could also lead to more frequent failure of stormwater and water treatment systems, providing another input for toxics to marine sediment. Sea level rise could expose new sources of toxics loading from industrial and brownfield sites due to increased coastal erosion and flooding. Higher temperatures and increased salinity can enhance toxicity once toxics enter the marine system.

The actual effects of climate change on marine sediment quality will vary by location based on the sources of sediment, its degree of toxicity, and the fate of toxic settlement in Puget Sound. If toxicity increases in Puget Sound sediments, the benthic community is likely to be negatively affected. However, since runoff already washes toxic sediments into Puget Sound, it is difficult to predict the degree of change that will occur due to increased extreme precipitation events in the future.

### 3.2.4 Toxics in Fish Vital Sign

#### *Vital Sign Attributes and Current Status*

The Toxics in Fish Vital Sign focuses on toxics in Chinook salmon, coho salmon, herring, and demersal fish and the invertebrate community. It has three indicators: (1) English Sole Contaminants and Disease, (2) Pacific Herring Contaminants, and (3) Salmon Contaminants. Some attributes are addressed in each indicator. To simplify this, workshop participants evaluated the following integrated set of attributes for this Vital Sign:

- Fish concentrations of polychlorinated biphenyls (PCBs), polybrominated diphenyls ethers (PBDEs or flame retardants), polycyclic aromatic hydrocarbons (PAHs or Hydrocarbon products of petroleum or combustion), and endocrine disrupting compounds (EDCs).

According to the Puget Sound Partnership's progress summary for the Toxics in Fish Vital Sign, PCBs exceeded health effects thresholds or have been identified as a risk to seafood consumers in recent years for (1) urban English sole, (2) adult Chinook salmon returning to Puget Sound rivers, (3) juvenile Chinook salmon in Puget Sound or its river mouths, and (4) Pacific herring in Southern and Central Puget Sound. It appears that PBDE levels in most species are at or below obvious, immediate concern for most areas. In addition, PBDE levels appear to be declining in Pacific herring from Central and South Puget Sound. PAH levels in herring from Central and South Puget Sound are cause for some concern. However PAH-related liver disease has declined to near background levels in one urban area (Elliott Bay). Endocrine disrupting compounds (EDCs) have been evaluated in two species, English sole (adults) and Chinook salmon (juveniles). EDC-related feminization of male English sole was observed at five of six sampled locations, and in juvenile Chinook salmon from three of four sampled locations.<sup>25</sup>

<sup>25</sup> [http://www.psp.wa.gov/vitalsigns/toxics\\_in\\_fish\\_indicator1.php](http://www.psp.wa.gov/vitalsigns/toxics_in_fish_indicator1.php). Accessed May 29, 2017.

### Risk Assessment Findings

Risk		Rating	Confidence
Moderate	<b>Likelihood of Impact</b>	Medium	High
	<b>Consequence</b>	Medium	High

Workshop participants rated this Vital Sign as moderate risk for the following reasons. More intense heavy rain events are expected to increase toxics loading into Puget Sound. This is likely to increase the concentration of toxics in fish and could further compromise ESA-listed species such as salmonids and orca. In addition, increased water temperatures are expected to affect metabolism and increase the bio-accumulation of toxins in some fish. However, the effects will vary by fish species and by location in Puget Sound, with demersal (or bottom feeding) fish and fish in urban areas being at higher risk. Fish populations with toxic concentrations above health effect thresholds are expected to experience higher incidence of disease and lower survival, and create higher health risks for humans who consume those fish.

### 3.3 PROTECT AND RESTORE HABITAT GOAL

The Protect and Restore Habitat Goal was established by the legislature as:

**Protect and Restore Habitat Goal:** A healthy Puget Sound where freshwater, estuary, nearshore, marine, and upland habitats are protected, restored, and sustained. (RCW 90.71.300)

This goal has five Vital Signs (in bold) and twelve associated indicators:

- **Floodplains:** Floodplain Restoration; Floodplain Function
- **Estuaries:** Area of Estuarine Wetlands Restored to Tidal Flooding; Estuary Restoration Meeting Salmon Recovery Goals
- **Eelgrass:** Eelgrass Area
- **Land Development and Cover:** Land Cover Change (Forest to Developed); Land Development Pressure (Conversion of Ecologically Important Lands); Land Cover Change (Riparian Restoration); Land Development Pressure (Growth in UGAs)
- **Shoreline Armoring:** Amount of Shoreline Armoring; Armoring on Feeder Bluffs; Use of Soft Shore Techniques

#### 3.3.1 Floodplains Vital Sign

##### *Vital Sign Attributes and Current Status*

The Floodplain Vital Sign focuses on large rivers and streams, freshwater tidal wetlands and riparian vegetation. The Vital Sign has two indicators: (1) Floodplain Restoration, and (2) Floodplain Function. To assess climate change impacts on floodplains, workshop participants evaluated the following attributes and desired future conditions of this Vital Sign:

- Freshwater floodplains that support natural processes and deliver ecological services to keep people and property safe during flood flows, support fisheries production, and provide water filtration and ground water recharge.
- Floodplain restoration, which is described as protection, loss and progress toward recovering the function of floodplains
- Floodplain function, which is described as connectivity and cover of floodplain areas

According to the Puget Sound Partnership’s progress summary for the Floodplains Vital Sign, the Floodplain Restoration Indicator is “Getting Better.” A 2016 analysis estimated that 290,380 acres of Puget Sound’s floodplains (or 62 percent of the total) are characterized as degraded. An estimated 3,851 acres of degraded floodplain area have been restored since federal fiscal year 2011. The restoration gain estimated to date represents about 9 percent of the total number of acres (43,557 acres) needed to reach the 15 percent restoration target.<sup>26</sup> Analysis of the Floodplain Function Indicator is pending until the characterization of floodplain function is completed.<sup>27</sup>

**Assessment Findings**

Risk		Rating	Confidence
<b>High</b>	<i>Likelihood of Impact</i>	<ul style="list-style-type: none"> <li>• Medium-high for well-functioning systems</li> <li>• High for compromised systems</li> </ul>	Medium
	<i>Consequence</i>	High	Medium

Workshop participants rated this Vital Sign as high risk for the following reasons. Reduced summer low flows are expected to diminish floodplain function, reduce connectivity to portions of the system, increase water temperatures, and impede salmon migration. These changes are expected to harm salmon in the lower elevation reaches of rivers and streams in the Puget Sound region, particularly in rain dominant and rain/snow mix watersheds. At higher elevations, accelerated snow and ice melt may help buffer stream volume and temperature in the near term.

In fall, the potential for higher streamflows is expected to enhance floodplain connectivity. However the potential for more bed scour in fall and winter could negatively affect salmon. If flooding events become more severe or more frequent, humans in some areas are likely to respond by increasing flood protection, which typically reduces floodplain function.

Impacts are likely to be spatially explicit and may build on one another (e.g., low flows leading to disconnected floodplains and higher stream temperatures). Well-functioning floodplain systems located in watershed with low imperviousness are likely to be more resilient to climate change impacts than compromised systems in urban watersheds.

**3.3.2 Estuaries Vital Sign**

*Vital Sign Attributes and Current Status*

The Estuaries Vital Sign addresses all estuaries of Puget Sound, including major rivers estuaries and pocket estuaries. The Vital Sign has two indicators: (1) Area of Estuarine Wetlands Restored to Tidal Flooding, and (2) Estuary Restoration Meeting Salmon Recovery Goals. To assess climate change impacts on floodplains, workshop participants evaluated the following attributes and desired future conditions for this Vital Sign:

- Protection, loss, and restoration of large and small tidally-influenced wetland habitats at the estuaries of Puget Sound’s major rivers that provide ecosystem functions, goods, and services.

<sup>26</sup> [http://www.psp.wa.gov/vitalsigns/flood\\_plains\\_indicator1.php](http://www.psp.wa.gov/vitalsigns/flood_plains_indicator1.php). Accessed June 5, 2017.

<sup>27</sup> [http://www.psp.wa.gov/vitalsigns/flood\\_plains\\_indicator2.php](http://www.psp.wa.gov/vitalsigns/flood_plains_indicator2.php). Accessed June 5, 2017.

- Area of estuarine wetlands restored to tidal flooding: the amount of land returned to tidal flooding in the deltas and the associated the provision of ecosystem services.
- Estuary restoration meeting salmon recovery goals: The number of Chinook salmon natal river deltas where 10-year salmon recovery goals have been met.
- Functional estuary surface area.
- Extent of shoreline armoring.

According to the Puget Sound Partnership’s progress summary for the Estuaries Vital Sign, the Area Of Estuarine Wetlands Restored to Tidal Flooding Indicator is “Getting Better.” According to 2016 data, approximately 2,791 acres, or about 38 percent of the 2020 target, of estuarine river delta wetlands were restored to tidal flooding between 2006 and 2016.<sup>28</sup> The indicator for Estuary Restoration Meeting Salmon Recovery Goals states that no data are available yet to assess progress.<sup>29</sup>

*Assessment Findings*

<b>Risk</b>		<b>Rating</b>	<b>Confidence</b>
<b>High</b>	<i>Likelihood of Impact</i>	High	High to Medium
	<i>Consequence</i>	High to Medium	Mixed: High, Medium and Low

Workshop participants rated this Vital Sign as high risk for the following reasons. Climate change impacts are generally expected to have a negative effect on estuaries and the ability to meet salmon recovery and estuary goals, although impacts will vary geographically and some changes could be beneficial. The consequences will be primarily influenced by sediment delivery, sea level rise, erosion, wave energy and increased water temperatures.

