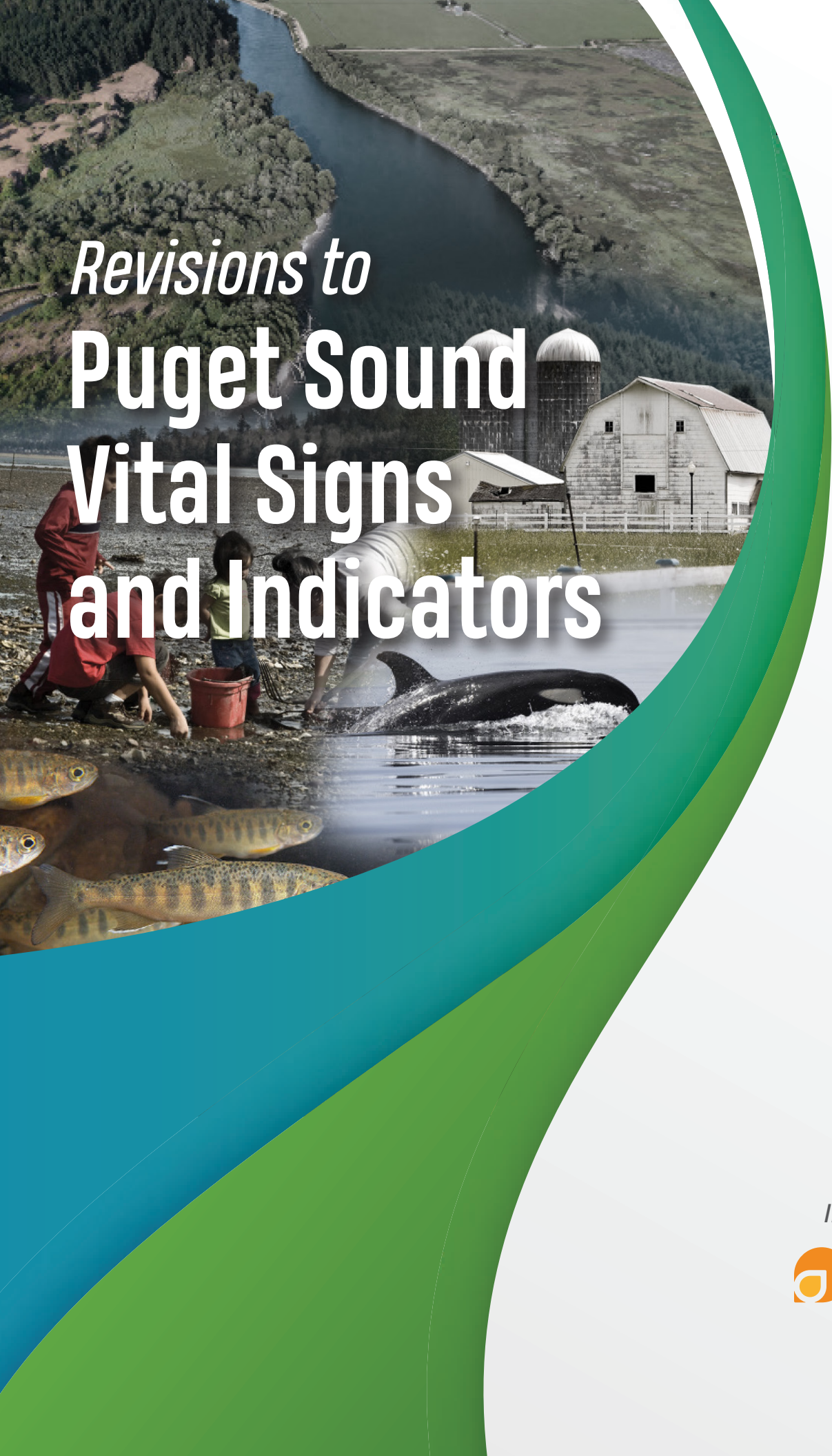




Revisions to **Puget Sound Vital Signs and Indicators**

Prepared by

ROSS
STRATEGIC

In collaboration with

 **PUGET SOUND**
PARTNERSHIP

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Contents

Key Terms.....	2
Summary.....	4
1. Background	8
2. Methods: Relying on Previous Studies and Analyses and Emphasizing Development of Shared Measures.....	14
3. Results: Revisions to Vital Signs and Indicators	23
4. Moving Forward and Additional Work Needed	33
5. Conclusions.....	34
Appendix A: Phase 1 of the Vital Signs Revision Project.....	37
Appendix B: Summary of Phase 2 Engagement Process in Support of Development of Shared Measures.....	38
Appendix C: Vital Signs Conceptual Models	44
Appendix D: May 2020 Focus Group Insights on Naming Vital Signs.....	62
Appendix E: Fate of Existing Biophysical Vital Signs and Indicators	64
Appendix F: Revised Vital Signs, Indicators, and Potential Future Indicators	70
Appendix G: Mapping of Recommended Measures to Puget Sound KEAs.....	74
Appendix H: Ancillary Measures, Intermediate Progress Measures, and Activity Progress Measures Identified During the Revision Effort	86

Key Terms

Activity Progress Measures (APM) – A type of progress measure that measures whether priority recovery actions in the Action Agenda are moving forward as planned and whether they are achieving the outputs they are expected to accomplish. APM describe activity outputs (e.g. number of Best Management Practices installed) that the recovery community has identified as necessary to advance recovery priorities. These measures demonstrate activity contributions towards improvement of Intermediate Progress Measures and Vital Signs and inspire implementation of actions that contribute to recovery priorities. Unlike other progress measures which are reported by a single reporting lead, APM are reported as accomplishments by individual projects or programs and aggregated across all reporters. They are intended to replace and expand existing Action Agenda performance measures. Examples of questions related to APM include:

- *What do we expect projects to accomplish? Are projects accomplishing what we expect, within the expected timelines and budgets?*
- *Are Action Agenda priority action owners delivering the outputs they expected to accomplish, within the expected timelines and budgets?*
- *What do we need to do more of, less of, or differently, to improve Vital Sign conditions? Where do we see barriers to implementation or lack of progress?*

Ancillary measure – Information about ecosystem conditions, processes, and relationships that helps explain and interpret changes in Vital Sign indicator results. Ancillary measures place Vital Sign results in context. An example of an ancillary measure is reproductive success of birds, as an aid in interpreting the abundance of birds. These measures may include information that is not directly affected by management interventions in Puget Sound (e.g., snowpack).

Biophysical Vital Signs – Vital Signs related to the statutory goals for water quality, water quantity, habitats, and species and food web.

Chinook Salmon Habitat Common Indicators (CCI) – Metrics used to track and report local progress in salmon recovery in a way that can be rolled up at the regional level to evaluate implementation and effectiveness of the Puget Sound Chinook Salmon Recovery Plan.

Conceptual models – Diagrams that describe the functional relationship among components of an ecosystem. They represent the prevailing scientific understanding of the relational hypotheses, pathways of effect, evidence, and uncertainties related to physical, chemical, and biological factors controlling Vital Sign condition and affecting outcomes, in addition to the relationships between Vital Signs and indicators. They also contain the pressures and stressors that impact factors controlling Vital Sign condition. They are, essentially, a problem statement to connect the source of pressure through to impacts on specific Vital Sign indicators.

Human wellbeing Vital Signs – Vital Signs related to the statutory goals for healthy human populations and vibrant quality of life. The Vital Signs Revision process did not focus on these Vital Signs, with the exception of a revision to On Site Sewage Systems to reflect the role of Vital Signs in the Progress Measures Framework.

Intermediate Progress Measures (IPM) – A type of progress measure that measures mid-term (“intermediate”) outcomes identified by the Puget Sound recovery community that must be achieved to improve the Vital Signs, including:

- reduction of key stressors on the ecosystem (e.g. habitat conversion and toxic pollutants),
- changes in human activities that put stress on the ecosystem (e.g. urban sprawl), and
- changes in the institutional, social, and political conditions that foster or enable recovery progress (e.g. increased funding).

IPM represent the cumulative effects of priority recovery strategies and actions identified in the Action Agenda and measure progress toward achieving Action Agenda priority outcomes. IPM often measure the cumulative impacts of multiple projects or programs and they establish a common understanding of social and ecological drivers causing changes to Vital Signs.

Compared to Vital Sign indicators, these measures are more directly influenced by management interventions within Puget Sound. IPM answer the following types of science and management questions:

- *Are the negative effects of human activities (stressors) being reduced or mitigated?*
- *Are human activities that put stress on the ecosystem being managed?*
- *Have the institutional, social, and political conditions needed to improve Vital Signs been achieved?*
- *Are the cumulative results of multiple projects and programs sufficient to achieve our Vital Sign goals?*
- *What management actions need to be scaled, reduced, or changed to increase the likelihood that Vital Sign goals will be achieved?*

Potential future indicator – A Vital Signs measure that has been identified through this project as important to understand, but for which more development is required before implementation. Indicators not deemed ready for assessment and reporting by January 2022 are labelled as potential future indicators.

Progress Measures Framework – The Progress Measures Framework is a suite of measures that describes the collective progress toward achieving Puget Sound recovery and resilience. This framework (1) facilitates a common understanding of the primary factors, including human and natural drivers, that influence ecosystem conditions and (2) supports effective, timely adaptation of the recovery effort by combining evidence about ecosystem conditions, contributing factors, and management interventions.

Vital Signs and their indicators – The Vital Signs and their indicators are types of progress measures. They are the measures of “ultimate outcomes” that reflect the condition of the Puget Sound ecosystem, including human wellbeing, relative to the goals established in the Puget Sound Partnership statute. Vital Signs and their indicators have three uses:

- (1) describe ecosystem conditions;
- (2) help track progress towards recovery goals and objectives and understand if progress is being made and management actions are working; and
- (3) inspire focused action.

Taken together, Vital Signs and their indicators describe what ecosystem recovery should “look like” by describing what the Puget Sound recovery community wants to protect and restore. The Vital Signs measure parts of the ecosystem that the Puget Sound recovery community has determined are important to know about and diagnose. They articulate the six statutory goals for ecosystem recovery defined in the law that created the Puget Sound Partnership agency. Vital Signs and indicators answer the following types of science and management questions:

- *Is the condition of the Vital Sign improving or not? How certain are we?*
- *Are we meeting the goals for ecosystem recovery?*
- *Are we reaching a tipping point or some other trigger for more assertive actions?*

Assessment of Vital Sign indicators, along with information about implementation and effectiveness of programs and activities, can address management questions such as:

- *Are management interventions working as intended and achieving expected results?*
- *Are projects and programs contributing to outcomes as expected?*
- *What have we learned about the effectiveness of actions and programs? What actions and programs have demonstrated effectiveness? What actions and programs are less effective than anticipated? How might they be adapted?*

Summary

In 2019 and the first half of 2020, the Puget Sound Partnership (Partnership) undertook a collaborative effort to revise the Puget Sound Vital Signs and their indicators related to water quality, water quantity, habitats, and species and food web, the “biophysical” Vital Signs.

Vital Signs and their indicators articulate the six statutory ecosystem recovery goals for Puget Sound (RCW 90.71.300) by defining more specifically what recovery should “look like” and describing what the Puget Sound recovery community wants to protect and restore. The *Vital Signs* are specific ecosystem components and conditions such as habitat or species types. *Vital Sign indicators* are key attributes of each Vital Sign which, taken together, communicate the status and trend of the Vital Sign.

In the context of the [overall Progress Measures Framework for Puget Sound](#), the Vital Signs and indicators are the measures of ultimate outcomes for Puget Sound. They are used to:

- (1) describe ecosystem conditions;
- (2) articulate shared statutory recovery goals and understand progress toward goals; and
- (3) inspire focused action to drive progress towards meeting shared goals.

Vital Signs and their indicators are supported by related progress measures that track intermediate outcomes associated with changes to drivers and pressures that act on Vital Signs and indicators (Intermediate Progress Measures) and activity and project-scale outcomes (Activity Progress Measures).

The project to revise the biophysical Vital Signs and indicators in 2020 responds to longstanding concerns and critiques and incorporates scientific and institutional information learned over the past ten years of Vital Sign and indicator implementation. This revision effort relied extensively on the reports by the Washington State Academy of Sciences (WSAS) review panel (2012) and O’Neill and co-authors (2018) and on the insights of the scientists (“indicator leads”) who assess and report on Puget Sound Vital Sign indicators.

To identify revisions to the biophysical Vital Signs and indicators, the project relied mainly on expert judgment from science and policy experts from throughout the Puget Sound recovery community, along with recommendations from previous studies and analyses, and conceptual models. The revision process emphasized iterative work with the Puget Sound recovery community to develop shared measures for Puget Sound recovery and, thereby, a selection of Vital Signs and indicators that were supported by relevant scientific and policy experts.

The process resulted in 13 biophysical Vital Signs, which encompass most of the ecosystem components and attributes addressed in the existing portfolio of Vital Signs and indicators. Table S1 shows these 13 Vital Signs and the ten human wellbeing Vital Signs organized under the relevant ecosystem recovery goals.

- Six of the revised biophysical Vital Signs essentially continue existing Vital Signs: Birds, Estuaries, Freshwater, Marine Water, Orcas, and Toxics in Aquatic Life.
- Five of the revised Vital Signs reframe or expand existing Vital Signs:
 - » Two of these Vital Signs present the element more clearly as an ecosystem component instead of a pressure: Land Development and Cover becomes *Forests and Wetlands*; Shoreline Armoring becomes *Beaches and Marine Vegetation*
 - » Two of these Vital Signs expand the component to better cover recovery goals: Chinook Salmon becomes more broadly *Salmon*; Pacific Herring becomes more broadly *Forage Fish*
 - » One of these Vital Signs combines habitat measures in the freshwater domain: Floodplains and Summer Stream Flows become *Streams and Floodplains*
- » Two new Vital Signs encompass measures that are newly added as indicators: *Groundfish and Benthic Invertebrates* and *Zooplankton*.

Table S1: Revised Vital Signs organized by statutory ecosystem recovery goals.

				
GOAL	GOAL	GOAL	GOAL	GOAL
Healthy Water Quality	Protected and Restored Habitat/ Abundant Water	Thriving Species and Food Web	Vibrant Quality of Life	Healthy Human Populations
Freshwater	Beaches and Marine Vegetation	Birds	Cultural Wellbeing	Air Quality
Marine Water	Estuaries	Forage Fish	Economic Vitality	Drinking Water
Toxics in Aquatic Life	Forests and Wetlands	Groundfish & Benthic Invertebrates	Good Governance	Local Foods
	Streams and Floodplains	Orcas	Sense of Place	Outdoor Activity
		Salmon	Sound Stewardship	Shellfish Beds
		Zooplankton		

The revision process resulted in 34 indicators for the biophysical Vital Signs (Table S2). The vast majority of the indicators continue or reframe existing indicators or draw from either [Evolving the Portfolio of Indicators to Assess and Report on the Condition and Recovery of the Puget Sound Ecosystem: Moving from Theory to Practice, O'Neill et al. \(2018\)](#) or from the [Chinook Salmon Habitat Common Indicators \(2019\)](#). Most of the selected indicators were recommended in more than one document.

The process identified an additional 19 measures for future consideration (“potential future indicators”). Potential future indicators fill important gaps, add depth to the portfolio, or provide a more robust measure for an existing indicator. However, the measures are not sufficiently developed. They are important to consider for the future but are not likely to be ready when reporting on the revised Vital Signs and indicators, which is expected to begin in January 2022. Two of the potential future indicators related to salmon harvest and the extent and frequency of drought emergencies are recommended as measures of human wellbeing. Table S2 lists indicators and potential future indicators for each revised Vital Sign organized under the relevant statutory recovery goals.

The Puget Sound Partnership Science Panel, the science advisory body of the Partnership, and scientists and practitioners from the Puget Sound recovery community reviewed an April 2020 draft of this report. The project team considered reviewers’ input in developing recommendations on Vital Sign and indicator revisions for the Puget Sound Partnership Leadership Council, and in finalizing this report. The Leadership Council considered recommendations for Vital Sign and indicator revisions at their June 2020 meeting and selected the Vital Signs and indicators presented in Tables S1 and S2.

Work will be needed to further develop the new Vital Sign indicators, to transition from the existing to the revised Vital Signs and indicators, and to fully realize the uses of the Vital Signs that were confirmed in this project. This work includes the following:

- Engage Puget Sound Ecosystem Monitoring Program (PSEMP) partners in developing expectations and necessary agreements with the Partnership for monitoring and reporting the revised Vital Signs and indicators. Identify indicator leads where needed. As the Partnership steps into conversations with partners, the agency should recognize that individual monitoring efforts are often embedded in a complex suite of ongoing programs. Supporting the agencies and organizations that lead those programs and helping them achieve their goals is central to attaining the monitoring and reporting goals for the Vital Signs.

- Work with PSEMP work groups and partners to identify data gaps. Document resources and capacity needed to monitor and report on the full suite of measures.
- Advocate for the necessary resources and capacity that PSEMP partners will need to continue monitoring and reporting of Vital Signs and indicators. In order to make a compelling argument for additional resources, the monitoring and reporting activities should be aligned with and central to an organization's mission.
- Develop monitoring and reporting protocols where needed, in collaboration with PSEMP work group and partners. The protocols could address issues such as baselines, space and time scales of reporting, reporting frequencies, and methods for evaluating status, trends and progress that are ideally consistent across indicators.
- Set targets for progress measures.
- Manage changes in Puget Sound Info and reflect the revisions in a new Vital Sign wheel.
- Incorporate the revisions into the development of the Action Agenda and associated Intermediate Progress Measures.
- Give attention to ancillary measures and the role they play in helping to understand changes in condition of Vital Signs and indicators. Ensure adequate resources for their monitoring.
- Develop potential future indicators as appropriate.
- Synthesize results from indicator reports and broader monitoring findings into meaningful information for science-based decision making and management. As a first step, develop synthesis methods to roll up indicators to tell a story about an affiliated Vital Sign and confidently answer science and management questions about how the Puget Sound ecosystem is doing and where more work is needed.
- Connect the Vital Signs and indicators with the Puget Sound Partnership Science Panel work on alternative future scenario analysis, to use Vital Signs and indicators to help communicate the future we wish to strive for.
- Apply an equity lens to indicators.

Table S2: Revised Puget Sound Indicators and potential future indicators¹

GOAL : Healthy Water Quality	GOAL : Protected and Restored Habitat/ Abundant Water	GOAL : Thriving Species and Food Web
Freshwater	Beaches and Marine Vegetation	Birds
Freshwater Benthic Index of Biotic Integrity (B-IBI)	Eelgrass Area	Abundance of marine bird populations
Water temperature in streams and rivers	Extent of forest cover in nearshore marine riparian areas*	Abundance of terrestrial bird populations
Nutrient concentration in streams and rivers	Floating kelp canopy area	Estuarine birds
Marine Water	Percent of feeder bluffs in functional condition*	Forage Fish
Dissolved oxygen in marine waters	Short and long-term eelgrass site status	Biomass of spawning Pacific herring
Marine Benthic Index	Drift cells in functional condition	Regional index of the stock presence and health of forage fish such as Sand Lance, Surf Smelt, and Anchovy
Marine water temperature	Miles of intertidal beach in functional condition	Groundfish and Benthic Invertebrates
Nutrient balance in marine water	Understory kelp abundance and condition	Abundance and biomass of benthic marine invertebrates
Ocean acidification	Estuaries	Abundance and biomass of groundfish
Sediment Chemistry Index	Percent of estuaries habitat area in functional condition*	Orcas
Marine Benthic Index, phase 2	Number of accessible pocket estuaries and embayments	Number of Southern Resident killer whales
Noise in marine water	Forests and Wetlands	Occupancy/residency of orcas in Puget Sound
Primary production in marine water	Extent of forest cover in the upper, middle, and lower areas of watersheds	Salmon
Toxics in Aquatic Life	Forest condition	Number of natural origin Chinook salmon on spawning grounds
Contaminants in adult salmon	Wetlands extent and condition	Number of natural-origin Coho salmon on spawning grounds
Contaminants in English sole	Streams and Floodplains	Number of natural-origin Puget Sound Steelhead on spawning grounds
Contaminants in juvenile salmon	Floodplain function in large and small river systems*	Number of natural-origin Summer Chum salmon on spawning grounds
Contaminants in Pacific herring	Summer low flows in streams and rivers	Zooplankton
Contaminants in caged mussels	Changes in hydrologic regime in streams and rivers	Average zooplankton biomass
	Extent of forest cover in freshwater riparian zones*	Integrated annual zooplankton biomass
	Frequency of flood events	Zooplankton index

GOAL : Vibrant Quality of Life	GOAL : Healthy Human Populations
Cultural Wellbeing	Air Quality
Participation in cultural practices	Exposure to impaired air quality
Economic Vitality	Drinking Water
Employment in natural resource industries	Index of Vulnerability for Elevated Nitrates in Groundwater
Natural resource industry output	Nitrate concentration in source water
Percent of employment in natural resource industries	Local Foods
Good Governance	Bivalve harvester-days
Good Governance Index	Locally harvestable foods
Sense of Place	Recreational Dungeness crab catch
Overall life satisfaction	Outdoor Activity
Psychological Wellbeing Index	Condition of swimming beaches
Sense of Place Index	Nature-based recreation
Sound Stewardship	Nature-based work
Engagement in stewardship activities	Shellfish Beds
Sound Behavior Index	Area of harvestable shellfish beds

Bold black text = Vital Sign
Black text = existing

Blue text = new indicator
Italics = potential future indicator

* Chinook Common Indicator

¹Two additional potential future indicators related to salmon harvest and drought emergency extent and frequency were recommended as measures of human wellbeing.

1. Background

Ecosystems such as the Puget Sound estuary and watersheds are complex socio-ecological systems. They require careful study to develop the scientific understandings that inform efforts to manage human activities over time. No single study or indicator captures the form, function, and processes that shape ecosystems. Instead, scientists and managers must work together to identify, assess, and report on an array of measures to manage and improve recovery actions over time ([Conservation Measures Partnership 2020](#)).

The Puget Sound Partnership is a Washington State agency and a backbone organization that supports the Puget Sound recovery effort. A backbone organization supports a wide range of groups to work together to achieve common goals. As a backbone organization, the Partnership is committed to continued learning and improvement of the agency's work, the work of its partners, and the Puget Sound recovery effort. One of the Partnership's key backbone roles is maintaining the shared measurement and monitoring infrastructure that enables learning and constant improvement. The Partnership maintains the infrastructure for reporting data and ensuring progress and accountability. This information contributes to the evaluation of effectiveness of actions, so that priorities are adjusted as appropriate in response to continued learning.

As a participant in EPA's National Estuary Program (NEP), the Partnership is required to report on the condition of the Puget Sound ecosystem (EPA, 2015). The need for a way to understand ecosystem conditions and report on progress is also addressed in the Washington State statute that authorizes the Partnership, where RCW 90.71.210 specifies that the Puget Sound Partnership Science Panel, the science advisory body of the Partnership, "shall identify environmental indicators measuring the health of Puget Sound, and recommend environmental benchmarks that need to be achieved to meet the goals of the Action Agenda." The ecosystem measures required by EPA and state statute have come to be known as the Puget Sound Vital Signs and their indicators.

Work on measures of Puget Sound health dates back to the 1990s when the Puget Sound Action Team assessed and reported on indicators in reports called "Puget Sound's Health." Indicators were carried through over time thanks to long-term monitoring programs – mostly at state agencies – that persisted over time through changes in institutional arrangements. The Partnership's adoption of indicators in 2010 built on this work and contributions from the [Puget Sound Nearshore Ecosystem Restoration Program and Puget Sound Science Review](#).

The existing portfolio of Puget Sound Vital Signs and their indicators are organized to articulate the six goals for Puget Sound recovery described in the Partnership's statute (See RCW 90.71.300 and Box 1). Four statutory goals address water quality, water abundance, habitats, and species and food web (the "biophysical" part of the system), and two address human health and quality of life (the "human wellbeing" part of the system).

The Puget Sound Partnership Leadership Council initially adopted Vital Signs and indicators in 2010 and 2011 based on recommendations in the [Executive Dashboard for the Puget Sound Ecosystem \(Levin et al., 2010\)](#). The Leadership Council adopted ecosystem recovery targets for many Vital Sign indicators in 2011¹. The Leadership Council adopted revised Vital Signs and indicators for human wellbeing in 2015 based on recommendations in [Human Wellbeing Vital Signs and Indicators for Puget Sound Recovery \(Stiles et al., 2015\)](#).

Figure 1 depicts what is known to as the "Vital Sign wheel." Indicators are not shown on the wheel but are listed and described on the [Vital Sign module](#) of the website Puget Sound Info².

Science experts ("indicator leads") monitor, manage, analyze, and typically report on most ecosystem components represented by Vital Signs and indicator data. Indicator leads work in federal, state, and county agencies and non-profit research groups throughout Puget Sound. Indicator leads operate by agreement with the Partnership to provide reports. The monitoring and indicator reporting work is a core element of the [Puget Sound Ecosystem Monitoring Program \(PSEMP\)](#), a network of monitoring programs that encompasses all monitoring for Puget Sound health, including (but not limited to) monitoring associated with Vital Signs and indicators.

Messages about the overall condition of Vital Signs and the status and trends of indicators as well as progress towards indicator-specific targets are reported in the Vital Signs module and every two years in the [State of the Sound report](#). The State of the Sound report is intended to promote partners and inform decision makers of progress with ecosystem recovery efforts. It also contains information on Puget Sound ecosystem recovery goals, ecosystem health, and partners' role in Puget Sound recovery.

¹A full description of past efforts to identify Indicators of Puget Sound recovery is in O'Neill et al. (2018), Section 2.

²Puget Sound Info is a collaborative platform for sharing information about Puget Sound recovery priorities, investments, accomplishments, and progress toward near-term results and long-term recovery goals. <https://www.pugetsoundinfo.wa.gov/>

Revising Vital Signs for biophysical goals



Figure 1: The current “Vital Sign wheel,” which includes statutory ecosystem recovery goals in the outer ring and current Vital Signs in the second ring. Both the biophysical and human wellbeing goals and associated Vital Signs are included. Biophysical Vital Signs were primarily the subject of the revisions project.

The relationship between Vital Signs and their indicators and targets and planning and adaptive management for Puget Sound recovery has evolved over time. Since 2012, the Vital Signs and indicators have been the main communication tool used to describe how the Puget Sound ecosystem is doing and how much effort is still needed to meet recovery goals. Historically, Vital Signs and indicators have guided development of the regionally developed, science-based, prioritized set of recovery programs and actions, the [Puget Sound Action Agenda](#). They also are used as planning guides and endpoints for [Implementation Strategies](#) and [Local Integrating Organization recovery plans](#), and for integration with the Puget Sound salmon recovery community’s [Chinook Salmon Habitat Common Indicators \(2019\)](#).

BOX 1. STATUTORY RECOVERY GOALS FOR PUGET SOUND

Washington State statute establishes six goals and eight objectives for Puget Sound recovery (RCW 90.71.300)

Goals

1. A healthy human population supported by a healthy Puget Sound that is not threatened by changes in the ecosystem.
2. A quality of human life that is sustained by a functioning Puget Sound ecosystem.
3. Healthy and sustaining populations of native species in Puget Sound, including a robust food web.
4. A healthy Puget Sound where freshwater, estuary, nearshore, marine, and upland habitats are protected, restored, and sustained.
5. 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.
6. Fresh and marine waters and sediments of a sufficient quality so that the waters in the region are safe for drinking, swimming, shellfish harvest and consumption, and other human uses and enjoyment, and are not harmful to the native marine mammals, fish, birds, and shellfish of the region.

Goals 3-6 address water quality, water quantity, habitats, and species and food web. Goals 3-6 give rise to the “biophysical” Vital Signs and indicators and were the subject of this effort.