Changes in sediment loading will be affected by erosion and sediment transport from rivers. Higher peak flows could flush sediment further outward, limiting deposition in the nearshore. Where sediment is limited, sea level rise is likely to have a negative impact on estuary habitats and function, particularly if the shoreline cannot migrate upslope due to shoreline armoring, bluffs, or other factors. Estuaries with a sediment supply may fare better if there is room for habitat to shift upslope. As habitats shift, mud flats are expected to decrease while tidal freshwater swamps are likely to increase. An expansion of tidal freshwater swamps would be beneficial because this habitat has high ecological value and much of it has been lost. Accretion could also lead to an expansion of marshes.

Water temperatures in the estuaries are also likely to be a concern. Lower summer streamflows and higher water temperatures in shallow portions of estuaries could push some estuaries closer to or beyond the temperature limits for salmon. If estuaries experience large-scale accretion, that accretion could exacerbate warming as water becomes shallower.

In addition, the effect of waves and sea level rise may combine to cause increased erosion in open systems. Spit systems are expected to be especially vulnerable. Sea level rise effects may affect smaller

<sup>28</sup> [http://www.psp.wa.gov/vitalsigns/estuaries\\_indicator1.php](http://www.psp.wa.gov/vitalsigns/estuaries_indicator1.php). Accessed on June 5, 2017.

<sup>29</sup> [http://www.psp.wa.gov/vitalsigns/estuaries\\_indicator2.php](http://www.psp.wa.gov/vitalsigns/estuaries_indicator2.php). Accessed on June 5, 2017.

pocket estuaries more than larger estuaries, but the effects will depend on sediment delivery, accretion rates and the opportunity for habitat to migrate upslope.

### 3.3.3 Eelgrass Vital Sign

#### *Vital Sign Attributes and Current Status*

The Eelgrass Vital Sign includes all native submerged aquatic vegetation beds (e.g. seagrasses) and brown (kelp), red and green algae. The Vital Sign has one indicator: Eelgrass Area. To assess climate change impacts on eelgrass, workshop participants evaluated the following attributes and desired future conditions for this Vital Sign:

- Progress toward recovering healthy eelgrass and other submerged aquatic vegetation beds.
- Changes in abundance or distribution of all native submerged aquatic vegetation beds (e.g. seagrasses) and brown (kelp), red and green algae.
- Number of increasing, decreasing, or stable eelgrass beds: count of eelgrass gains and losses on a per site basis.

According to the Puget Sound Partnership’s progress summary for the Eelgrass Vital Sign, the Eelgrass Area Indicator is “Not Changing.” Puget Sound supports about 55,000 acres of eelgrass (average 2009-2015). Sound-wide eelgrass area has not increased relative to the 2000-2008 baseline. There is no significant trend in eelgrass area between 2009 and 2015.<sup>30</sup>

#### *Assessment Findings*

Risk		Rating	Confidence
Low	<i>Likelihood of Impact</i>	Low	Medium
	<i>Consequence</i>	Low	Low

Workshop participants rated this Vital Sign as low risk for the following reasons. Climate change impacts on eelgrass growth are likely to be both negative and positive, depending on the impact. Warmer air and water temperatures are expected to have a negative impact on eelgrass growth and contribute to an increased incidence of disease. For example, higher water temperatures in spring, combined with increased nutrient delivery, could lead to an increase in green algae that could smother eelgrass.

Eelgrass growth could also be harmed if increased sediment loading leads to more shading. However, if the water remains clear, increased sediment could benefit eelgrass growth. Sea level rise is likely to be neutral to positive because it could provide additional places for eelgrass to grow unless armoring or geomorphology such as bluffs limit expansion.

The negative impacts on eelgrass are expected to be offset to some degree by ocean acidification, which could benefit eelgrass. Eelgrass is CO<sub>2</sub>-limited; an increase in CO<sub>2</sub> is expected to enhance growing conditions. While the net effects may be neutral or even beneficial through 2050, the net effects of climate change may shift to negative after 2050.

<sup>30</sup> [http://www.psp.wa.gov/vitalsigns/eelgrass\\_indicator1.php](http://www.psp.wa.gov/vitalsigns/eelgrass_indicator1.php). Accessed June 7, 2017.

### 3.3.4 Land Development and Cover Vital Sign

#### *Vital Sign Attributes and Current Status*

The Land Development and Cover Vital Sign has four indicators: (1) Land Cover Change (Forest to Developed); (2) Land Development Pressure (Conversion of Ecologically Important Lands); (3) Land Cover Change (Riparian Restoration); and (4) Land Development Pressure (Growth in Urban Growth Areas (UGAs)). To assess climate change impacts on land development and cover, workshop participants evaluated the following attributes and desired future conditions for this Vital Sign:

- Gains (through restoration), maintenance (through protection) and losses of habitat (through development).
- How well we are directing our region’s ongoing growth to protect our best remaining natural areas and working forests.
- Land Cover Change (Forest to Developed): The number of acres of non-federal forest land cover converted to development.
- Land Development Pressure (Conversion of Ecologically Important Lands): The fate of ecologically important lands under development pressure in Puget Sound watersheds.
- Land Cover Change (Riparian Restoration): The amount of new vegetated cover delivered by restoration projects along riparian corridors.
- Land Development Pressure (Growth in UGAs): The proportion of population growth occurring within UGAs.

According to the Puget Sound Partnership’s progress summary for the Land Development and Cover Vital Sign:

- The Forest Loss Indicator is “Getting Better.” Non-federal forestlands were lost to development at a rate of 2,176 acres per year for the period 2001 – 2006, the baseline reference year. Between 2006 and 2011, the most recent period with available data, the rate of forest loss decreased by almost half to 1,196 acres per year. The target value of 1000 acres per year was nearly reached during the 2006-2011 period.<sup>31</sup>
- The Riparian Restoration Indicator is “Getting Better.” The cumulative amount of restoration of vegetation along riparian corridors increases incrementally every year.<sup>32</sup>
- The Conversion of Ecologically Important Lands Indicator is “Getting Worse.” The five-year baseline rate of land cover change on the indicator land base across all 12 counties in Puget Sound for the period 2001 - 2006 was 0.28 percent and increased to 0.36 percent over the period 2006-2011. Achieving the 2020 target will require reducing the conversion of ecologically important lands to development to less than half the rate of conversion observed in 2006 – 2011.<sup>33</sup>
- The Growth in UGAs Indicator states that “No Data are available yet to assess progress.” Basin-wide, 83 percent of new population growth from 2000 to 2010 occurred within urban growth areas. For individual counties, the proportion of growth occurring within urban growth areas ranged from a low of 28 percent for Mason and Jefferson counties to highs of 92 percent and 101 percent for Snohomish and King counties, respectively.<sup>34</sup>

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<sup>31</sup> [http://www.psp.wa.gov/vitalsigns/land\\_cover\\_and\\_development\\_indicator1.php](http://www.psp.wa.gov/vitalsigns/land_cover_and_development_indicator1.php). Accessed June 14, 2017.

<sup>32</sup> [http://www.psp.wa.gov/vitalsigns/land\\_cover\\_and\\_development\\_indicator2.php](http://www.psp.wa.gov/vitalsigns/land_cover_and_development_indicator2.php). Accessed June 14, 2017.

<sup>33</sup> [http://www.psp.wa.gov/vitalsigns/land\\_cover\\_and\\_development\\_indicator3.php](http://www.psp.wa.gov/vitalsigns/land_cover_and_development_indicator3.php). Accessed June 14, 2017.

<sup>34</sup> [http://www.psp.wa.gov/vitalsigns/land\\_cover\\_and\\_development\\_indicator4.php](http://www.psp.wa.gov/vitalsigns/land_cover_and_development_indicator4.php). Accessed June 14, 2017.



*Assessment Findings*

Risk		Rating	Confidence
Low	<i>Likelihood of Impact</i>	Low	High
	<i>Consequence</i>	Medium	High to Medium

Workshop participants rated this Vital Sign as low risk for the following reasons. Climate change impacts are unlikely to affect development and land cover change. While there are concerns about climate-related human migration, there is little evidence thus far. The climate change impacts of greatest concern relate to vegetation changes that could affect riparian restoration efforts and other habitat. A longer growing season could be beneficial, especially in high elevations. However, in low elevations, trees are likely to be stressed by increased temperature and reduced soil moisture. Warming is expected to alter vegetation growth and increase fire hazard. Unmanaged forests are expected to be the most susceptible to negative impacts. However, as currently defined, this Vital Sign does not address changes in vegetation for reasons other than development and restoration projects.

**3.3.5 Shoreline Armoring Vital Sign**

*Vital Sign Attributes and Current Status*

The Shoreline Armoring Vital Sign has three indicators: (1) Amount of Shoreline Armoring, (2) Armoring on Feeder Bluffs, and (3) Use of Soft Shore Techniques. To assess climate change impacts on shoreline armoring, workshop participants evaluated the following attributes and desired future conditions for this Vital Sign:

- Progress toward protecting intact shorelines, to reducing the total amount of shoreline armoring – particularly in those areas along feeder bluffs – and replacing armoring with soft-shore techniques, and reducing new armoring (whether hard or soft) in our effort to restore the natural processes and function of shorelines.
- Feeder bluffs receive strategic attention for removal of existing armoring and avoidance of new armoring.
- Soft shore techniques are used for all new and replacement armoring, unless it is demonstrably infeasible.

According to the Puget Sound Partnership’s progress summary for the Shoreline Armoring Vital Sign, the Amount of Shoreline Armoring Indicator is “Getting Better.” The rate of adding new armoring has slowed and more armoring was removed than added in 2014.<sup>35</sup> The Armoring on Feeder Bluffs Indicator and the Use of Soft Shore Techniques Indicator is not rated.<sup>36</sup>

*Assessment Findings*

Risk		Rating	Confidence
High	<i>Likelihood of Impact</i>	High	High
	<i>Consequence</i>	High	High

Workshop participants rated this Vital Sign as high risk for the following reasons. Sea level rise and increased storm surge are expected to lead coastal landowners to strengthen existing armoring, add new armoring, and resist efforts to remove armoring. The consequences of armoring include degraded

<sup>35</sup> [http://www.psp.wa.gov/vitalsigns/shoreline\\_armoring\\_indicator1.php](http://www.psp.wa.gov/vitalsigns/shoreline_armoring_indicator1.php). Accessed June 7, 2017.

<sup>36</sup> [http://www.psp.wa.gov/vitalsigns/shoreline\\_armoring.php](http://www.psp.wa.gov/vitalsigns/shoreline_armoring.php). Accessed June 7, 2017.

marine riparian habitats, reduced connectivity between the marine and upland systems, and coastal squeeze (which occurs when sea level rises and the intertidal zone cannot migrate landward due to armoring or geomorphology such as bluffs). Armoring also disconnects feeder bluffs from the beach, reducing sediment delivery. The effects of sea level rise on softshore techniques are uncertain.

### 3.4 SPECIES AND FOOD WEBS GOAL

The Protect and Restore Habitat Goal was established by the legislature as:

**Species and Food Webs Goal:** Healthy and sustaining populations of native species in Puget Sound, including a robust food web. (RCW 90.71.300)

This goal has four Vital Signs (in bold) and five associated indicators:

- **Pacific Herring:** Biomass of Spawning Pacific Herring
- **Chinook Salmon:** Chinook Salmon Population Abundance as Measured by the Number of Natural Origin Adult Fish Returning to Spawn
- **Birds:** Marine Bird Population Abundance (rhinoceros auklet, pigeon guillemot, marbled murrelet, surf scoter, white-winged scoter, black scoter); Terrestrial Bird Population Abundance (1a. associated with interior conifer forests: brown creeper, varied thrush, golden-crowned kinglets. 1b. Associated with human development: American crow, rock pigeon, house sparrow, house finch, and European starling)
- **Orcas:** Number of Southern Resident Killer Whales

#### 3.4.1 Pacific Herring Vital Sign

##### *Vital Sign Attributes and Current Status*

The Pacific Herring Vital Sign has one indicator: Biomass of Spawning Pacific Herring. To assess climate change impacts on Pacific herring and other forage fish, call participants evaluated the following attributes and desired future conditions for this Vital Sign:

- Health of forage fish in Puget Sound, including Pacific herring, surf smelt and sand lance.
- Annual tonnage of spawning herring (based on the estimated quantity of eggs deposited by herring on marine vegetation).

According to the Puget Sound Partnership’s progress summary for the Pacific Herring Vital Sign: the Biomass of Spawning Pacific Herring Indicator is “Getting Worse.” Despite seeing minor increases in overall spawn biomass in 2015-16 compared to the ten year average, none of the 2020 target values for individual Pacific herring stocks or groups of stocks are met. Overall, the current spawning biomass of all stocks is below both their respective 25-year mean reference and their 2020 target values. The Cherry Point herring stock in North Puget Sound, once the largest stock in the Sound, has declined by over 90 percent since the earliest sampling date in 1973 and shows little sign of recovery. The Squaxin Pass and other combined Puget Sound stocks do not exhibit the sharp decline seen in the Cherry Point stock. In fact, in some years, these stocks have gone above their target values.<sup>37</sup>

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<sup>37</sup> [http://www.psp.wa.gov/vitalsigns/pacific\\_herring\\_indicator1.php](http://www.psp.wa.gov/vitalsigns/pacific_herring_indicator1.php). Accessed June 14, 2017.

*Assessment Findings*

<b>Risk</b>		<b>Rating</b>	<b>Confidence</b>
<b>High</b>	<b><i>Likelihood of Impact</i></b>	High	High
	<b><i>Consequence</i></b>	High for herring Medium for forage fish guild Medium for pelagic food web	High for herring Medium for forage fish guild Medium for pelagic food web

Call participants rated this Vital Sign as high risk for the following reasons. Sea level rise, increased armoring and coastal squeeze<sup>38</sup> are likely to reduce spawning area for Pacific herring. Because Pacific herring and other forage fish rely on the subtidal and intertidal zone for spawning, this directly affects the reproduction potential of forage fish in Puget Sound. Increasing ocean acidification is also expected to cause declines in the availability and quality of forage fish prey, especially plankton, crab larvae, copepods, and pteropods.

While Pacific herring populations are expected to decline, the range of variables and complexity of biological interactions are difficult to predict. A forage fish community is likely to persist, although its composition may change. Other species such as anchovies may enter the system and provide a forage fish-like prey base for some species. Currently, Chinook salmon rely on herring as a major prey base. If predators such as Chinook can prey on new forage fish species, they may do well. If not, Chinook and other predators are likely to be negatively affected by herring declines.

### 3.4.2 Chinook Salmon Vital Sign

*Vital Sign Attributes and Current Status*

The Chinook Salmon Vital Sign has one indicator: Chinook Salmon Population Abundance as Measured by the Number of Natural Origin Adult Fish Returning to Spawn. To assess climate change impacts on salmonids, workshop participants evaluated the following attributes and desired future conditions for this Vital Sign:

- Spatially and genetically diverse collection of viable Chinook salmon populations.
- The health of all salmon and steelhead species in Puget Sound.
- The number of natural origin spawners.
- The number of natural origin recruits.

According to the Puget Sound Partnership’s progress summary for the Chinook Salmon Vital Sign, the Chinook Salmon Population Abundance Indicator is “Getting Worse.” The total number of naturally spawning Chinook salmon has declined, the 2014 interim targets for spawning Chinook salmon have not been met, there is little sign of improvement in each biogeographic region, and most populations remain far below their recovery planning targets adopted by the National Marine Fisheries Service.

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<sup>38</sup> As described previously, coastal squeeze occurs when sea level rises and the intertidal zone cannot migrate landward due to armoring or geomorphology such as bluffs.

*Assessment Findings*

Risk		Rating	Confidence
High	<i>Likelihood of Impact</i>	High	High
	<i>Consequence</i>	High	High

There is a significant body of research and literature regarding salmon and climate change. This section summarizes a brief discussion during the climate assessment workshop, but is not intended to substitute for that body of information.

Workshop participants rated this Vital Sign as high risk for the following reasons. All components of Chinook life history are negatively affected by climate change. A primary concern for Chinook and coho is increased water temperature in estuaries, which can be lethal or increase disease incidence during their juvenile stage. Increased temperatures also appear to reduce fecundity by increasing prespawn mortality. In addition, warmer temperatures appear to lead herring (a prey species for Chinook) to spawn earlier in Puget Sound which allows them to grow large enough that they are no longer prey to juvenile Chinook. This is expected to diminish prey availability for Chinook, as is shoreline armoring due to negative effects on spawning habitat for forage fish. Crabs are also critical prey during specific life stages, and while the drivers for crab survival are not well documented, ocean acidification is expected to harm their survival.

Steelhead are affected differently because they spend little time in saltwater (approximately 2 weeks) and they don't typically use the estuary. The primary concern for steelhead is the negative effects of reduced low flows on spawning habitat and migration.

**3.4.3 Birds Vital Sign**

*Vital Sign Attributes and Current Status*

The Birds Vital Sign has two indicators: (1) Marine Bird Population Abundance and (2) Terrestrial Bird Population Abundance. To assess climate change impacts on birds, workshop participants evaluated the following attributes and desired future conditions for this Vital Sign:

- The health of populations of native resident and migratory species of birds.
- The abundance of marine bird populations that reside most, if not all, of the year in Puget Sound. For example, spring/summer at-sea densities of rhinoceros auklet, pigeon guillemot and marbled murrelet; and at-sea abundance trends of scoter species that overwinter in Puget Sound and Strait of Juan de Fuca.
- The abundance of terrestrial bird populations that reside most, if not all, of the year in Puget Sound. For example, golden-crowned kinglet, varied thrush and brown creeper; American crow, rock pigeon, house sparrow, house finch, and European starling.