Objectives

1. Protect existing habitat and prevent further losses;
2. Restore habitat functions and values;
3. Significantly reduce toxics entering Puget Sound fresh and marine waters;
4. Significantly reduce nutrients and pathogens entering Puget Sound fresh and marine waters;
5. Improve water quality and habitat by managing stormwater runoff;
6. Provide water for people, fish and wildlife, and the environment;
7. Protect ecosystem biodiversity and recover imperiled species; and
8. Build and sustain the capacity for action.

1.1 Critiques of the Existing Portfolio of Biophysical Vital Signs and Indicators

Advisors and partners have expressed concerns about the biophysical Vital Signs and indicators for Puget Sound beginning soon after these measures were first adopted. In 2012, in response to a request from the Science Panel, the Washington State Academy of Sciences (WSAS) published an independent review of the Vital Signs and indicators, [Sound Indicators: A Review for the Puget Sound Partnership](#) (WSAS, 2012). This review “identified and described significant flaws and inconsistencies in the processes that the Partnership used to select a set of indicators to monitor trends in the condition of the Puget Sound ecosystem and to assess the consequences of management interventions.” The report also described the following critiques:

- The process for selecting Vital Signs lacked a conceptual model and framework to guide the selection of ecological attributes.
- Vital Sign selection was flawed because the evaluation criteria were not weighted to emphasize scientific validity.
- For the indicators, several key ecological attributes (KEAs) were not measured, meaning the indicators as a whole failed to fully represent the ecosystem and statutory goals.

- The indicators did not measure the ecological KEAs they were supposed to represent.
- The portfolio of indicators was skewed with more indicators for the Water Quality and Habitat goal areas.
- There was insufficient attention to specific metrics, or ways of measuring change, for biophysical indicators.

In addition, the groups and experts who advise on and support reporting of Vital Signs and indicators and use them for planning and adaptive management – including PSEMP workgroups, indicator leads, Implementation Strategy leads, and the local groups responsible for Puget Sound and salmon recovery, [Local Integrating Organizations](#) (LIOs), and [Lead Entities/Watershed Leads](#) – have voiced concerns. Types of concerns expressed include:

- There are too many Vital Signs and indicators, thus diluting focus and hindering communication efforts and directed action.
- There are too few Vital Signs and indicators, such that the current suite misses important aspects of ecosystem conditions (e.g., sub-tidal ecology) and important ecosystem endpoints that should be used in recovery planning (e.g., small estuaries, non-Chinook salmonids).
- Vital Signs and indicators do not specifically track climate change or address resilience.
- Using Vital Signs and indicators as the only measures of progress for Puget Sound recovery is challenging during development of the Puget Sound Action Agenda and related Puget Sound Implementation Strategies, because Vital Signs and indicators do not provide information on short- or intermediate-term progress towards achieving recovery goals.
- The indicators may be right in principle, but the specific areas or time periods being reported are not sufficiently informative or useful to support adaptive management (e.g., summer low flows).
- The relationships among Vital Signs (and their indicators) are ill-defined, and underlying causes for change unclear, making planning difficult; they tend to be thought about in silos.
- There is no shared, compelling story from the collection of Vital Signs and indicators that describes ecosystem conditions and progress toward recovery.
- It is not clear how the indicators and information about ecosystem conditions drive recovery priorities and actions.

In response to the [WSAS 2012](#) critique and ongoing concerns about the portfolio of Vital Signs and indicators from the recovery community, the Partnership commissioned an effort led by Sandra O'Neill at the Washington Department of Fish and Wildlife (WDFW) to propose a framework for an update (“evolution”) of the Vital Sign indicators. This effort was finalized in October 2018 and culminated in a report (O'Neill et al. 2018). O'Neill et al (2018) defined and executed a systematic process to define a biophysical framework for Puget Sound and to select and refine indicators of biophysical condition to represent statutory goals for Puget Sound recovery. Candidate indicators were evaluated using defined criteria which included conceptual validity, data and statistical properties, measurability, feasibility, and management and reporting needs. As a result of this effort, O'Neill et al. (2018) recommended keeping 23 of the 25 existing biophysical indicators and adding 20 new indicators, plus some ancillary measures. The recommendations included several indicators related to climate change and a discussion of addressing resilience.

O'Neill et al. pointed out that many of the existing indicators are “lagging” indicators that should not be expected to respond quickly to management actions. These indicators are useful to understand long-term changes and for communication, but less suitable for periodically assessing progress towards recovery goals and objectives. O'Neill et al. acknowledged that, in addition to indicators of biophysical condition, the Partnership would need pressures and management response indicators (or affiliated monitoring)--used within an adaptive management framework--to adequately assess progress towards the recovery goals and objectives.

1.2 Development of the Puget Sound Progress Measures Framework

Vital Signs and indicators are critical for understanding ecosystem conditions and articulating and tracking progress toward recovery goals. However, they are not on their own sufficient for program planning and adaptive management. Measures of human activities and pressures, and information about an array of controlling factors, also are needed to assess:

- (1) whether actions are contributing to desired results as anticipated in the Implementation Strategies and outcomes identified in the Action Agenda,
- (2) where (topically and geographically) investments and changes in conditions are focused, and
- (3) whether actions are producing necessary change in human behavior and ecosystem stressors that leads to positive changes in the Vital Signs and their indicators.

The Partnership developed the Puget Sound Progress Measures Framework (Figure 2) to meet these needs. The Progress Measures Framework articulates a suite of interconnected measures that describes the collective progress toward achieving Puget Sound recovery and resilience. The framework is designed to track the results of recovery actions in relation to the Vital Signs. The framework shows whether the region is on a path to improving the Vital Signs and Puget Sound health *and* provides information on a timescale useful for decision-making and adaptive management.

The Progress Measures Framework defines three types of progress measures:

- (1) *Vital Signs and indicators* are the ultimate outcomes progress measures. They help the recovery community understand ecosystem conditions and they articulate and track progress toward statutory goals for Puget Sound recovery.
- (2) *Intermediate Progress Measures* (IPM) measure outcomes that are important to achieving improvements in Vital Signs. They are focused on changes in drivers of ecosystem condition--including reductions in pressure sources and stressors--and often represent the cumulative impacts of multiple projects or programs.
- (3) *Activity Progress Measures* (APM) measure whether actions are moving forward as planned and whether they are having the intended direct effects or outcomes. They demonstrate activity contributions towards improvement of Vital Signs and indicators, and they inspire continuation of existing actions and implementation of new actions.

This full suite of progress measures provides the information necessary to determine:

- if the Partnership is successfully implementing recovery actions that have been identified to be the highest priority (APMs);
- if individual and collective actions are contributing to desired social changes and stressor reduction (IPMs); and
- if Puget Sound health is improving (Vital Signs and indicators).

Taken together, information from the Vital Signs and indicators, along with information from IPM and APM, will help the Partnership understand key science and management questions related to Puget Sound recovery, including:

- What actions are being implemented to recover Puget Sound?
- Are actions having the intended effect? Are they resulting in progress towards goals? If not, why not?
- Are ecosystem conditions getting better, worse, or staying the same? Do we know why?
- How can we be most effective and accountable in the investment of taxpayer funds?

PUGET SOUND RECOVERY PROGRESS MEASURE FRAMEWORK

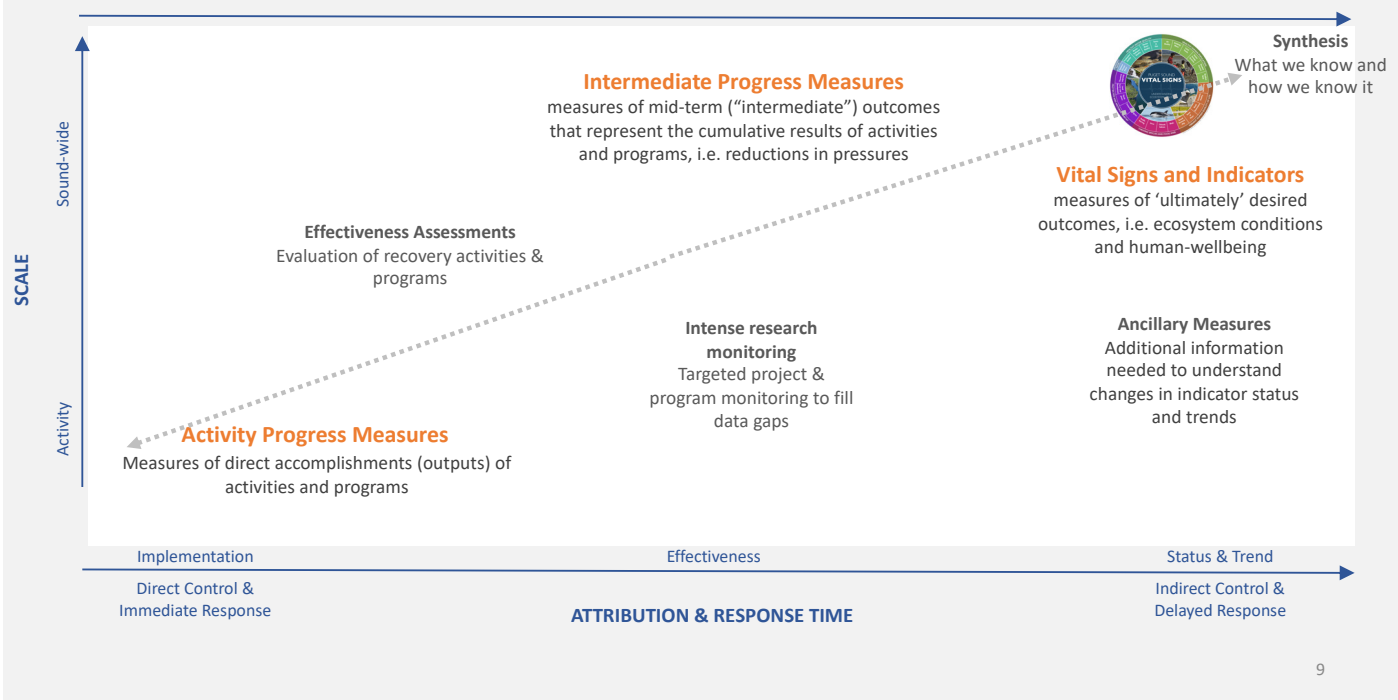


Figure 2: Progress Measures Framework shared during the revisions project. Measure types are shown in orange. Other types of related information, such as ancillary measures, assessments, and synthesis, are shown in gray.

1.3 Initiation of the Vital Signs and Indicators Revision Project

In recognition of the critiques of the existing portfolio and the new Progress Measures Framework, in July 2018, the Science Panel approved a collaborative effort to revise the Puget Sound Vital Signs and indicators. Shortly thereafter, the Partnership convened a “Vital Signs Revision Advisory Team,” a multi-disciplinary team of science and policy experts from throughout the Puget Sound recovery community, both to confirm a common vision for how Vital Signs and indicators should be used to drive and adaptively manage recovery efforts, and to scope and advise on the Vital Sign revision work. The first phase of the project, spanning from January to June 2019, focused on clarifying how Vital Signs and indicators would be used in the future in the context of the Progress Measures Framework. More information on Phase 1 is provided in Appendix A. In the second phase, from June 2019 to June 2020, revisions to Vital Signs and indicators were selected. Phase 2 is the main subject of the rest of this report.

The revision process was timed to be completed well before the 2022 Action Agenda planning cycle begins, so that there is enough time for the results of this effort to be factored into development of the Action Agenda.

2. Methods: Relying on Previous Studies and Analyses and Emphasizing Development of Shared Measures

The Vital Signs revision project used an iterative and collaborative process to identify recommended revisions to Vital Signs and indicators. It emphasized work with science and policy practitioners in the Puget Sound recovery community to develop “shared measures” that could be broadly supported and used. In this context, shared measures means that members of the Puget Sound recovery community were part of the process to identify the Vital Sign and indicator revisions and see the results as a positive, incremental step in Puget Sound progress measurement. It also means that data collection and reporting on measures is shared, such that partner organizations prioritize monitoring and reporting as part of their program plans, and results from these measures are used by multiple recovery partners and decision makers, consistent with their own individual missions and priorities. The process was guided by the uses of Vital Signs and indicators and the Progress Measures Framework, and informed by previous studies, analyses, and conceptual models (defined in section 2.2.3) compiled for this effort.

Throughout the effort, relevant standing groups were provided with status updates and briefings, especially the PSEMP Steering Committee, PSEMP workgroups, LIOs, the Science Panel, and the Partnership Tribal Coordinating Council. Finally, the Vital Signs Revision Advisory Team reviewed process steps and emerging outcomes, and provided feedback and direction throughout the project. Appendix B provides additional information on the process and engagement steps used in the Vital Signs revision project.

2.1 Developing an Initial Menu of Potential Vital Sign and Indicator Revisions from Existing Studies and Analyses

The scope of the Vital Signs revisions was to address known shortcomings with the existing Vital Signs and indicators, relying on existing studies and analyses. This approach balances the benefits of addressing known problems with Vital Signs and indicators with an acceptable level of effort and potential disruption, and the need to provide significant, incremental improvement to the Vital Signs and indicators. As a first step, the project team compiled an initial menu of potential revisions to Vital Signs and indicators, relying mainly on the [2015 Partnership Director’s Interpretation \(Sahandy, 2015\)](#), the recommendations for indicators in [O’Neill et al. \(2018\)](#), and [Chinook Salmon Habitat Common Indicators, 2019 \(PSP, 2019\)](#).

From August through October 2019, the project team held 17 meetings with indicator leads to review the initial menu in a structured conversation to make adjustments and additions. Over the same timeframe, the project team briefed the PSEMP Steering Committee and PSEMP Workgroups on the initial menu to the extent their regular meetings allowed for discussion. The project team also had discussions about the initial menu with LIO Coordinators, the Science Panel, and the Vital Sign Revision Advisory Team. This resulted in a revised initial menu of nearly 40 potential revisions to Vital Signs and indicators.