According to the Puget Sound Partnership's progress summary for the Birds Vital Sign, the Marine Bird Population Abundance Indicator shows "Mixed Results." Sound-wide, the densities of pigeon guillemot and rhinoceros auklet have fluctuated year-to-year but show no trend over the past 14 years. In contrast, the marbled murrelet population has declined by 5.4 percent per year over the past 14 years,

and this trend is statistically significant. Long-term trends of scoter populations are forthcoming.<sup>39</sup> The Terrestrial Bird Population Abundance Indicator states that “No Data” is available to assess progress.<sup>40</sup>

### Assessment Findings

Risk		Rating	Confidence
Moderate	<i>Likelihood of Impact</i>	Medium	Medium
	<i>Consequence</i>	Medium	Low to Medium

Workshop participants rated this Vital Sign as moderate risk for the following reasons. Marine birds are expected to be affected by climate change primarily through changes in prey, including shifts in availability, quality and timing of prey. Generalists that can switch easily between prey species are likely to be less affected. Specialists that rely on specific prey species and are not able to switch are more likely to be at risk. Marine bird prey include herring, sand lance, smelt, juvenile salmon, and other forage fish that are expected to be negatively affected by climate change impacts. Scoters consume bivalves, which are expected to be harmed by ocean acidification. Marbled murrelet is sensitive to loss of big trees and wildfire, which would impact its nesting area.

Terrestrial birds are expected to be affected by climate change primarily through changes in and loss of forests and other habitat areas. Increased wildfire, disease, insects and other climate-related disturbances are likely to reduce the quality and extent of bird habitat. Most terrestrial birds do not specialize on prey, so shifts in prey are unlikely to have large effects. Changes in species composition for forests and other habitats are expected to occur over extended time scales (e.g. changes in understory, composition of trees, wildfire). However, by 2050 these features are unlikely to change significantly unless there is a fire or disease that eliminates the habitat potential for a large portion of forest. The primary concern for terrestrial birds is the availability of forested interior that remains unfragmented. Non-climate effects such as land conversion due to development will likely compound the impacts.

### 3.4.4 Orcas Vital Sign

#### *Vital Sign Attributes and Current Status*

The Orcas Vital Sign has one indicator: Number of Southern Resident Killer Whales. To assess climate change impacts on orcas, call participants evaluated the following attributes and desired future conditions for this Vital Sign:

- Viable population of southern resident killer whales

According to the Puget Sound Partnership’s progress summary for the Orcas Vital Sign, the Number of Southern Resident Killer Whales Indicator is “Getting Worse.” The 2014 interim target of 89 whales was not met. The 2014 census counted 78 whales, the lowest number reported in 20 years. The July 2015 census led by the Center for Whale Research reports 81 whales, which includes four new calves. Since the July census, four new calves were discovered and one individual passed away, bringing the count up to 84 whales (updated December 2015).<sup>41</sup>

<sup>39</sup> [http://www.psp.wa.gov/vitalsigns/birds\\_indicator1.php](http://www.psp.wa.gov/vitalsigns/birds_indicator1.php). Accessed June 9, 2017.

<sup>40</sup> [http://www.psp.wa.gov/vitalsigns/birds\\_indicator2.php](http://www.psp.wa.gov/vitalsigns/birds_indicator2.php). Accessed June 9, 2017.

<sup>41</sup> [http://www.psp.wa.gov/vitalsigns/orcas\\_indicator1.php](http://www.psp.wa.gov/vitalsigns/orcas_indicator1.php). Accessed June 9, 2017.

*Assessment Findings*

Risk		Rating	Confidence
High	<i>Likelihood of Impact</i>	High	High
	<i>Consequence</i>	High	High

This Vital Sign was rated as high risk for the following reasons. Climate change impacts are expected to reduce the quality and availability of Chinook salmon, which is a primary prey species for resident orcas. As Chinook abundance declines, orcas are expected to become nutritionally stressed and more susceptible to disease. Increased water temperatures may contribute to new pathogen and disease vectors that could harm orca. Overall, orca recovery goals are not being met and it is expected that climate change will make those goals harder to attain.

### 3.5 HEALTHY HUMAN POPULATION GOAL

The Healthy Human Population Goal was established by the legislature as:

- **Healthy Human Population Goal:** A healthy human population supported by a healthy Puget Sound that is not threatened by changes in the ecosystem. (RCW 90.71.300)

This goal has six Vital Signs (in bold) and eight associated indicators. Two Vital Signs do not have indicators yet.

- **Air Quality:** No indicator
- **Drinking Water:** No indicator
- **Locally Harvestable Foods:** Locally Harvestable Foods; Recreational Shellfish Beds
- **Onsite Sewage Systems:** Inventory, Inspection, and Repair of On-Site Sewage Systems; Percent of Unsewered Shoreline that has Inspection Program
- **Outdoor Activity:** Condition of Swimming Beaches; Nature-based Recreation in Puget Sound Region; Nature-Based Work in Puget Sound Region
- **Shellfish beds:** Acres of Harvestable Shellfish Beds

#### 3.5.1 Air Quality Vital Sign

*Vital Sign Attributes and Current Status*

The Air Quality Vital Sign has does not have an indicator. To assess climate change impacts on air quality, call participants evaluated the following attributes and desired future conditions for this Vital Sign:

- The status of air quality across Puget Sound.
- Whether specific demographic groups are more exposed to poor air quality than others.
- The sources of poor quality in different areas.

According to the Puget Sound Partnership’s progress summary for the Air Quality Vital Sign, no data are currently available for this indicator.<sup>42</sup>

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<sup>42</sup> [http://www.psp.wa.gov/vitalsigns/air\\_quality\\_indicator1.php](http://www.psp.wa.gov/vitalsigns/air_quality_indicator1.php). Accessed June 14, 2017.

*Assessment Findings*

<b>Risk</b>		<b>Rating</b>	<b>Confidence</b>
<b>High</b>	<i>Likelihood of Impact</i>	High for wildfire Unknown for stagnations Medium for other impacts	Low for stagnations High for other impacts
	<i>Consequence</i>	High for wildfire, stagnations, allergens Medium for ozone	High for wildfire and stagnations Low to medium for other impacts

Call participants rated this Vital Sign as high risk for the following reasons. Wildfires are projected to increase in frequency and area burned, leading to more smoke that degrades air quality. Ground level ozone is expected to increase due to higher summer temperatures and more extreme heat events. The ozone standard is more likely to be exceeded under conditions that include sunlight and temperatures above 90°F. While days above 90°F are projected to become more frequent, data are not available on changes in the frequency of sunny days and the relationship between the two. Aero allergens are also projected to increase in intensity and the allergy season is projected to lengthen.

Currently, stagnant air during winter wood burning season tends to be the most significant air quality concern in Puget Sound. Air quality and health impacts from wood burning typically occur during a stagnation event (high pressure, inversion, little winds) which traps the smoke close to the ground. Warmer temperatures are expected to reduce home heating demand, which should be beneficial for air quality (assuming no increase in air stagnation events). If stagnant air events increase, any air quality benefits associated with reduced heating demand may be offset. Projected changes in stagnant air days are not available.

Air quality is not equal throughout Puget Sound. Areas that are socially or economically disadvantaged are often located near industrial and high diesel-emitting areas like highways, and can be disproportionately affected by wood smoke. These changes are expected to have significant human health consequences, including increased incidence of heart and lung disease. Populations of concern (e.g., children, elderly, and socially or economically disadvantaged) are expected to suffer disproportionately from the negative impacts of reduced air quality.

### 3.5.2 Drinking Water Vital Sign

*Vital Sign Attributes and Current Status*

The Drinking Water Vital Sign does not have an indicator. To assess climate change impacts on drinking water, call participants evaluated the following attributes and desired future conditions for this Vital Sign:

- The quality of all drinking water systems, including large and small public and private drinking water systems.
- Access to safe drinking water.

According to the Puget Sound Partnership’s progress summary for the Drinking Water Vital Sign, no data are currently available for this indicator.<sup>43</sup>

<sup>43</sup> [http://www.psp.wa.gov/vitalsigns/drinking\\_water\\_indicator1.php](http://www.psp.wa.gov/vitalsigns/drinking_water_indicator1.php). Accessed June 14, 2017.

### Assessment Findings

Risk		Rating	Confidence
High	<i>Likelihood of Impact</i>	High for small drinking water systems Low to medium for large drinking water systems	High for systems on surface water Low for systems on groundwater
	<i>Consequence</i>	Medium for most systems High for system with current quality and reliability issues	Medium

Call participants rated this Vital Sign as high risk for the following reasons. Reduced summer water availability is expected to affect small drinking water systems that rely on shallow groundwater wells, exacerbating operational challenges that many small systems already face even in normal years. Impacts include supply loss if the groundwater table drops below well intakes, reduced water quality, and increased well maintenance and drilling costs. The degree to which these changes affect individual water systems will vary by aquifer type and the rate of recharge versus demand.