The project team broadly circulated the revised initial menu in the Puget Sound recovery community and convened a discussion at a Puget Sound recovery community workshop in October 2019. At the workshop, a structured process invited consideration of:

- (1) Relationships and assumptions underpinning each Vital Sign and indicator, through review of initial drafts of the Vital Signs conceptual models;
- (2) Potential revisions to Vital Signs and indicators (the initial menu), with an emphasis on understanding where potential changes were most broadly supported and identifying and filling gaps; and
- (3) How Vital Signs and indicators might be used to communicate about and inspire Puget Sound recovery, and what that work should imply for revisions to Vital Signs and indicators.

After the workshop, the project team again revised the menu and organized science and policy experts into Vital Sign small groups to further review potential revisions and develop recommendations.

2.2 Selecting the Vital Signs and Indicator Revisions to Move Forward from the Initial Menu

Starting with the revised menu developed after the first Vital Signs revision workshop, small groups of science and policy experts and the project team met to further refine potential revisions and develop recommendations. The following guidelines were used to identify which revisions to Vital Signs and indicators to recommend:

- Ensure consistency with specified uses of Vital Signs and indicators and the Progress Measures Framework.
- Ensure consistency with Chinook Salmon Habitat Common Indicators.
- Ensure coverage of the Puget Sound biophysical framework, address statutory recovery goals, and consider conceptual models.
- Consider the O'Neill et al. (2018) indicator selection criteria for any new indicator ideas to ensure candidates were appropriate.
- Ensure shared measures.

From October 2019 to January 2020 the project team held more than 25 meetings with small groups of science and policy experts to support this effort. Most groups met at least twice. The project team supplemented small group meetings with more than a dozen one-on-one conversations with key experts, and with regular briefings to the PSEMP Steering Committee, LIO Coordinators, Watershed Leads, the Science Panel, and other standing advisory groups. Overall, more than 140 people participated in these discussions and more than 100 potential Vital Signs and indicator revisions were considered. Many of these revision ideas did not develop as recommended revisions to Vital Signs and indicators because of one or more of the guidelines above. Some ideas moved forward as recommended potential future indicators or ancillary measures, which are discussed in the section 2.2.1 and 2.2.4, respectively.

2.2.1 Ensure Consistency with Specified Uses of Vital Signs and Indicators and the Progress Measures Framework

The Leadership Council specified three uses of Vital Signs and indicators:

- Understand the condition of the ecosystem.
- Articulate our shared statutory recovery goals and understand if we are achieving them.
- Inspire focused action to drive progress towards meeting our shared goals.

The Progress Measures Framework similarly specifies Vital Signs and indicators as the measures of “ultimate outcomes” for Puget Sound, as opposed to measures of activity or changes in pressures or drivers. The uses of Vital Signs and indicators and the Progress Measures Framework helped small groups ensure that indicator recommendations were focused on ecosystem conditions, as expressed in the Puget Sound biophysical framework as discussed below, as opposed to measures of pressure sources and stressors or human activity. Existing indicators that measure activities (e.g., acres of estuary restored) or changes in pressures (e.g., miles of net shoreline armoring) were moved from Vital Sign indicators and replaced with measures that more cleanly focus on ecosystem conditions and ultimate recovery outcomes (e.g., percent estuarine habitat in functional condition, and feeder bluffs in functional condition).

Ancillary Measures

The uses of Vital Signs and indicators and the Progress Measures Framework helped groups distinguish between Vital Sign indicators and ancillary measures. The concept of ancillary measures was introduced in O'Neill et al (2018) as variables whose assessment and reporting helps the recovery community understand the causes of changes in Vital Sign indicator results and provides context for the results. This revision project broadened the concept of ancillary measures to include measures that are:

- (1) less likely to clearly respond to local and regional management actions or
- (2) potentially more difficult for the public or decision makers to immediately understand, or otherwise less compelling for inspiration and communication and therefore not appropriate as Vital Sign indicators.

This project considered O'Neill et al.'s (2018) recommended ancillary measures and identified additional such measures as part of its development and evaluation of indicator revisions.

Appendix H provides the initial list of ancillary measures identified during this effort, including existing Vital Sign indicators that are recommended as ancillary measures. These measures are not discussed in section 3, but the project team recommends attention to the development of ancillary measures among the next steps presented in section 4.

2.2.2 Ensure Consistency with Chinook Salmon Habitat Common Indicators

[*The Chinook Salmon Habitat Common Indicators \(CCI\)*](#) are a set of metrics used to track and report local progress in salmon recovery in a way that can be rolled up at the regional level to evaluate implementation and effectiveness of the Puget Sound Chinook Salmon Recovery Plan. The Common Indicators program established regional monitoring protocols and provides source data for local ecosystem recovery planning by Lead Entities, Local Integrating Organizations (LIOs), and other local partners. Where a habitat type addressed in the CCI was also recommended as a Vital Sign indicator, the CCI measure was used to ensure consistency with the region's salmon recovery system.

2.2.3 Ensure Coverage of the Puget Sound Biophysical Framework and Statutory Goals, and Consider Conceptual Models

The project team relied on the Puget Sound biophysical framework developed in O'Neill et al. (2018) to ensure Vital Signs and indicators adequately covered the attributes of the Puget Sound ecosystem needed to reflect progress toward statutory recovery goals and objectives. O'Neill and her co-authors specifically developed this framework to support identification of indicators that would fully represent the recovery goals and objectives for the Puget Sound ecosystem as expressed in Washington State statute at RCW 90.71.300.

This framework is consistent with the [*Open Standards for the Practice of Conservation*](#); it identifies the focal ecosystem components and key ecosystem attributes (KEAs), or the aspects of the component biology or ecology that define a healthy ecosystem when present and, if missing or altered, would lead to the outright loss or extreme degradation of the component over time. Following advice from the WSAS review panel (2012), the O'Neill approach relied on EPA's [*A Framework for Assessing and Reporting on Ecological Condition*](#) (EPA Science Advisory Board, 2002).

The [*O'Neill et al. \(2018\)*](#) biophysical framework for Puget Sound begins with three ecosystem domains (terrestrial, freshwater, and marine nearshore) and 19 components (see [*O'Neill et al. \(2018\)*](#), figure 4-1B). Based on EPA's (2002) framework, O'Neill et al. (2018) identified 36 KEAs that would be needed to comprehensively assess the biophysical condition of Puget Sound's three ecosystem domains (see [*O'Neill et al. \(2018\)*](#), table 4-2) and a subset of 20 of these KEAs as the focus for Vital Sign indicators (see [*O'Neill et al. \(2018\)*](#), table 4-3). Table 1 in Appendix G summarizes the KEAs for Vital Sign indicators and provides the definitions from EPA (EPA Science Advisory Board, 2002).

Where small groups identified indicator gaps in the menu of revisions, the project team added recommended indicators from O'Neill et al. (2018) to the menu.

Mapping to Statutory Goals and Retaining Indicators to Address Water Quality and Stream Flows

As a secondary check, the project team also mapped proposed Vital Signs and indicators to the biophysical goals for Puget Sound recovery to ensure all were well addressed. The project team identified the recovery goal primarily addressed by each proposed indicator.

As noted above in the discussion of the Progress Measures Framework, measures of changes in drivers and pressures should appear as IPM. The project team adhered to this convention, except that some indicators are maintained as Vital Sign indicators directly related to water quality and water quantity recovery goals, even though these measures can also be understood to be drivers or controlling factors for habitat condition or species viability. That is, where a measure could legitimately be considered either an indicator of a stressed condition of an ecosystem component, such as effects of contaminant exposure in biota, or a driver of condition in other indicators, the project team chose to maintain Vital Signs and indicators to fully address statutory recovery goals. Some Vital Signs (e.g., freshwater conditions, marine water quality) are both means to improvement in other Vital Signs and ends unto themselves, as described in the statutory goals.

Conceptual Models

Conceptual models are the diagrams that describe the functional relationship among components of an ecosystem. They represent the prevailing scientific understanding of the relational hypotheses, pathways of effect, evidence, and uncertainties related to physical, chemical, and biological factors controlling Vital Sign condition and affecting outcomes, in addition to the relationships between Vital Signs and indicators. They also contain the pressures and stressors that impact factors controlling Vital Sign condition. They are, essentially, a problem statement to connect the source of pressure through to impacts on specific Vital Sign indicators.

The project team provided draft conceptual models to small groups for their consideration of potential revisions to Vital Signs and indicators and development of recommendations. To supplement small groups' work, the project team also used the models as a check on Vital Signs and indicator recommendations, particularly when considering whether Vital Signs and indicators adequately covered statutory goals for recovery.

The project team developed the draft conceptual models from an inventory of existing models developed in Phase 1 of this project ([IEC, 2019](#)). This inventory includes models developed by the Partnership, LIOs, Lead Entities, other state and federal government agencies, academic entities, and other parties. In compiling the initial drafts, emphasis was placed on more recent models and on models that had undergone collaborative review or development (e.g., models from Implementation Strategies, or from LIO ecosystem recovery plans).

The conceptual models developed during the Vital Sign and indicators revision process are living documents. They will be available to inform future efforts and can be further refined and updated as Puget Sound recovery efforts continue. Beyond the term of the Vital Sign revision project, the project team continues to add information to the models on the strength of the relationships among drivers, pressures, KEAs, and Vital Signs and indicators. When complete, this work will increase understanding of which drivers and pressures are most influential on Vital Sign and indicator condition and will support, among other things, the identification of IPM.

Appendix C provides a snapshot of the conceptual models as of summer 2020, with a more detailed description of their use and development. The models are publicly available in the online platform miradishare.org, in the project called [Puget Sound Partnership Vital Signs Revision 2020](#).

2.2.4 Indicators Already Recommended by O'Neill or other Studies Considered Pre-Qualified; Consideration of O'Neill et al. (2018) Indicator Selection Criteria for New Indicator Ideas

The project team considered Vital Signs and indicators recommended by [O'Neill et al. \(2018\)](#), existing Vital Sign indicators, and [Chinook Salmon Habitat Common Indicators. \(PSP, 2019\)](#) to be qualified indicators and did not further assess them against existing or new indicator selection criteria.

The Puget Sound recovery community previously invested in numerous efforts to select Puget Sound progress measures, including the work of Levin et al. (2010), which implemented the approach in the Puget Sound Science Review (2011), the Chinook Salmon Habitat Common Indicators work, and [O'Neill et al. \(2018\)](#). Each of those efforts engaged multiple science and policy experts from throughout the region in criteria-driven efforts to identify, evaluate, rank, and propose appropriate indicators. The Puget Sound Science Review and O'Neill et al. efforts went through external peer review processes overseen by the Science Panel. The Leadership Council directed the project team to use a focused revision based on known or suspected shortcomings in the Vital Sign and indicators identified by existing studies and analyses. In addition, the team was mindful of the significant investment of time and money represented by these past studies, and so relied on results from these previous efforts to inform this revision process. The majority of potential revisions to Vital Signs and indicators included on the initial menu and discussed by small groups were considered pre-qualified using this approach.

To assess new indicator ideas, the project team provided small groups with the [O'Neill et al. \(2018\)](#) indicator selection criteria (Box 2) and asked the groups to identify any “red flags” relative to the Vital Signs and indicators they were considering. “Red flags” were defined as significant weaknesses in the potential indicator with respect to one or more criterion.

The project team and the Vital Signs Revision Advisory Team also considered the [O'Neill et al. \(2018\)](#) criteria when reviewing and providing feedback on potential new Vital Signs and indicators. When red flags were identified, those indicators were set aside (i.e., rejected from further consideration) or moved forward as potential future indicators or ancillary measures (as discussed in section 2.2.1).

Potential Future Indicators

Ideas were moved forward as potential future indicators when experts believed:

- (1) they are necessary to fully and effectively articulate recovery goals and understand progress; and
- (2) a valid indicator that would meet the O'Neill et al. (2018) criteria is not currently available but could be developed with adequate time and resources.

For example, experts strongly support development of an indicator for *the regional index of the stock presence and health of forage fish such as sand lance, surf smelt, and anchovy* and believe a valid indicator can be developed; however, resources will be needed to develop the indicator protocol and for monitoring and reporting. Similarly, experts strongly support a revised *Marine Benthic Index* indicator to replace the existing marine benthic indicator.

If an indicator supported by experts was considered theoretically sound but needed more development to resolve monitoring and reporting frameworks, and it was believed this development could be complete by January 2022 in a way that would satisfy the O'Neill et al (2018) criteria, the indicator was moved forward with the recognition that more development work would be needed. Continued attention to the O'Neill et al (2018) criteria will be important to guide further development of these indicators and to design monitoring and reporting frameworks.

The Partnership plans to transition to the revised Vital Signs and indicators after reporting on the existing Vital Signs and indicators through calendar year 2021. Monitoring and reporting on revised Vital Signs and indicators is planned to begin in January 2022. Indicators that experts believed necessary to fully and effectively articulate recovery goals and understand progress, but that likely would not be ready to monitor and report on by January 2022, were carried forward as potential future indicators.

BOX 2. O'NEILL ET AL. (2018) INDICATOR CRITERIA

- **Conceptual Validity**
 - » Theoretically-sound: Scientific, peer-reviewed findings should demonstrate that indicators can act as reliable surrogates for ecosystem attributes.
 - » Responds predictably and is sufficiently sensitive to changes in a specific ecosystem attribute(s): Indicators should respond unambiguously to variation in the ecosystem attribute(s) they are intended to measure (i.e., KEAs identified for Puget Sound), in an either theoretically or empirically expected direction.
- **Data and Statistical Properties**
 - » High signal-to-noise ratio: It should be possible to estimate measurement and process uncertainty associated with each indicator, and to ensure that variability in indicator values does not prevent detection of significant changes.
 - » Consistently measurable: Indicators should be directly and consistently measurable.
 - » Spatial and temporal variation understood: Daily, seasonal, annual, and decadal variability in the indicators should be understood, as should spatial heterogeneity in indicator values.
- **Feasibility**
 - » Operationally manageable: The methods for sampling, measuring, processing, and analyzing the indicator data should be technically feasible.
 - » Cost-effective: Sampling, measuring, processing, and analyzing the indicator data should make effective use of limited financial resources.
- **Management and Reporting Needs**
 - » Relevant to management concerns: Indicators should provide information related to specific management goals and strategies as reflected in the Partnership's ecosystem recovery goals and objectives.
 - » Responds predictably and is sufficiently sensitive to changes from specific management action(s) or pressure(s): Management actions or other human-induced pressures should cause detectable changes in the indicators, in a theoretically or empirically-expected direction, and it should be possible to distinguish the effects of other factors on the response.
 - » Linkable to scientifically defined reference points and progress targets: Indicator values should be able to be linked to quantitative or qualitative reference points and target reference points, which imply progress toward ecosystem goals.

2.2.5 Ensure Shared Measures

An overarching principle of the Vital Sign revision effort was to iteratively engage the Puget Sound recovery community to develop shared measures. Participants in small groups were encouraged to react to one another's concerns and priorities. They were supported in reaching agreement about which Vital Sign indicators to move forward, which to set aside, and which to address as potential future indicators or ancillary measures.

2.3 Review of Preliminary Draft of Vital Sign Revisions

The project team compiled a preliminary draft of potential Vital Sign and indicator revisions, circulated this draft, and convened a second workshop where this draft was discussed in late January 2020. The purpose of the workshop was to examine the preliminary draft to identify where there might be overlap between Vital Signs and indicators, so that numbers could be reduced, and where there were gaps.

Based on discussion at the January 2020 workshop, the project team set aside a number of indicator revision ideas and developed a new Vital Sign and related indicators for Groundfish and Benthic Invertebrates.

After the January workshop there was additional outreach to small groups and experts by email and in meetings. A revised draft was circulated in February, and further adjustments were made.

2.4 Review of Draft Report and Recommendations and Science Panel Peer Review

The project team prepared a final draft of anticipated Vital Sign and indicator revisions, broadly circulated this draft, and convened two virtual workshops to discuss it with the Puget Sound recovery community in late March 2020. This version presented options for Vital Sign portfolios of seven to 16 Vital Signs, depending on how indicators were grouped into Vital Signs, and recommended 36 indicators and 12 potential future indicators.

These workshops focused on ensuring people were comfortable with the accuracy of draft Vital Sign indicator names and descriptions, in addition to making any clarifications needed. During this time, indicator leads for the existing portfolio were contacted for final checks on the proposed fate of the indicators for which they are responsible. They were also asked for any comments on the names and descriptions for new indicators.

In mid-April 2020 the project team prepared a draft of this report for review by the recovery community and for peer review by a subcommittee of Science Panel members. This final version of the report responds to comments from the recovery community and scientific review, insights from focus groups as discussed in section 2.5, and the decisions of the Leadership Council in June 2020.

The mid-April draft report presented four options for grouping the same recommended set of 36 indicators into as few as seven or as many as 16 Vital Signs. Feedback from the March workshops and the Vital Signs Revision Advisory Team indicated a preference for intermediate options, with 11 or 13 Vital Signs.

2.5 Focus Groups on Communication and Inspiration

The Vital Signs and indicators serve as the critical tools for communication and inspiration around Puget Sound recovery. The collection of Vital Signs and indicators (but not each specific measure) must describe the conditions of the ecosystem, more specifically define all statutory recovery goals, and resonate with decision makers and the general public. It was at times challenging to reconcile these three imperatives. The need to reflect statutory recovery goals well and completely suggested higher numbers of Vital Signs and indicators that were more specific and precise. The need to effectively communicate and inspire action suggested fewer Vital Signs and indicators that were more familiar and engaging. At the end, the project team sought to fill the need to describe statutory recovery goals well and completely at the indicator level and emphasize communication and inspiration at the Vital Sign level.

In May 2020, the Partnership commissioned two focus groups to help understand which Vital Sign names and groupings of indicators, as presented in the draft report, best resonated with partners and Puget Sound residents, inspired action, and communicated about ecosystem conditions and progress toward recovery goals. The first focus group convened Puget Sound residents (referred to as “public”) online on May 6, 2020. There was no interaction among the 34 participants in this first group. The second focus group convened 11 Partnership board members interacting with each other in a virtual platform (Zoom) on May 20, 2020. In this second focus group, all 11 participants answered “poll questions” posed by the facilitator, but only six of the 11 participants engaged in discussions with one another and the facilitator about the questions.

Overall, focus group participants preferred a smaller number of Vital Signs called by simpler names, representing concepts, places, and animals that people could easily imagine. For example, focus group participants preferred Vital Sign names like “Forests and Wetlands” over less familiar names like “Watersheds.” Vital Signs that referred to well-known Puget Sound species, such as salmon and orca, were preferred over Vital Signs that referred to lesser known species, such as forage fish and zooplankton.

Reports on the focus group findings are available online: [May 6](#) and [May 20](#), and a summary of focus group discussions is provided in Appendix D. Focus group findings were consistent with preferences expressed by the Vital Sign Revision Advisory Team and most other partners during report development, and with most comments submitted on the draft report. The project team relied heavily on focus group findings when preparing the options for Vital Sign revisions to present to the Leadership Council.

Another way of thinking about “inspiring action” is to recognize that the selection and naming of Vital Signs focuses attention on selected topics, and therefore away from other topics. To better understand partners’ perspectives on the focus conveyed by Vital Signs, portfolio options were discussed with Partnership boards and other advisory groups in April and May 2020. Their feedback and insights were used to shape final Vital Sign options presented to the [Puget Sound Partnership Leadership Council in June 2020](#).

2.6 Final Options Presented to the Puget Sound Partnership Leadership Council

The project team presented three options for revised Vital Sign portfolios, and a status quo option of no revisions to Vital Signs, to the Leadership Council for consideration (Table 1). All options shared the following features:

- All recommend adopting the same set of 34 indicators that, given adequate resources, staff capacity, and partner engagement, will be ready to monitor and report on by January 2022. All options also recommend 19 potential future indicators which fill important gaps, add depth to the portfolio, or replace existing indicators with a more robust measure, but which are not likely to be ready by January 2022.
- All Vital Sign options include new indicators to cover longstanding gaps in the Vital Signs portfolio, including indicators of additional salmon species (not just Chinook), indicators for small and pocket estuaries, and indicators for zooplankton.
- All include the Chinook Salmon Habitat Common Indicators wherever there was topical overlap between the Vital Sign and the common indicator measures, ensuring consistency between the watershed-focused salmon recovery efforts and the Puget Sound-scale Vital Signs and indicators.
- All maintain the habitat types, species, and water quality and quantity features addressed in the existing Vital Signs portfolio.
- All contain exclusively indicators of ecosystem conditions. That is, the project team moved existing indicators that track reductions in pressures and stressors (e.g., miles of shoreline armoring) to the catalog of IPM consistent with the Progress Measures Framework. The project team replaced them with related measures of ecosystem conditions (e.g., unarmored drift cells).
- All simplified the names of Vital Signs consistent with focus group and partner feedback, although the specific approach to simplification varied among the options.

Table 1. Vital Signs portfolio options.

Statutory Goals	Vital Signs Option 1	Vital Signs Option 2	Vital Signs Option 3	Vital Signs Option 4 (no action, existing Vital Signs)
Healthy water quality	Freshwater	Freshwater	Freshwater	Freshwater Quality
	Marine Water	Marine Water	Marine Water	Marine Water Quality
	Toxics in Aquatic Life	Toxics in Aquatic Life	Toxics in Aquatic Life	Marine Sediment Quality
Abundant water	Streams and Floodplains	Forests, Wetlands, Rivers, and Streams	Streams and Floodplains	Stream Flows
Protected and restored habitats	Forests and Wetlands		Forests and Wetlands	Floodplains
	Estuaries	Estuaries, Beaches, and Marine Vegetation	Estuaries	Land Development and Cover
	Beaches		Beaches and Marine Vegetation	Estuaries
				Shoreline Armoring
Thriving species and food web	Orcas	Orcas	Orcas	Eelgrass
	Salmon	Salmon	Salmon	Orcas
	Birds	Birds	Birds	Chinook Salmon
	Groundfish and Benthic Invertebrates	Marine Fish and Invertebrates	Groundfish and Benthic Invertebrates	Birds
	Base of Marine Food Web		Forage Fish	Pacific Herring
			Zooplankton	

Option 1 balances focus group feedback, number of Vital Signs, and complexity of the groupings, and results in 12 Vital Signs. This option groups indicators for forage fish, zooplankton, and primary production into a single “Base of marine food web” Vital Sign.

Option 2 has the fewest Vital Signs (nine). It is the same as option 1 with respect to Vital Signs for water quality, but it groups the habitat Vital Signs more aggressively, combining all indicators for freshwater and terrestrial habitat into a single Vital Sign (“Forests, Wetlands, Rivers, and Streams”) and all indicators for marine habitat into a single Vital Sign (“Estuaries, Beaches, and Marine Vegetation”). At the species level, option 2 combines indicators for groundfish and benthic invertebrates, forage fish, and zooplankton into a single Vital Sign (“Marine Fish and Invertebrates”). In this option indicators of primary production are part of the Vital Sign for Marine Water.

Option 3 has the most Vital Signs (13). It is the same as option 1 with respect to Vital Signs related to habitats and water quality, but includes more granularity in Vital Signs related to species and food web to reflect the importance of different aspects of the lower food web (Forage Fish and Zooplankton) as advised by many experts. In this option, as in option 2, indicators of primary production are part of the Vital Sign for Marine Water.

The project team recommended option 1, but endorsed all three options as valid choices for Vital Sign and indicator revisions.

The Leadership Council also considered an option to retain the existing set of Vital Signs and indicators, essentially a “no action” option. This is option 4 in the table above and was not recommended.

3. Results: Revisions to Vital Signs and Indicators

The Leadership Council adopted revisions to Puget Sound Vital Signs and indicators in June 2020.

3.1 Revisions to Vital Signs

The Leadership Council selected 13 biophysical Vital Signs: option 3 in Table 1.

Six of the revised biophysical Vital Signs essentially continue existing Vital Signs: Birds, Estuaries, Freshwater, Marine Water, Orcas, and Toxics in Aquatic Life.

Five of the revised Vital Signs reframe or expand existing Vital Signs:

- Two of these Vital Signs are more clearly an ecosystem component instead of a pressure: Land Development and Cover becomes *Forests and Wetlands*; Shoreline Armoring becomes *Beaches and Marine Vegetation*
- Two of these Vital Signs expand the component to better cover recovery goals: Chinook Salmon becomes more broadly *Salmon*; Pacific Herring becomes more broadly *Forage Fish*
- One of these Vital Signs combines habitat measures in the freshwater domain: Floodplains and Summer Stream Flows become *Streams and Floodplains*

Two new Vital Signs encompass measures that are newly added as indicators: *Groundfish and Benthic Invertebrates* and *Zooplankton*.

Table S1 shows the Vital Signs organized under the primary statutory recovery goal that they represent. This revision to the Vital Signs means that the recovery goal of abundant water is no longer represented by a unique Vital Sign. The complete list of revised Vital Signs and their primary statutory goals, including those for human wellbeing, is found in Table S1.

All ecosystem components addressed in the existing Vital Sign portfolio are retained in the revision, although, as shown in Table 2, some are addressed differently. As described above, Vital Signs for habitats have been re-oriented from pressure reductions; this is consistent with the first use of Vital Signs and indicators specified by the Leadership Council, to help us “understand ecosystem conditions.”

Table 2: Change between the existing and revised Vital Signs.

Statutory Goals	Existing Vital Signs	Revised Vital Signs
Healthy water quality	Freshwater Quality	Freshwater
	Marine Water Quality	Marine Water
	Marine Sediment Quality	
	Toxics in Fish	Toxics in Aquatic Life
Abundant water	Stream Flows	Streams and Floodplains
Protected and restored habitats	Floodplains	
	Land Development and Cover	Forests and Wetlands
	Estuaries	Estuaries
	Shoreline Armoring	Beaches and Marine Vegetation
	Eelgrass	
Thriving species and food web	Orcas	Orcas
	Chinook Salmon	Salmon
	Birds	Birds
		Groundfish and Benthic Invertebrates
	Pacific Herring	Forage Fish
		Zooplankton

3.2 Revisions to Indicators

The 13 Vital Signs encompass 34 Vital Sign indicators (biophysical only). The vast majority of the indicators reframe existing measures or are drawn from either [Evolving the Portfolio of Indicators to Assess and Report on the Condition and Recovery of the Puget Sound Ecosystem: Moving from Theory to Practice, O'Neill et al. \(2018\)](#) or from the [Chinook Salmon Habitat Common Indicators, 2019](#). Most of the adopted indicators were recommended in more than one document (Table 3). Appendix E provides descriptions of the indicators established by the revision effort and additional information about how these indicators compare to the existing Vital Sign indicators and to the recommendations in [O'Neill et al 2018](#).

Table 3: Indicators and potential future indicators and sources of recommendation.