More intense heavy rain events can also be a problem for public and private water supply systems. Changes in precipitation are projected to cause wetter winters with more intense heavy rain events that can flood drinking water systems, cause damage and loss of power and allow for intrusion of pollutants into wells and water distribution systems.

Surface water quality for drinking water may also be affected by warmer water temperatures and increased sediment loading. Sea level rise could increase the likelihood of salt water intrusion in some coastal areas, especially islands and isthmuses. Increased wildfire and subsequent runoff can also damage water systems and harm water quality.

### 3.5.3 Locally Harvestable Foods Vital Sign

#### *Vital Sign Attributes and Current Status*

The Locally Harvestable Foods Vital Sign has two indicators: (1) Locally Harvestable Foods, and (2) Recreational Shellfish Beds. To assess climate change impacts on locally harvestable foods, call participants evaluated the following attributes and desired future conditions for this Vital Sign:

- The quality and availability of all local marine, freshwater and terrestrial plants, fungus, and animals harvested as food for traditional, sustenance, and recreational use.
- This includes foods like fish, shellfish, and plants, and mushrooms that occur naturally
- Locally harvestable foods, including finfish and shellfish, animals (including wild game and birds), and plant-based greens, roots, nuts, fruits and mushrooms that occur naturally.
- Access to recreational shellfish beds, based on the health of the natural resource.

According to the Puget Sound Partnership’s progress summary for the Locally Harvestable Foods Vital Sign, no data are available for either of the indicators used to assess progress on this Vital Sign.<sup>44, 45</sup>

<sup>44</sup> [http://www.psp.wa.gov/vitalsigns/local\\_foods\\_indicator1.php](http://www.psp.wa.gov/vitalsigns/local_foods_indicator1.php). Accessed June 14, 2017.

<sup>45</sup> [http://www.psp.wa.gov/vitalsigns/local\\_foods\\_indicator2.php](http://www.psp.wa.gov/vitalsigns/local_foods_indicator2.php). Accessed June 14, 2017.



*Assessment Findings*

<b>Risk</b>		<b>Rating</b>	<b>Confidence</b>
<b>High</b>	<i>Likelihood of Impact</i>	High for shellfish Medium to High for terrestrial foods	Medium high for shellfish Low to Medium for terrestrial foods
	<i>Consequence</i>	High for shellfish High for terrestrial foods	High to Medium for shellfish Medium to High for terrestrial foods

Call participants rated this Vital Sign as high risk for the following reasons. Shellfish are expected to be harmed by increasing ocean acidification; the potential for more harmful algal blooms, vibrio and hypoxia; and increased contaminant loading related to more intense heavy rain events and the likelihood for more storm water run-off and combined sewer overflows.

For terrestrially harvested foods, climate change impacts include increased flooding, increased salinity due to sea level rise and groundwater intrusion, and reduced summer water availability. Some terrestrial foods may be negatively impacted while others may benefit. New foods are likely to be introduced either intentionally or through species migration, leading to a change in what is available for harvesting. However, many traditional foods are not substitutable for tribes. The consequences disproportionately affect those who rely on locally harvested foods and include declines in food security, curtailment of cultural and traditional practices, loss of income and increased risk of illness.

**3.5.4 Onsite Sewage Systems Vital Sign**

*Vital Sign Attributes and Current Status*

The Onsite Sewage Systems Vital Sign has two indicators: (1) Inventory, Inspection, and Repair of On-Site Sewage Systems, and (2) Percent of Unsewered Shoreline that has Inspection Program. To assess climate change impacts on onsite sewage systems, call participants evaluated the following attributes and desired future conditions for this Vital Sign:

- Management of onsite sewage systems and the protection measures put in place to protect nearshore areas in sensitive and high-risk areas of Puget Sound, in order to protect public health and water quality.
- Inventory, inspection and repair of onsite sewage systems in designated areas.

According to the Puget Sound Partnership’s progress summary for the Onsite Sewage Systems Vital Sign, the Inventory, Inspection, And Repair of On-Site Sewage Systems Indicator shows “Mixed Results.” The 2014 interim target for inventories was met, but the interim target for inspection rates fell short. Progress toward the 2020 target to inventory, inspect and repair onsite sewage systems in designated areas is mixed. There have been advances in inventorying and inspecting septic systems. However, the analysis of progress on fixing failures of septic systems is pending due to lack of data.<sup>46</sup>

<sup>46</sup> [http://www.psp.wa.gov/vitalsigns/onsite\\_sewage\\_indicator1.php](http://www.psp.wa.gov/vitalsigns/onsite_sewage_indicator1.php). Accessed June 14, 2017.

*Assessment Findings*

Risk		Rating	Confidence
High	<i>Likelihood of Impact</i>	Medium to High	Medium
	<i>Consequence</i>	Medium to High	Medium to High

Call participants rated this Vital Sign as high risk for the following reasons. Older and marginal onsite sewer systems are likely to fail more frequently due to increased extreme precipitation and flooding, sea level rise, and increased groundwater saturation in winter. The consequences include increased illness due to water contamination, increased costs for repair (especially for low income communities) and reduced ability to harvest foods, including economic loss of recreational and commercial shellfish harvest.

**3.5.5 Outdoor Activity Vital Sign**

*Vital Sign Attributes and Current Status*

The Outdoor Activity Vital Sign has three indicators: (1) Condition of Swimming Beaches, (2) Nature-Based Recreation in Puget Sound Region, and (3) Nature-Based Work in Puget Sound Region. To assess climate change impacts on outdoor activity, call and workshop participants evaluated the following attributes and desired future conditions for this Vital Sign:

- Beaches exceeding one swimming advisory or closure during the summer and the enterococcus level at beaches.
- Participation in nature-based recreation or work activities.
- Recreational activities include wildlife-watching, nature-walking, fishing, clamming, hiking, bicycling, canoeing, kayaking, camping, art in the natural environment, etc.
- Occupations that depend on outdoor activities include logging, fishing, aquaculture, agriculture, trail maintenance and nature-based tourism.

Regarding the current status for this Vital Sign, no data are available for indicators on the Puget Sound Partnership’s website.<sup>47</sup>

*Assessment Findings*

Risk		Rating	Confidence
High	<i>Likelihood of Impact</i>	High for swimming beaches Medium to High for nature-based recreation Medium to High for nature-based work	High for swimming beaches Medium to High for nature-based recreation Medium for nature-based work
	<i>Consequence</i>	High for swimming beaches Medium to High for nature-based recreation Medium to High for nature-based work	High for swimming beaches Medium to High for nature-based recreation Low to Medium for nature-based work

Call and workshop participants rated this Vital Sign as high risk for the following reasons. At swimming beaches, more intense heavy rain events are likely to lead to more flooding and stormwater runoff,

<sup>47</sup> [http://www.psp.wa.gov/vitalsigns/outdoor\\_activities.php](http://www.psp.wa.gov/vitalsigns/outdoor_activities.php). Accessed June 14, 2017.

more combined sewer overflow discharges and an increased potential for wastewater treatment plant failures. These impacts are more likely to occur in winter (based on the seasonality of precipitation in the region), however the effects on water quality can extend beyond any single event.

During the summer months, warmer air temperatures are expected to increase beach visits by humans and pets, which tends to degrade water quality and increase bacterial levels. Warmer summer water temperatures are expected to exacerbate water quality impacts associated with increased recreational use of the beaches by people and pets. Lower summer streamflows are expected to contribute to macro-algae and eutrophication, leading to decomposing beach wrack that can increase fecal indicator bacteria. Beaches most at risk are those near dense population areas and those that are heavily used or near outfalls. These impacts are expected to increase the frequency of enterococcus levels exceeding standards and consequently increase the potential for illness and the frequency of beach closures. Similar water quality concerns, combined with ocean acidification, are expected to reduce recreational shellfish activity (see shellfish discussion under Locally Harvestable Foods Vital Sign).

The effects of climate change on participation in nature-based recreation activities is likely to vary by activity. Weather often influences recreation choices and many recreation activities are substitutable depending on conditions. Increasing temperatures may be beneficial for some activities but are projected to be harmful for snow-based activities. Reduced snowpack and a shortened winter season would have a detrimental effect on winter alpine activities. Other activities that rely on a healthy snowpack, such as paddling and fishing, are also expected to be harmed by declining snowpack and summer streamflows. Intense heat may curtail activities requiring high levels of exertion such as running, biking or hiking.

Erosion and washouts of road and trails used to access nature-based recreation opportunities are likely to increase with more intense heavy rain events. Increased wildfires, forest insects and diseases could also impede access to recreation areas, make them less desirable following disturbance and degrade air quality during fires. Communities that rely on outdoor recreation negatively affected by climate change could be harmed due to reduced income.

For outdoor work, extreme heat events are expected to put outdoor workers' health and safety at greater risk. Construction workers, loggers, farming communities and rural areas with a high proportion of outdoor work are expected to be disproportionately affected.