Indicator	Existing	O'Neill et al. 2018	Chinook Common Indicators	2015 Director's Memo	New
Freshwater Benthic Index of Biotic Integrity (B-IBI)	X	X			
Water temperature in streams and rivers	X	X	X		
Nutrient concentration in streams and rivers	X	X			
Dissolved oxygen in marine water	X	X			
Marine Benthic Index	X	X			
Marine water temperature	X	X	X		
Nutrient balance in marine water	X	X	X		
Ocean acidification		X			
Sediment Chemistry Index	X	X			
• <i>Marine Benthic Index, phase 2</i>					X
• <i>Noise in marine water</i>					X
• <i>Primary production in marine water</i>	X	X			
Contaminants in English sole	X	X			
Contaminants in Pacific herring	X	X			
Contaminants in juvenile salmon	X	X			
Contaminants in adult salmon	X	X			
• <i>Contaminants in caged mussels</i>		X			
Eelgrass area	X	X	X		
Extent of forest cover in nearshore marine riparian areas			X		
Percent of feeder bluffs in functional condition	X		X		
Floating kelp canopy area					X
Short and long-term eelgrass site status					X
• <i>Drift cells in functional condition</i>					X
• <i>Miles of intertidal beach in functional condition</i>					X
• <i>Understory kelp abundance and condition</i>					X
Percent estuaries habitat area in functional condition			X		
• <i>Number of accessible pocket estuaries and embayments</i>			X	X	
Extent of forest cover in the upper, middle, and lower areas of watersheds					
• <i>Forest condition</i>		X			
• <i>Wetlands extent and condition</i>		X	X		
Floodplain function in large and small systems	X	X	X	X	
Summer low flows in streams and rivers	X	X	X		

• *Potential future indicator*

Indicator	Existing	O'Neill et al. 2018	Chinook Common Indicators	2015 Director's Memo	New
• <i>Changes in hydrologic regime in streams and rivers</i>					X
• <i>Drought emergency extent and frequency - for human wellbeing</i>					X
• <i>Extent of forest cover in riparian zones</i>			X		
• <i>Frequency of flood events</i>		X			
Abundance of marine bird populations	X	X			
Abundance of terrestrial bird populations	X	X			
• <i>Estuarine birds</i>					X
Biomass of spawning Pacific herring	X	X			
• <i>Regional index of the stock presence and health of forage fish such as sand lance, surf smelt, and anchovy</i>				X	
Abundance and biomass of groundfish					X
Abundance and biomass of benthic marine invertebrates					X
Number of Southern Resident killer whales	X	X			
Occupancy/residency of orcas in Puget Sound		X			
Number of natural-origin Chinook salmon on spawning grounds	X	X			
Number of natural-origin Coho salmon on spawning grounds				X	
Number of natural-origin Puget Sound Steelhead on spawning grounds				X	
Number of natural-origin Summer Chum salmon on spawning grounds				X	
• <i>Harvest - for human wellbeing</i>					X
Average zooplankton biomass		X			
• <i>Integrated annual zooplankton biomass</i>		X			
• <i>Zooplankton Index</i>		X			

• *Potential future indicator*

3.3 Potential Future Indicators

The revision process recommends 19 measures as potential future indicators for further consideration and development. Potential future indicators fill important gaps, add depth to the portfolio, or replace an adopted indicator with a more robust measure. They are important to consider for the future but are generally not expected to be ready with monitoring or reporting by January 2022.

Two potential future indicators may in fact prove to be ready to monitor and report on by January 2022. Extent of forest cover in riparian zones, which is also a Chinook Common Indicator, is being developed as a measure to inform salmon recovery. Contaminants in caged mussels is being used as an ongoing status and trends measure in the Stormwater Action Monitoring program. These measures have a high likelihood of being fully developed within the next two years. The other potential future indicators are not as fully developed and were not receiving development attention as of June 2020. The project team recommends that the Partnership and PSEMP consider developing and adopting these measures as refinements to the Progress Measures Framework.

If developed, some of potential future indicators could replace indicators established in this revision effort. For example, a Marine Benthic Index phase 2 indicator would replace the Marine Benthic Index established in this revision (and carried forward from the existing Vital Sign portfolio). Similarly, an integrated annual zooplankton biomass indicator could replace the average annual zooplankton biomass indicator.

One potential future indicator would combine information from a pair of the revised indicators: drift cells in functional condition could replace indicators for extent of marine riparian cover and feeder bluffs in functional condition. Development and adoption of this concept as an indicator should consider how this relates to the effort in this revision to break compound or index indicators into their component parts.

The O'Neill et al. (2018) candidate indicator criteria should serve as guidance in development of potential future indicators – that is, if developed, potential future indicators should meet these criteria before being adopted into the Vital Signs and indicators portfolio.

Appendix F provides descriptions of the recommended potential future indicators.

3.4 How the Vital Signs and Indicators Cover the Biophysical Framework for Puget Sound

A key critique in the WSAS (2012) review of the Partnership's Vital Signs and focus of the O'Neill et al. (2018) recommendations was to ensure that the selected Vital Sign indicators cover the three domains and key attributes of the Puget Sound ecosystem. Figure 3 shows how many indicators map to each KEA subcategory in the O'Neill et al. (2018) biophysical framework for Puget Sound. Indicator counts in this figure are greater than the numbers presented in sections 3.2 and 3.3 because individual indicators map to multiple KEA subcategories.

All KEA subcategories are covered by one or more indicators or potential future indicators. KEAs related to biotic condition (species-focused measures) and landscape condition (habitat-focused measures) are addressed by the most indicators.

Table 4 provides additional detail to Figure 3 and summarizes how each of the indicators and potential future indicators maps to the KEA subcategories. Coverage of KEAs for population structure, nutrient concentrations (nitrogen, phosphorus, and other nutrients), pH, temperature, sediment and material transport, and flood events is increased in the revision compared to their coverage in the existing Vital Sign portfolio. Potential future indicators would provide additional depth of coverage, although again largely in the areas of biotic condition and landscape condition.

A complete summary of how the entire portfolio of proposed indicators, potential future indicators, and ancillary measures maps to the KEAs is available in Appendix G.

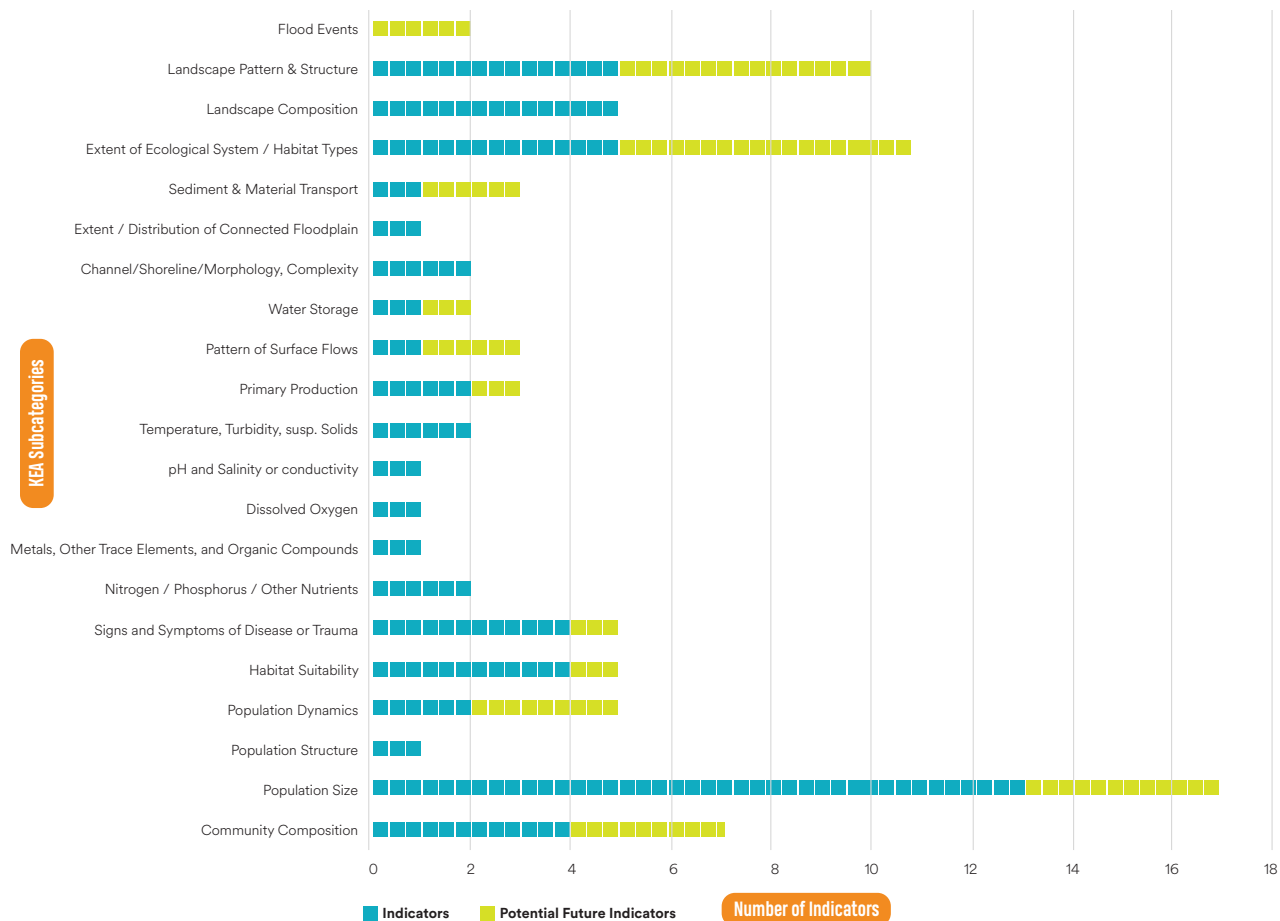


Figure 3. Number of Vital Sign indicators and potential future indicators for each KEA Subcategory.

Table 4. Indicators and potential future indicators mapped to O’Neill et al. (2018) biophysical framework.

	KEA Category	KEA Subcategory	Indicators	Potential Future Indicators
Biotic Condition	Ecosystems & Communities	Community Composition	Freshwater Benthic Index of Biotic Integrity (B-IBI); Marine Benthic Index; Short and long-term eelgrass site status; Floating kelp canopy area	Marine Benthic Index, phase 2; Understory kelp abundance/condition; Zooplankton Index
	Species & Populations	Population Size	Eelgrass Area; Floating kelp canopy area; Abundance of marine bird populations; Abundance of terrestrial bird populations; Biomass of spawning Pacific herring; Abundance and biomass of groundfish; Abundance and biomass of benthic marine invertebrates; Number of Southern Resident killer whales; Number of natural-origin Chinook salmon on spawning grounds; Number of natural-origin Coho salmon on spawning grounds; Number of natural-origin Summer Chum salmon on spawning grounds; Number of natural-origin Puget Sound Steelhead on spawning grounds; Average zooplankton biomass	Understory kelp abundance and condition; Estuarine Birds; Regional index of the stock presence and health of forage fish such as sand lance, surf smelt, and anchovy; Integrated annual zooplankton biomass
		Population Structure	Occupancy/residency of orcas in Salish Sea	
		Population Dynamics	Short and long-term eelgrass site status; Floating kelp canopy area	Understory kelp abundance/condition; Regional index of the stock presence and health of forage fish such as sand lance, surf smelt, and anchovy; Integrated annual zooplankton biomass
		Habitat Suitability	Nutrient balance in marine waters; Short and long-term eelgrass site status; Floating kelp canopy area; Occupancy/ residency of orcas in Puget Sound	Understory kelp abundance and condition
		Signs and Symptoms of Disease or Trauma	Contaminants in English sole; Contaminants in Pacific herring; Contaminants in juvenile salmon; Contaminants in adult salmon	Contaminants in caged mussels

	KEA Category	KEA Subcategory	Indicators	Potential Future Indicators
Chemical & Physical Characteristics	Nutrient Concentrations	Nitrogen / phosphorus / other nutrients	Nutrient concentration in streams and rivers; Nutrient balance in marine waters	
	Trace inorganic & organic chemical	Metals, other trace elements, and organic compounds	Sediment Chemistry Index	
	Other chemical parameters	Dissolved oxygen	Dissolved oxygen in marine water	
		pH and Salinity or conductivity	Ocean acidification	
	Physical parameters	Temperature, turbidity, suspended solids	Water temperature in streams and rivers; Water temperature in marine water	
Ecological Processes	Energy Flow	Primary production	Nutrient balance in marine water; Nutrient concentration in streams and rivers	Primary production in marine waters
Hydrology & Geomorphology	Surface & groundwater flows	Pattern of surface flows	Summer low flows in streams and rivers	Changes in hydrologic regime in streams and rivers; Frequency of flood events
		Water storage	Summer low flows in streams and rivers	Wetlands extent and condition
	Dynamic structural characteristics	Channel / shoreline / morphology, complexity	Percent estuarine habitat in functional condition; Floodplain function in small and large systems	
		Extent / distribution of connected floodplain	Floodplain function in small and large systems	
	Sediment & material transport	Sediment & material transport	Percent of feeder bluffs in functional condition	Drift cells in functional condition; Miles of intertidal beach in functional condition
Landscape Condition	Extent of ecological system / habitat types	Extent of ecological system / habitat types	Extent of forest cover in nearshore/marine riparian area; Eelgrass area; Floating kelp canopy area; Percent estuarine habitat in functional condition; Extent of forest cover	Understory kelp abundance and condition; Miles of intertidal beach in functional condition; Accessible pocket estuaries and embayments; Wetlands extent and condition; Forest condition; Extent of forest cover in riparian zone
	Landscape composition	Landscape composition	Floodplain function in small and large systems; Extent of forest cover in nearshore marine riparian area; Extent of forest cover	Forest condition; Extent of forest cover in riparian zone
	Landscape pattern & structure	Landscape pattern & structure	Feeder bluffs in functional condition; Extent of forest cover in nearshore marine riparian area; Percent estuarine habitat in functional condition; Extent of forest cover; Floodplain function in small and large systems	Drift cells in functional condition; Accessible pocket estuaries and embayments; Wetlands extent and condition; Forest condition; Extent of forest cover in riparian zone
Natural Disturbance Regimes	Frequency / intensity/extent/ duration	Flood Events		Changes in hydrologic regime in streams and rivers; Frequency of flood events

3.5 How Vital Signs and Indicators Represent Statutory Goals for Water Quality, Water Quantity, Habitats, and Species and Food Web

One of the three uses of Vital Signs and indicators described by the Progress Measures Framework is to articulate and help track progress toward statutory goals for Puget Sound. As discussed above, all the recovery goals which are the subject of biophysical Vital Signs and indicators have at least one associated Vital Sign, although as with the existing portfolio not all goals are represented by the same number of Vital Signs or indicators.

Although the Partnership and this project often emphasize a primary association between recovery goals and Vital Signs and indicators, we recognize a many-to-many relationship between the Vital Signs and indicators and the statutory goals. Table 5 summarizes how the Vital Signs, indicators, and potential future indicators map to the biophysical goals for Puget Sound recovery. The goal for thriving species and food web is represented by the most Vital Signs (ten) and indicators (28). The goals for habitats and for water quantity are addressed together and are represented by six Vital Signs and 22 indicators. The goal for water quality is represented by three Vital Signs and 17 indicators.