### 3.5.6 Shellfish Beds Vital Sign

#### *Vital Sign Attributes and Current Status*

The Shellfish Beds Vital Sign has one indicator: Acres of Harvestable Shellfish Beds. To assess climate change impacts on shellfish beds, workshop participants evaluated the following attributes and desired future conditions for this Vital Sign:

- Fecal coliform bacteria
- Salinity
- Temperature

According to the Puget Sound Partnership's progress summary for the Shellfish Beds Vital Sign, the Acres of Harvestable Shellfish Beds Indicator is "Getting Better." The shellfish growing areas in Puget Sound cover roughly 225,000 acres. About 84% (188,000 acres) of the shellfish growing areas are suitable for

harvest. Because there was an overall increase in cumulative net area of harvestable shellfish beds since 2007, including from the prohibited category, the indicator is making progress toward the 2020 target.<sup>48</sup>

*Assessment Findings*

Risk		Rating	Confidence
High	<i>Likelihood of Impact</i>	High	High
	<i>Consequence</i>	High	High

Workshop participants rated this Vital Sign as high risk for the following reasons. The suitability for harvest of some shellfish beds is expected to decrease due to increased water temperatures, the potential for more fecal coliform bacteria, increased harmful algal blooms and vibrio, and ocean acidification. Increased extreme precipitation is expected to cause more fecal loading and more combined sewer overflow events. Harmful algal blooms are expected to increase in frequency and severity due to warmer water temperatures. Ocean acidification may increase the toxicity of some harmful algal blooms and affected shellfish. These effects are expected to lead to an increased frequency of shellfish bed closures and increased harm to human health.

### 3.6 HUMAN QUALITY OF LIFE GOAL

The Healthy Quality of Life Goal was established by the legislature as:

- **Human Quality of Life Goal:** A quality of human life that is sustained by a functioning Puget Sound ecosystem. (RCW 90.71.300)

This goal has five Vital Signs (in bold) and ten associated indicators:

- **Cultural Wellbeing:** Participation in Cultural Practices
- **Economic Vitality:** Natural Resource Industry Output (Gross Domestic Product, GDP); Percent of GDP in Natural Resource-Based Industries to Total GDP; Employment in Natural Resource Industries
- **Good Governance:** Good Governance Index: (1) Opportunity to influence decisions; (2) Freedom to make decisions; (3) Trust in local and regional government; (4) Representation in community and government leaders; (5) Access to information
- **Sense of Place:** Sense of Place Index (1a. Positive connections to region; 1b. Sense of stewardship for watershed; 1c. Pride of place for Puget Sound); Psychological Wellbeing Index (2a. Inspiration; 2b. Stress reduction); Overall Life Satisfaction
- **Sound Stewardship:** Engagement in Stewardship Activities; Sound Behavior Index

#### 3.6.1 Cultural Wellbeing Vital Sign

*Vital Sign Attributes and Current Status*

The Cultural Wellbeing Vital Sign has one indicator: Participation in Cultural Practices. To assess climate change impacts on cultural wellbeing, call participants evaluated the following attributes and desired future conditions for this Vital Sign:

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<sup>48</sup> [http://www.psp.wa.gov/vitalsigns/shellfish\\_beds\\_reopened\\_indicator1.php](http://www.psp.wa.gov/vitalsigns/shellfish_beds_reopened_indicator1.php). Accessed June 14, 2017.

- The extent to which people feel able to maintain their cultural traditions. This includes all cultural practices and traditions related to people’s engagement with the natural environment for recreational or livelihood purposes.
- Puget Sound residents’ perception of their ability to engage in cultural practices as a result of either natural resource quality or management restrictions. This includes tribal cultural practices related to the use, celebration, and stewardship of natural resources. It also includes non-tribal participation in practices associated with natural resource industries, such as agriculture, timber harvest, fishing and aquaculture; and to individual participation in cultural practices associated with nature-based outdoor recreation.

According to the Puget Sound Partnership’s progress summary for the Cultural Wellbeing Vital Sign, the Participation in Cultural Practices Indicator states that “no data are available for this indicator.”<sup>49</sup>

*Assessment Findings*

<b>Risk</b>		<b>Rating</b>	<b>Confidence</b>
<b>Not Rated</b>	<i>Likelihood of Impact</i>	High	High
	<i>Consequence</i>	Not Rated	Not Rated

As a preface to this discussion, call participants emphasized that they were not tribal members and they do not speak for tribes. They provided information for this assessment from their personal experience.

Call participants did not rate the consequences of climate change impacts on the Vital Sign and thus there is no risk rating for this Vital Sign. Call participants rated the likelihood of impact for this Vital Sign as high for the following reasons. There are a wide range of cultural practices, both tribal and non-tribal, and a wide range of ways that climate change can impact them. Examples of cultural practices potentially affected by climate change include fishing, foraging, first foods, canoe journeys, traditional medicines, community health, and cultural gatherings (e.g., if road washouts prevent access to powwows or important ceremonial sites). Tribes are likely to be disproportionately impacted because reservation boundaries and Usual and Accustomed areas don’t move with changing climate conditions. At a broad level, there is a high likelihood that climate change will have negative impacts on at least some aspects of cultural wellbeing. However, culture is not static and cultures tend to be resilient. Information was insufficient to assess consequences.

**3.6.2 Economic Vitality Vital Sign**

*Vital Sign Attributes and Current Status*

The Economic Vitality Vital Sign has three indicators: (1) Natural Resource Industry Output, (2) Percent of GDP in Natural Resource-Based Industries to Total GDP, and (3) Employment in Natural Resource Industries. To assess climate change impacts on economic vitality, call participants evaluated the following attributes and desired future conditions for this Vital Sign:

- How well natural resource-based industries are doing economically over time, as well as compared to non-natural resource-based industries. This includes natural resource-based

<sup>49</sup> [http://www.psp.wa.gov/vitalsigns/cultural\\_practices\\_indicator1.php](http://www.psp.wa.gov/vitalsigns/cultural_practices_indicator1.php). Accessed June 14, 2017.

industries including fisheries (salmon, shrimp, crab, shellfish), shellfish and finfish aquaculture, timber, non-timber products, agriculture, mining, and tourism.

- Number of jobs supported by natural resource industries in Puget Sound.

According to the Puget Sound Partnership’s progress summary for the Economic Vitality Vital Sign, no data are currently available for any of the three indicators for this Vita Sign.<sup>50,51,52</sup>

*Assessment Findings*

Risk		Rating	Confidence
High	<i>Likelihood of Impact</i>	Medium to high	Medium to high
	<i>Consequence</i>	High	Medium to high

Call participants rated this Vital Sign as high risk for the following reasons. Climate change impacts are expected to negatively affect the economic base and job prospects for many natural resource-based industries including fisheries, shellfish and finfish aquaculture, timber, non-timber products, and snow-based recreation tourism. Net economic impact to agriculture, mining and the overall tourism industry is expected to be minimal.

The timber industry has a high likelihood of being negatively affected by increased fire, insects and disease. The shellfish industry has a high likelihood of impact due to ocean acidification, harmful algal blooms and other impacts. Commercial and recreational fishing have a high likelihood of impact due to expected reductions in currently harvested species. Other species are expected to enter the system and thus the net economic impact will be influenced by the marketability of those species.

The overall tourism industry is likely to experience a positive impact due to warmer temperatures during the shoulder seasons. However, snow-based recreation has a high likelihood of being negatively impacted due to higher temperatures and reduced snowpack.

Agriculture could benefit from longer growing seasons and higher CO<sub>2</sub>, but could also be negatively impacted by increased winter flooding and reduced summer water supply. New agricultural products could have positive or negative economic effects depending on the value of the product. For example, a shift to wine grape production could generate higher revenue per acre than many current crops.

Overall economic vitality is likely to benefit due to population increase and development. As a result, the consequences to the overall economy are not likely to be significant. However, consequences could be large for specific sectors and for the natural resource economy generally. The consequences will depend on the ability of specific sectors to respond.

### 3.6.3 Good Governance Vital Sign

*Vital Sign Attributes and Current Status*

The Good Governance Vital Sign is measured by the Good Governance Index which tracks (1) Opportunity to influence decisions; (2) Freedom to make decisions; (3) Trust in local and regional

<sup>50</sup> [http://www.psp.wa.gov/vitalsigns/economic\\_vitality\\_indicator1.php](http://www.psp.wa.gov/vitalsigns/economic_vitality_indicator1.php). Accessed June 14, 2017.

<sup>51</sup> [http://www.psp.wa.gov/vitalsigns/economic\\_vitality\\_indicator2.php](http://www.psp.wa.gov/vitalsigns/economic_vitality_indicator2.php). Accessed June 14, 2017.

<sup>52</sup> [http://www.psp.wa.gov/vitalsigns/economic\\_vitality\\_indicator3.php](http://www.psp.wa.gov/vitalsigns/economic_vitality_indicator3.php). Accessed June 14, 2017.

government; (4) Representation in community and government leaders; (5) Access to information. To assess climate change impacts on good governance, call participants evaluated the following attributes and desired future conditions for this Vital Sign:

- The health of our management process and the degree to which we are effectively engaging the Puget Sound community in the recovery effort.
- Governance structures and processes related to natural resource protection, restoration and management.
- How Puget Sound residents perceive the way decisions are made regarding management and use of the natural environment.

According to the Puget Sound Partnership’s progress summary for the Good Governance Vital Sign, no data are available for the Good Governance Index indicator.<sup>53</sup>

### Assessment Findings

Risk		Rating	Confidence
Moderate	<i>Likelihood of Impact</i>	Low to Medium	Medium
	<i>Consequence</i>	Medium	Medium

Call participants rated this Vital Sign as moderate risk for the following reasons. Climate change impacts such as fire, floods, landslides, or loss of drinking water could cause large social and economic dislocations that could undermine trust in government. Climate change impacts such as sea level rise, fire, and reduced water supply could lead to increased regulations that restrict actions on private property (e.g., coastal development or access to water) and may compromise citizens’ sense of freedom to make decisions. However, if citizens believe that government is responding appropriately, trust could be enhanced.

### 3.6.4 Sense of Place Vital Sign

#### *Vital Sign Attributes and Current Status*

The Sense of Place Vital Sign has three indicators: (1) The Sense of Place Index (1a. Positive connections to region; 1b. Sense of stewardship for watershed; 1c. Pride of place for Puget Sound); (2) The Psychological Wellbeing Index (2a. Inspiration; 2b. Stress reduction); and (3) Overall Life Satisfaction. To assess climate change impacts on sense of place, call participants evaluated the following attributes and desired future conditions for this Vital Sign:

- The extent to which people identify with and feel positively attached to Puget Sound.
- Peoples’ emotional connection to Puget Sound.
- Whether Puget Sound residents experience inspiration and stress reduction while in nature.
- How trends in environmental health or recovery efforts are affecting overall human wellbeing.

According to the Puget Sound Partnership’s progress summary for the Sense of Place Vital Sign, no data are currently available for any of the three indicators for this Vita Sign.<sup>54, 55, 56</sup>

<sup>53</sup> [http://www.psp.wa.gov/vitalsigns/good\\_governance\\_indicator1.php](http://www.psp.wa.gov/vitalsigns/good_governance_indicator1.php). Accessed June 14, 2017.

<sup>54</sup> [http://www.psp.wa.gov/vitalsigns/sense\\_of\\_place\\_indicator1.php](http://www.psp.wa.gov/vitalsigns/sense_of_place_indicator1.php). Accessed June 14, 2017.

<sup>55</sup> [http://www.psp.wa.gov/vitalsigns/sense\\_of\\_place\\_indicator2.php](http://www.psp.wa.gov/vitalsigns/sense_of_place_indicator2.php). Accessed June 14, 2017.

<sup>56</sup> [http://www.psp.wa.gov/vitalsigns/sense\\_of\\_place\\_indicator3.php](http://www.psp.wa.gov/vitalsigns/sense_of_place_indicator3.php). Accessed June 14, 2017.

*Assessment Findings*

Risk		Rating	Confidence
High	<i>Likelihood of Impact</i>	Medium to High	Medium
	<i>Consequence</i>	Medium to High	Medium to High

Call participants rated this Vital Sign as high risk for the following reasons. Climate change impacts are likely to negatively affect trends in environmental health and ecosystem degradation could negatively impact people’s stress levels. More specifically, people’s emotional connection to natural resources could be diminished due to a sense of reduced ecological integrity and reduced access to valued places or activities. Impacts on a person’s sense of attachment to Puget Sound and its natural resources will vary depending on preferences. For example, large-scale fires could burn highly valued forest areas while ocean acidification and harmful algal blooms could reduce or eliminate recreational shellfish harvest. For those whose attachment is primarily based on the aesthetic beauty of Puget Sound, well-being may not be significantly affected. Some communities, especially tribes, are likely to be disproportionately impacted.

**3.6.5 Sound Stewardship Vital Sign**

*Vital Sign Attributes and Current Status*

The Sound Stewardship Vital Sign has two indicators: (1) Engagement in Stewardship Activities, and (2) Sound Behavior Index. To assess climate change impacts on sound stewardship, call participants evaluated the following attributes and desired future conditions for this Vital Sign:

- The effectiveness of our management actions related to human behaviors that can affect the health of Puget Sound.
- The degree to which engagement in stewardship contributes to people’s wellbeing.
- Activities and behaviors that positively and negatively affect the quality or extent of the Puget Sound natural environment.
- The extent to which Puget Sound residents engage in collective environmental stewardship activities.
- Long-term shifts in priority behaviors and practices that affect environmental quality.

According to the Puget Sound Partnership’s progress summary for the Sound Stewardship Vital Sign, progress on the Sound Behavior Index is mixed. Results from three surveys so far show that about half (11) of the behaviors improved slightly, about half (10) declined and a few (7) did not change. When combined into an index score, results indicate very little change over time.<sup>57</sup> No data are currently available for the Engagement in Stewardship Activities indicator.<sup>58</sup>

*Assessment Findings*

Risk		Rating	Confidence
Not Rated	<i>Likelihood of Impact</i>	Low	Medium
	<i>Consequence</i>	Not rated	Not rated

Call participants did not rate the consequences of climate change impacts on the Vital Sign and thus there is no risk rating for this Vital Sign. Call participants rated the likelihood of impact for this Vital Sign

<sup>57</sup> [http://www.psp.wa.gov/vitalsigns/sound\\_behavior\\_index\\_indicator1.php](http://www.psp.wa.gov/vitalsigns/sound_behavior_index_indicator1.php). Accessed June 25, 2017.

<sup>58</sup> [http://www.psp.wa.gov/vitalsigns/sound\\_behavior\\_index\\_indicator2.php](http://www.psp.wa.gov/vitalsigns/sound_behavior_index_indicator2.php). Accessed June 25, 2017.



as low for the following reasons. People's responses toward stewardship appear to depend on how they perceive the threat and the degree to which they believe that action can be meaningful. If people believe that climate change is responsible for negative consequences and there is value in taking action, climate change may enhance engagement in stewardship. Factors that foster a sense of stewardship appear to include regular activity with the resource and generational connectivity to the place or resource. There is a possibility that engagement in stewardship might actually be enhanced by climate change concerns because they may spur discussion and heighten the sense of responsibility to take action. However, if the ability to influence conditions appears futile, engagement is likely to decline.

## 4 SUMMARY AND CONCLUSIONS

As described previously, the central question for this assessment is: How will changing climate and ocean conditions projected for the 2050s affect the Partnership’s ability to achieve Puget Sound recovery goals?

The results of the assessment indicate that each of the Partnership’s six goals is threatened by climate change impacts and that 19 of 25 Vital Signs are at high risk. Three Vital Signs are at moderate risk and three are at low risk (Figure 3). For those Vital Signs at high or moderate risk, climate change impacts projected for 2050 are expected to make achieving or maintaining recovery goals more difficult.

**Figure 3: Vital Sign Risk Ranking**

Goal	Vital Sign Risk Ranking		
	High Risk	Moderate Risk	Low Risk
<b>Water quantity</b>	Summer stream flows		
<b>Water quality</b>	Freshwater quality Marine water quality Marine sediment quality	Toxics in fish	
<b>Protect and restore habitat</b>	Floodplains Estuaries Shoreline armoring		Eelgrass Land development and cover
<b>Species and food web</b>	Chinook salmon Orca Pacific herring	Birds	
<b>Healthy human population</b>	Air quality Drinking water Locally harvestable foods Onsite sewage systems Outdoor activity Shellfish beds		
<b>Human quality of life</b>	Cultural wellbeing Economic vitality Sense of place	Good governance	Sound stewardship

The results of the assessment reveal the inter-related effects of climate change on the Vital Signs. For example, higher air temperatures and a longer summer dry season are expected to reduce summer stream flows (the Vital Sign for the Water Quantity Goal). These effects, combined with other climate change impacts, are expected to negatively affect freshwater quality, marine water quality, floodplains, and estuaries (Vital Signs for the Water Quality and Protect and Restore Habitat Goals). Those changes, in turn, are expected to negatively affect Chinook salmon, Pacific herring, drinking water and other Vital Signs under the Species and Food Web Goal and the Healthy Human Population Goal. Similarly, increased water temperature in estuaries is expected to negatively affect Chinook salmon health and abundance, which is then expected to negatively affect the orca, locally harvestable foods, outdoor activity, cultural wellbeing, economic vitality, and sense of place Vital Signs.

Similar linkages can be drawn between other climate impacts and Vital Signs, often connecting physical climate changes to negative consequences for ecological, biological and ultimately human systems. While many Vital Signs are rated as high risk, these results reflect their inter-related connection to one another and the consistent influence of specific physical climate drivers.

The results of the assessment also underscore the potential for climate change to exacerbate current stressors. One workshop participant noted that “Ocean acidification makes a bad day worse.” In many cases, this is true for climate change impacts in general. Healthy, well-functioning systems are more likely to withstand temporary perturbations. However, systems that are stressed or poorly functioning are more likely to be negatively affected by climate change impacts. For example, well-functioning floodplain systems located in watersheds with low imperviousness are likely to be more resilient to climate change impacts than compromised systems in urban watersheds. For marine water quality, ocean acidification is expected to exacerbate the negative consequences of existing stressors and natural variability on marine organisms. For many of the 2020 targets that are not currently being met, climate change impacts are expected to increase the difficulty of achieving them.