Table 5. Vital Signs, indicators, and potential future indicators mapped to biophysical recovery goals.¹

Measure Type	Measure Name	Species and Food Web	Habitats and Water Quantity		Water Quality
Vital Sign	Freshwater	X	X	X	X
Indicator	Freshwater Benthic Index of Biotic Integrity (BIBI)	X	X	X	X
Indicator	Water temperature in streams and rivers				X
Indicator	Nutrient concentration in streams and rivers	X	X		X
Vital Sign	Marine Water	X			X
Indicator	Dissolved oxygen in marine waters				X
Indicator	Marine Benthic Index	X			X
Indicator	Marine water temperature				X
Indicator	Nutrient balance in marine waters				X
Indicator	Ocean acidification				X
Indicator	Sediment Chemistry Index				X
<i>Potential future indicator</i>	<i>Marine Benthic Index, phase 2</i>	X			X
<i>Potential future indicator</i>	<i>Noise in marine water</i>	X			X
<i>Potential future indicator</i>	<i>Primary production in marine water</i>	X			X
Vital Sign	Toxics in Aquatic Life	X			X
Indicator	Contaminants in adult salmon	X			X
Indicator	Contaminants in English sole	X			X
Indicator	Contaminants in juvenile salmon	X			X
Indicator	Contaminants in Pacific herring	X			X
<i>Potential future indicator</i>	<i>Contaminants in caged mussels</i>				X
Vital Sign	Beaches and Marine Vegetation	X	X		
Indicator	Eelgrass area	X	X		
Indicator	Extent of forest cover in nearshore marine riparian areas		X		
Indicator	Floating kelp canopy area		X		
Indicator	Percent feeder bluffs in functional condition		X		

Measure Type	Measure Name	Species and Food Web	Habitats and Water Quantity		Water Quality
Indicator	Short and long-term eelgrass site status	X	X		
Potential future indicator	Understory kelp abundance and condition		X		
Potential future indicator	Drift cells in functional condition	X	X		
Potential future indicator	Miles of intertidal beach in functional condition		X		
Vital Sign	Estuaries		X		
Indicator	Percent estuarine habitat area in functional condition		X		
Potential future indicator	Accessible pocket estuaries and embayments		X		
Vital Sign	Forests and Wetlands		X		
Indicator	Extent of forest cover in the upper, middle, and lower areas of watersheds		X		
Potential future indicator	Forest condition		X		
Potential future indicator	Wetlands extent and condition		X	X	
Vital Sign	Streams and Floodplains		X	X	
Indicator	Floodplain function in large and small systems		X	X	
Indicator	Summer low flows in streams and rivers			X	
Potential future indicator	Extent of forest cover in freshwater riparian zones		X		
Potential future indicator	Changes in hydrologic regime in streams and rivers		X	X	
Potential future indicator	Frequency of flood events		X	X	
Vital Sign	Birds	X			
Indicator	Abundance of marine bird populations	X			
Indicator	Abundance of terrestrial bird populations	X	X		
Potential future indicator	Estuarine birds	X	X		
Vital Sign	Forage Fish	X			
Indicator	Biomass of spawning Pacific herring	X			
Potential future indicator	Regional index of the stock presence and health of forage fish such as sand lance, surf smelt, and anchovy	X			
Vital Sign	Groundfish and Benthic Invertebrates	X			
Indicator	Biomass and abundance of groundfish	X			
Indicator	Biomass and abundance of benthic marine invertebrates	X			
Vital Sign	Orcas	X			
Indicator	Number of Southern Resident killer whales	X			
Indicator	Occupancy/residency of orcas in Puget Sound	X			

Measure Type	Measure Name	Species and Food Web	Habitats and Water Quantity	Water Quality
Vital Sign	Salmon	X		
Indicator	Number of natural-origin Chinook salmon on spawning grounds	X		
Indicator	Number of natural-origin Coho salmon on spawning grounds	X		
Indicator	Number of natural-origin Puget Sound Steelhead on spawning grounds	X		
Indicator	Number of natural-origin Summer Chum salmon on spawning grounds	X		
Vital Sign	Zooplankton	X		
Indicator	Average zooplankton biomass			
<i>Potential future indicator</i>	<i>Integrated annual zooplankton biomass</i>	X		
<i>Potential future indicator</i>	<i>Zooplankton Index</i>	X		

¹Two potential future indicators are primarily associated with human wellbeing goals for recovery and are not included in this table.

3.6 How Revised Vital Signs and Indicators Respond to Critiques and Address Known Shortcomings

The revision project considered and responds to critiques of the Vital Signs and indicators and shortcomings of the existing portfolio that have emerged over the past 10 years. The Vital Signs and indicators established in the revision effort addressed the critiques and shortcomings as follows:

- The adopted Vital Signs and indicators incorporate definitions and measures consistent with the [2015 PSP Director's Interpretation](#) (Sahandy, 2015), which established a broader interpretation of Vital Signs for estuaries, floodplains, eelgrass, forage fish, and salmon.
- The revision process specifically used the biophysical framework, indicator selection criteria, and recommended indicators from [O'Neill et al. \(2018\)](#), which was developed specifically in response to WSAS concerns ([WSAS, 2012](#)).
- The revised Vital Sign indicators reflect many of the specific recommendations in O'Neill et al (2018). The recommendations in O'Neill et al (2018) were the starting point during conversations with indicator leads and small groups. In a few cases, topical experts advised otherwise, or the indicators were re-sorted into a different part of the Progress Measures Framework. In total, 11 of O'Neill et al.'s 42 proposed Vital Sign indicators were not among the indicators and potential future indicators recommended to the Leadership Council, namely: river and stream physical habitat, timing of peak stream flows, snowpack, air temperature, freshwater quality index, pesticides in small streams, periphyton biomass in freshwater, coho prespawn mortality, toxic chemical contaminants in resident fish in lakes and rivers, sediment supply to nearshore, and sediment supply to rivers.
- The adopted Vital Signs and indicators are informed by, and articulated in, a consistent set of conceptual models also in response to WSAS concerns ([WSAS, 2012](#))

The Vital Signs and indicators established by the revision effort also address and are consistent with management initiatives that have been developed since the existing portfolio was established. In particular:

- Vital Signs indicators are consistent with Chinook Salmon Habitat Common Indicators. This ensures consistency between the watershed-focused salmon recovery efforts and the Puget Sound-scale Vital Signs and indicators. Indicators for estuaries, floodplains, sediment supply, and marine and freshwater riparian cover were adopted from the Chinook Common Indicators.

- The adopted Vital Signs implement the new Progress Measures Framework by reclassifying indicators that measure changes in pressures or drivers of ecosystem conditions to IPM (e.g., net extent of shoreline armor) and indicators that measure programmatic activity to Activity or Intermediate Progress Measures (e.g., acres of estuary restored). Ensuring consistency with the Progress Measures Framework addresses concerns that the existing Vital Signs and indicators mix measures of ecosystem conditions, pressure reduction, and activity, and clearly focuses the Vital Signs and indicators on ecosystem conditions.

Other concerns are less fully addressed by this effort. For instance, the revised Vital Signs and indicators do not specifically track climate change because they focus on ecosystem conditions as opposed to measures of pressure sources and stressors (such as sea level rise or climate effects on flows). The project team consulted with the Partnership's Climate Advisory Team (CAT) early in the process. One discussion topic was about which indicators were best suited for climate change mitigation and adaptation. Because so many aspects of ecosystem conditions are affected by climate stressors (as was noted in the [2017 Preliminary Climate Change Assessment for the Puget Sound Partnership](#), Siemann and Whitely Binder 2017), the CAT recommended that the project team justify their choice for particular subsets of indicators for climate change, with a possible focus on indicators of the physical condition of Puget Sound that are more directly impacted by climate. Though this report does not characterize indicators in terms of climate change assessment, the project team recommends that the Partnership include a climate lens to future analysis and reporting of indicators related to water temperature, ocean acidification, estuary habitat area, forest condition, summer low flows, changes in hydrologic regime, and frequency of flood events.

This effort was not designed to produce syntheses that use information from Vital Signs and indicators--along with information from other progress measures and findings from broader monitoring and assessment studies--to tell clear and engaging stories about how the Puget Sound ecosystem is doing, what additional work is needed, and what actions must be taken if recovery is to be achieved. This type of overarching work is needed and was the subject of ongoing conversations and much interest throughout the revisions process.

Finally, while the Vital Signs and indicators are broadly supported, they likely will not fully satisfy all interests. In particular, there remain differences in perspectives about how many or how few Vital Signs and indicators are needed to best serve Puget Sound recovery. Some see the Vital Signs and indicators primarily as a science-driven ecosystem assessment effort; they argue for many Vital Signs and many indicators to fully describe the Puget Sound ecosystem and for selection of indicators based primarily on their scientific value. They see grouping concepts, habitat types, or species as missed opportunities to educate people on how Puget Sound works. Others see the Vital Signs and indicators as mainly communication tools that need to clearly illuminate the crisis Puget Sound is facing and inspire the types of difficult choices and significant investments that are needed to accelerate recovery. They argue that too many Vital Signs and indicators dilute focus, obscure the problem, and give rise to extensive monitoring without a clear pathway to drive action. They prefer a smaller set of Vital Signs and indicators. This revision effort landed somewhere in the middle, with a credible set of Vital Signs and indicators that fully represents the statutory recovery goals for Puget Sound, but that is neither the largest nor the smallest of the options considered.

3.7 Vital Signs and Indicators Related to Human Wellbeing

This effort did not set out to consider Vital Signs and indicators related to recovery goals for human health and human quality of life, together referred to as human wellbeing. That portion of the Partnership's Vital Signs and indicators was informed by the recent scientific effort reported in Stiles et al. (2015).

This project identified two potential future indicators related to human wellbeing. The project team recommends that that Partnership and advisors consider adopting additional human wellbeing indicators for:

- Drought emergency extent and frequency – which could track the duration and frequency of drought advisories and emergencies for watersheds in the Puget Sound basin. Watershed emergencies are declared by the Department of Ecology based on a combination of water availability (looking at storage and flows) and an economic hardship factor, reflective of water demand not being met.
- Salmon harvest – which could be framed to help better understand whether people have access to harvestable numbers of fish that are safe enough to consume at desired rates. This could complement existing measures of salmon population abundance and fish consumption advisories.

Finally, the Partnership's adoption of the Progress Measures Framework means that one human wellbeing Vital Sign, On-Site Sewage, will be retired and its two indicators either retired or moved to another part of the Progress Measures Framework.

4. Moving Forward and Additional Work Needed

Revising the Partnership's biophysical Vital Signs and indicators is a first step in bolstering the ecosystem conditions reporting program and setting the course for the Partnership's ecosystem recovery planning efforts.

Achieving the goals and objectives for ecosystem recovery and socio-ecological resilience is a long-term process that will take continual work. The evaluation of Vital Signs and indicators will similarly need continual work and support as a fundamental element of the PSEMP's mission and the Partnership's strategic plan. The revised Vital Signs and indicators are an ambitious set of measures. They depend on renewed support for a collection of ongoing monitoring programs, led by various organizations, as well as new monitoring and assessment programs that are not yet fully funded.

Work now must turn to ensuring the resources and capacity to monitor and report on the revised Vital Signs and indicators. Ongoing support, leadership, and investment of resources from the Partnership, the PSEMP network, and the Science Panel are needed to fully realize the three uses of the Vital Signs, i.e., understand ecosystem conditions, articulate goals, and inspire actions.

We propose the following activities as immediate to long-term steps to realize the three uses of the Vital Signs:

- Engage PSEMP partners in developing expectations and necessary agreements with the Partnership for monitoring and reporting the revised Vital Signs and indicators. Identify indicator leads where needed. As the Partnership steps into conversations with partners, the agency should recognize that individual monitoring efforts are often embedded in a complex suite of ongoing programs. Supporting the agencies and organizations that lead those programs and helping them achieve their goals is central to attaining the monitoring and reporting goals for the Vital Signs.
- Work with PSEMP work groups and partners to identify data gaps. Document resources and capacity needed to monitor and report on the full suite of measures.
- Advocate for the necessary resources and capacity that PSEMP partners will need to continue monitoring and reporting of Vital Signs and indicators. In order to make a compelling argument for additional resources, the monitoring and reporting activities should be aligned with and central to an organization's mission.
- Develop monitoring and reporting protocols where needed, in collaboration with PSEMP work group and partners. The protocols could address issues such as baselines, space and time scales of reporting, reporting frequencies, and methods for evaluating status, trends, and progress that are ideally consistent across indicators.
- Set targets for progress measures.
- Manage the changes in Puget Sound Info and reflect the revisions in a new Vital Sign wheel.
- Incorporate the revisions into the development of the Action Agenda and associated IPM.
- Give attention to ancillary measures and the role they play in helping to understand changes in condition of Vital Signs and indicators. Ensure adequate resources for their monitoring.
- Develop potential future indicators as appropriate.
- Synthesize results from indicator reports and broader monitoring findings into meaningful information for science-based decision making and management. As a first step, develop synthesis methods to roll up the indicators to tell a story about the affiliated Vital Sign and confidently answer science and management questions about how the Puget Sound ecosystem is doing and where more work is needed.
- Connect the Vital Signs and indicators with the Science Panel work on alternative future scenario analysis, to use Vital Signs and indicators to help communicate the future we wish to strive for.
- Apply an equity lens to indicators.

Nesting the revised Vital Signs and indicators within the new, more complete Progress Measures Framework means that the new IPM and APM will take over some roles, especially in planning, that are currently filled by Vital Signs and indicators. The new IPM will identify short- and mid-term outcomes that are important to Puget Sound recovery and that help the recovery community understand if it is on track to make progress improving Vital Signs and indicators. They should amplify intermediate outcomes, illuminate management actions that have the potential to improve the condition of multiple Vital Signs and indicators, and cut across the "silos" in the portfolio of Vital Signs. The current thinking is that these intermediate outcomes will be the organizing principles for future Action Agenda development and development of near-term actions, with the ties to the existing Vital Signs and indicators still present but more in the background. This, in turn, could require development of separate, distinct targets for IPM, indicators, and Vital Signs. It also could have implications for funding decisions, where connectivity to IPM becomes an important funding criterion. This is a significant evolution of how things are currently done and will require coordination and deliberate transition to accomplish well.