In addition to ratings for likelihood and consequence, participants rated the confidence in those ratings (low, medium and high). In Figure 4, Vital Signs are categorized by their risk ranking and participants’ ratings for confidence in the consequence rating.<sup>59</sup> The results reveal that participants have high confidence in the consequence rating for five high-risk Vital Signs (upper right corner), medium confidence in the consequence rating for twelve high-risk Vital Signs (upper middle box), and low confidence in the consequence rating for one high-risk Vital Sign (upper left corner). Vital Signs ranked moderate and low risk also have varying degrees of confidence in the consequence rating. Two Vital Signs (cultural wellbeing and sound stewardship) did not receive a confidence rating for consequence and so are not included in the matrix.

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<sup>59</sup> A confidence rating was made for likelihood and consequence, but not for risk. Thus, the risk ranking does not have its own confidence rating. In this matrix, the risk ranking is displayed on the vertical axis and was chosen because it encompasses both likelihood and consequence and reflects the degree of threat to recovery goals. The horizontal axis displays the confidence in consequence rating and was chosen because it reflects workshop and call participants’ level of certainty with regard to the degree of harm that may result if climate change impacts occur.

**Figure 4: Confidence Rating for Consequence Compared with Risk Ranking<sup>60</sup>**

Risk Rating of Vital Sign	<b>High</b>	Marine Sediment Quality	Summer Stream Flows Freshwater Quality Floodplains Estuaries Pacific Herring Air Quality Drinking Water Locally Harvestable Foods Onsite Sewage Systems Outdoor Activity Economic Vitality Sense Of Place	Marine Water Quality Shoreline Armoring Chinook Salmon Orcas Shellfish Beds
	<b>Moderate</b>	Birds	Good Governance	Toxics in Fish
	<b>Low</b>	Eelgrass	Land Development and Cover	
		Low	Medium	High
Confidence in Consequence Rating for Vital Sign				

Vital signs ranked as high risk and with high confidence (upper right corner of Figure 4) are those for which confidence is high that climate change impacts will have negative consequences for ecosystem recovery by 2050. Vital Signs in this category are likely to warrant priority for developing adaptation actions to address climate risks.

Vital Signs ranked as high risk but with medium or low confidence (upper center and left) are those for which climate change impacts are expected to have negative consequences for ecosystem recovery, but information gaps exists. The uncertainties may deserve investigation to determine whether sufficient information exists to take action or whether additional information gathering is necessary.

Vital Signs ranked moderate or low risk should be evaluated on a case by case basis. Vital Signs that were not rated require further investigation.

<sup>60</sup> Note that two Vital Signs (Cultural Wellbeing and Sound Stewardship) were not given confidence ratings by participants and thus are not included in this matrix.

## 5 NEXT STEPS

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The intent of this assessment is to support climate adaptation planning, identify gaps in knowledge related to climate change impacts, and to identify opportunities for further refining climate risk assessment for Puget Sound. As a preliminary assessment of climate change impacts, this report provides an initial sorting of Vital Signs into low, medium and high risk and it provides insights into the likelihood of climate change impacts and the consequences if they occur. However, this assessment is only a first step in a continuing process of learning, evaluating, and most importantly, responding to climate change threats. As the Puget Sound Partnership continues to lead the region's collective effort to restore and protect Puget Sound, the authors of this assessment recommend an integrated approach of promoting climate adaptive strategies, supporting research to fill gaps in knowledge, and continuing to assess climate-related risks to restoration and protection goals. In addition, this assessment identified Vital Signs, indicators and targets that were defined without consideration of climate change impacts; redefining these to include climate change considerations would help ensure that the Partnership is tracking relevant changes affecting its goals.

### 5.1 PROMOTE CLIMATE-ADAPTIVE STRATEGIES AND ACTIONS

The assessment results identify significant climate related risks to ecosystem recovery and long-term protection. Each goal and Vital Sign is likely to be negatively affected by climate change impacts in some way, though the pathways and degree of risk vary. During the assessment process, many participants expressed a sense of urgency for the Partnership to develop responses to these climate change threats. As the Partnership updates the Action Agenda and supports strategic initiatives and near term actions, these efforts should include strategies and actions for reducing the likelihood and consequences of climate change impacts.

The assessment illustrates that some Vital Signs are at greater risk than others and that the degree of certainty in existing knowledge regarding climate change impacts varies. To determine which Vital Signs might be prioritized for climate-adaptive strategy development, candidates include those Vital Signs rated as high risk and ranked medium to high confidence in the consequence. The results of the assessment indicate that 17 of 25 Vital Signs are at high risk from climate change impacts and have a medium or high confidence in the consequences (Figure 4). For these 17 Vital Signs, there is likely sufficient confidence in current information to begin developing climate adaptive strategies and actions.

In many cases, climate change impacts and consequences are location specific and are influenced by the unique interactions of climate change effects on the local system. This preliminary assessment identified some of those interactions, but in many cases additional evaluation is warranted. Strategies and actions that are tailored to the specific climate change impacts and locations are more likely to be effective.

Finally, Partnership staff and partners would benefit from support and guidance on how to develop climate-adaptive strategies and actions and how to apply the information contained in this assessment. Climate change adaptation is a relatively young field of practice and few people have training or experience to effectively address the range of climate change-related challenges. Building capacity among the Partnership's staff and partners to address climate change impacts is likely to be a wise investment.

## 5.2 SUPPORT RESEARCH TO FILL INFORMATION GAPS

The assessment also revealed a range of information gaps that influenced the level of confidence in impact and consequence ratings for many of the Vital Signs. Thirteen Vital Signs were rated as high risk but with low or medium confidence in the consequences (Figure 4). For some of these Vital Signs, specific information gaps are identified that could be filled. For others, location specific effects vary widely and additional general information is unlikely to increase confidence. Where additional information or research would inform development of strategies and actions, the Partnership is encouraged to support those information gathering efforts.

## 5.3 CONTINUE TO ASSESS CLIMATE-RELATED RISKS

This assessment was designed to be an initial step in assessing and responding to climate change risks. Climate change is likely to be a “forever problem” for the Partnership, and climate change knowledge will continue to evolve. While this assessment provides a useful platform for developing strategies and actions and designing research to fill information gaps, it is only a first step. As climate science advances and our understanding of climate change impacts on biological, ecological and human systems improves, the Partnership is encouraged to periodically reassess the likelihood of climate change impacts and potential consequences on its targets, indicators, Vital Signs and goals for ecosystem recovery. Periodic reassessments should be focused on enhancing the effectiveness of strategies and actions that address climate change risks.

## 5.4 INCORPORATE CLIMATE CHANGE CONSIDERATIONS IN VITAL SIGNS, INDICATORS AND TARGETS

During the assessment, participants identified opportunities to improve the Vital Signs, indicators and targets. While improving the metrics was not the focus of this assessment, consideration of climate change impacts on the Vital Signs naturally led to evaluation of the Vital Signs themselves. Participants noted that in some cases Vital Signs could be modified or better defined, others have multiple indicators that measure the same attributes, and others have indicators that are incomplete measures of the topic. Some participants suggested that Vital Signs and indicators would be more precise if they clearly focused on specific attributes. While these topics were outside the scope of this report, Partnership staff made note of these opportunities for future consideration.

Assessment participants also noted that in nearly every case, the Vital Signs, indicators and targets lack explicit consideration of climate change impacts. While not every Vital Sign necessarily warrants an explicit climate change treatment, some Vital Sign metrics may benefit from incorporating climate change considerations to more accurately reflect the stressors, attributes and desired future conditions. This assessment provides an indication of the ways that climate change is expected to affect Vital Signs and restoration goals. As Puget Sound Partnership reconsiders its goals and metrics for post-2020 work, incorporating climate change considerations would provide a more robust set of tools to measure trends and outcomes.

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## APPENDIX 1: Climate Assessment Questions

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Vital Sign: \_\_\_\_\_

1. What is the **likelihood** that climate change will negatively affect the Vital Sign by 2050? Please explain why.
  - Low: Unlikely to negatively affect the Vital Sign by 2050.
  - Medium: May negatively affect the Vital Sign by 2050.
  - High: Expected to negatively affect the Vital Sign by 2050.
2. Rate your **Confidence** of this ranking. Criteria include strength and consistency of the observed evidence; the consistency of model projections; and insights from peer-reviewed sources.<sup>61</sup>
  - Low
  - Medium
  - High
3. Assuming climate impacts occur at the magnitude projected for 2050, what is the **Consequence** to our ability to achieve the desired future conditions associated with the Vital Sign?
  - Low: Would have minimal effects on our ability to achieve the desired future condition(s) for this Vital Sign.
  - Medium: Would have moderate effects on our ability to achieve the desired future condition(s) for this Vital Sign.
  - High: Would significantly impede our ability to achieve the desired future condition(s) for this Vital Sign.
4. Rate your **Confidence** of this ranking. Criteria include strength and consistency of the observed evidence; the consistency of model projections; and insights from peer-reviewed sources.
  - Low
  - Medium
  - High
5. Are there **geographic or other distinctions** that deserve special attention?
6. What **additional information** would help us make better decisions?

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<sup>61</sup> Source: Melillo et al. 2014.