Finally, throughout this effort, individuals and small groups emphasized the importance of getting Vital Signs and indicator reporting out of silos to see a more integrated picture of Puget Sound. This will help us better understand what indicator results tell us about the veracity of our ideas regarding what work is needed to recover Puget Sound and what outcomes we can expect from different types of actions. It is critical to using the Vital Sign and indicator information to understand progress, illuminate where additional research is needed, and adaptively manage strategies and actions to accelerate results.

Similarly, people are very interested in using the Vital Signs and indicators and related Intermediate and APM to better articulate the "story" of Puget Sound – that is, to simply and confidently answer questions like "How is Puget Sound doing?" "How do we know?" "What work is needed?" and to think about these questions at both the Puget Sound and the watershed scales.

Effective communication work, ideally supported by communication professionals and social scientists, will be important to realizing the full value of the Vital Signs and indicators. The science and policy community who participated in this effort are eager to be part of these next steps which might include:

- Graphics depicting relationship between Vital Signs
- New ways to visualize progress
- Road shows with partner agencies
- Outreach to policy setters and decision makers
- Explicit or implied links to policy questions

5. Conclusions

The revised Vital Signs and indicators are the result of all the studies and analyses of progress measures for Puget Sound that were published before, and countless hours of time and expertise volunteered by science and policy experts from throughout the Puget Sound recovery community. They represent the best current thinking about progress measurement and are an important evolution of a critical part of the structure of Puget Sound recovery. In addition to remediating known shortcomings with the existing portfolio, the project team anticipated the revised Vital Signs and indicators will support other improvements:

- The biophysical Vital Signs and indicators' focus on ecosystem conditions better support quantifying habitat losses and gains – instead of just gains from restoration efforts.
- Linking indicators to KEAs and embedding them in conceptual models demonstrate how measures relate to one another and illuminate commonalities and dependencies. For example, climate stressors on flow, temperature, and nearshore habitat inundation are expressed in graphical conceptual models as factors influencing the measures of stream flow, marine and freshwater conditions, shorelines and estuaries.
- Investment in development of the Vital Signs and indicators as shared measures paves the way for more collaborative monitoring and reporting. It increases the likelihood that Vital Sign and indicator results will be relevant to and used by ongoing programs supportive of Puget Sound recovery.

- Placing the Vital Signs and indicators in the context of Intermediate and APM and making connections between these measure types supports syntheses, which allows the recovery community to more confidently and compellingly answer science and management questions for Puget Sound recovery.

While the benefits of the revisions recommended here are significant, any set of Vital Signs and indicators will not be, on its own, sufficient to guarantee a successful or accelerating recovery effort, nor identify all the potential limiting factors that are inhibiting recovery. Recovery requires action, and it takes funding. Vital Signs and indicators can help illuminate what actions are needed, but they require individuals, policy setters, decision makers, and funders to do their parts if progress is to be made.

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Appendix A: Phase 1 of the Vital Signs Revision Project

Phase 1 of the Vital Signs revision project took place from January 2019 through June 2019. This phase focused on (1) defining how Vital Signs and indicators are used, and (2) refining the scope for the Vital Signs revision project.

How Vital Signs and Indicators Are Used

In June 2019 the Puget Sound Partnership Leadership Council confirmed three primary uses of Vital Signs and indicators:

- Understand the condition of the ecosystem.
- Articulate shared statutory recovery goals and understand if we are achieving them.
- Inspire focused action to drive progress towards meeting shared goals.

Other approaches to using Vital Signs and indicators were considered; however, none of these presented a practical, viable alternative to the uses described above in a way that warranted further investment in evaluation. Significant other approaches that were considered included the following:

- Using Vital Signs and indicators to serve all progress measurement and planning needs, which is how they have been used in the past, since they were the only available measures. Vital Signs do not provide short- or intermediate-term information and so indicators are not suited as near-term planning endpoints, nor do they acknowledge the more complete understanding of work priorities emerging from Implementation Strategies. Vital Signs and indicators will be most effective at communicating progress toward recovery goals, inspiring action, and informing adaptation of recovery plans if used in combination with additional types of progress measures that provide near-term and intermediate information on the implementation and effectiveness of recovery activities. Vital Signs and indicators are important measures, but they should not be the only measures of progress nor the sole thing that recovery is planned around.
- Deploying Vital Signs and indicators only as assessments of ecosystem conditions (i.e., not linked to statutory goals and objectives). This approach is inconsistent with EPA's guidance for progress measurement in NEP programs and the Open Standards for the Practice of Conservation framework, which direct that progress measures be linked to assessment objectives. This approach would also be a dramatic departure from how the Partnership and other groups have used Vital Signs and indicators to date, out of proportion to any critique so far offered (i.e., no one has so far said that Vital Signs and indicators should not be linked to goals for Puget Sound recovery). The project team is, however, proposing a continued emphasis on the Vital Signs and indicators as descriptive of overall ecosystem conditions (encompassing both human wellbeing and biophysical conditions). The project team also recognizes that some additional biophysical Vital Signs and indicators would be needed to fully reflect ecosystem conditions consistent with the [*WSAS 2012*](#) review of the Vital Signs and indicators and addressed by [*O'Neill et al. \(2018\)*](#) in their proposed revisions to Vital Signs and indicators.

The three uses of Vital Signs and indicators confirmed by the Leadership Council during Phase 1 framed experts' discussions, workshop activities with the ecosystem recovery community, and review of potential revisions to Vital Signs and indicators during Phase 2.

Scope of the Vital Signs Revision Process

Five options were considered for the scope of the Vital Signs revision project, ranging from a do-nothing approach to a foundational reassessment of Vital Signs and indicators.

The Vital Signs Advisory Team recommended a focused revision, relying on existing studies and analyses, to address known concerns with the current Vital Signs and indicators. This approach balanced the benefits of addressing known concerns and problems with Vital Signs and indicators with an acceptable level of effort and potential disruption. This approach was endorsed by the Puget Sound Partnership Science Panel and the Puget Sound Partnership Leadership Council.

The project team and advisors identified the following studies and inputs to use as the basis for a focused revision to Vital Signs and indicators:

- The [*Partnership Director's interpretation: Scope of Vital Sign Indicators for Near-term Action Submissions \(Sahandy, 2015\)*](#) which clarified where the Vital Sign scope was broader than specific indicators and more comprehensive than that described by existing targets for Pacific herring, Chinook salmon, estuaries, floodplains, and eelgrass.
- [*O'Neill et al. \(2018\) report*](#), which developed a biophysical framework for assessment of Puget Sound relative to statutory goals. The report recommended several new Vital Signs and indicators responding to the [*WSAS 2012*](#) review and critique of the existing portfolio.
- [*Chinook Salmon Habitat Common Indicators \(CCIs\) \(PSP, 2019\)*](#). The project team aimed for consistency with the CCI framework whenever possible.

In addition to these published works, the project also sought to draw on:

- Insights from science and policy experts from throughout the Puget Sound recovery on use of Vital Signs and indicators as planning endpoints in Implementation Strategies, strategic initiatives, the Action Agenda, and LIO ecosystem recovery plans. These insights were drawn from a structured, collaborative process that engaged science and policy expertise from throughout the Puget Sound recovery community and were also supported by conceptual models.
- Insights from indicator leads and the PSEMP workgroup community.
- Consistency with the new Progress Measures Framework.

Appendix B: Summary of Phase 2 Engagement Process in Support of Development of Shared Measures

Vital Signs Revision Advisory Team

A cross-sector Vital Signs Revision Advisory Team, composed of individuals with topical expertise, led Phase I of the project and continued to lead during Phase 2. The project was supported by science program staff at the Partnership and a contract team from Ross Strategic, Anchor QEA, and Industrial Economics (IEc). Members of the team are:

- Scott Redman (PSP Science staff)
- Ron Thom (PSP Science staff)
- Jenna Judge (PSP Science staff)
- Ken Currens (Northwest Indian Fisheries Commission)
- Randy Lumper (Northwest Indian Fisheries Commission)
- Tim Quinn (Washington Department of Fish and Wildlife)
- Kirsten Feifel (Department of Natural Resources)

- Emily Sanford (Dept of Health)
- Bill Blake (Skagit CD)
- Kathy Peters (Kitsap County)
- Tom Kantz (Pierce County)
- Robert Warren (Bonneville Environment Foundation)
- Tracy Collier
- Gl James (Lummi Nation)
- Lisa Wilson (Lummi Nation)
- Haley Kennard (Makah)
- Angela Adams (Environmental Protection Agency)
- Michael Rylko (Environmental Protection Agency)

During Phase 2, the role of the Vital Signs Revision Advisory Team was to provide ongoing guidance on the following:

- science and policy questions
- Vital Sign and indicator revision and partner engagement, and
- development of recommendations to the Leadership Council on how Vital Signs should be used to guide recovery and what process should be used for the Vital Signs revision.

The advisory team met several times, both in-person and via conference call, during Phase 2 of the project:

- July 12, 2019 (via conference call and in person at the Center for Urban Waters)
- September 6, 2019 (via conference call and in person at the Center for Urban Waters)
- November 6, 2019 (via conference call and in person at the Kitsap County Administration Building)
- January 10, 2020 (via conference call and in person at the Kitsap County Administration Building)
- February 12, 2020 (via conference call and in person at the Center for Urban Waters)
- March 3, 2020 (via conference call)
- June 22, 2020 (via conference call)

The advisory team organized experts into small groups and community workshops to ensure that potential revisions were captured and discussed beyond the silos of each Vital Sign. Small groups and workshops also allowed the Vital Signs Revision Advisory Team and recovery community to address the overall goals and purpose of the Vital Signs and assess whether the Vital Signs and indicators were meeting the three use cases.

Indicator Leads Conversations

Meetings were organized with the Vital Signs Core Team (PSP staff and contractor support) and indicator leads, from various organizations, to discuss existing indicators and potential revisions. The purpose of these initial calls was to provide indicator leads with updates on the Vital Signs and indicator revision process, describe process steps, answer questions, and collect feedback to improve the process design. Indicator leads were invited to review a working-draft “menu” of potential changes to the Vital Signs and indicators and offer feedback. Indicator leads also reviewed working-draft conceptual models for their Vital Sign and indicators and provided guidance on next steps most appropriate for each Vital Sign and indicator. There were 17 calls between August and October 2019 with indicator leads on the following Vital Signs:

- Birds
- Chinook
- Eelgrass
- Estuaries
- Floodplains
- Freshwater Quality
- Land Development and Cover
- Marine Sediment Quality
- Marine Water Quality
- Pacific Herring
- Shellfish and Onsite Sewage Systems
- Shoreline Armoring
- Summer Stream Flows
- Toxics in Fish

Workshops

Vital Signs community workshops invited the Puget Sound recovery community to discuss the scope, objectives, process, and schedule for the revision project. Participants were presented with a project overview and review of the Progress Measures Framework. Throughout both workshops, participants engaged in breakout sessions to provide input on potential changes and conceptual models for Vital Signs and indicators. During the most recent workshop in January, participants reconvened to discuss portfolios of Vital Signs and indicators as well as use of candidate selection criteria.

- **October 10th, 2019 workshop – 65 attendees**
The first community workshop in October focused on discussing the origin of the Vital Signs and indicators revision effort, the scope, and the timeline. The workshop was then divided into small groups, organized around the individual Vital Signs and their indicators, to review simple draft conceptual models and initial menus of potential changes (compiled from existing studies and analyses and drawing from initial conversations with indicator leads and other experts). During this workshop, participants discussed how Vital Signs and indicators are used to understand and tell stories about Puget Sound’s condition and what work is needed.
- **January 21st, 2020 workshop – 46 attendees**
The January community workshop objectives were to look across work of small groups and adjust as needed, gain input on types of portfolios to develop and portfolio selection, begin identification of Intermediate Progress Measures, and preview work of the next three months and make adjustments if needed.

- **March 20th, 2020 and March 31st, 2020 virtual workshops – 44 and 43 attendees, respectively**

Lastly, the March virtual workshops were intended to make sure people were comfortable with the indicator names and descriptions that were moving forward and to make any clarifications or improvements needed. The workshop breakout groups were used to identify remaining gaps in revisions and start thinking toward what it would mean to implement new Vital Signs and indicators, including the need to develop monitoring and reporting frameworks.

Small Group Work

Following the October 10th community workshop, indicator leads and key technical experts were invited to join small groups dedicated to each Vital Sign. The purpose of these small groups was to accomplish the following:

- vet and refine a simple conceptual model for each Vital Sign and set of indicators;
- vet and refine draft recommendations for revisions to Vital Signs and indicators drawn from existing studies and analyses; and
- collaborate in community workshops to review all draft recommendations and make further edits and refinements to develop a robust, meaningful, and workable set of Vital Signs and indicators across the board.

Birds and Orca did not have small groups and instead a smaller number of indicator leads and key technical experts were contacted for guidance and feedback on potential revisions.

- There were 11 calls with small groups between November and December 2019
- An additional 14 calls with small groups in January 2020 continued to refine indicators
- Small groups
 - » Beaches and Shorelines
 - » Eelgrass
 - » Forage Fish
 - » Forests and Wetlands
 - » Freshwater Quality
 - » Marine Water Quality
 - » Marine Sediment Quality
 - » Rivers, Streams, and Floodplains
 - » Salmon
 - » Summer Stream Flows
 - » Toxics in Aquatic Life

Small group participants were invited to use Mural, an online collaborative space, to review and edit draft conceptual models for each Vital Sign. Participants could use digital sticky notes to record comments and identify missing elements

or connections, elements or connections that should be eliminated, the most important stressors, controlling factors, and certainty and uncertainty of components in the models. Participants could also review and respond to each other's comments. Mural spaces were created with conceptual models for the following Vital Signs:

- Beaches and Shorelines
- Eelgrass
- Forage Fish
- Forests and Wetlands
- Freshwater Quality
- Marine Water Quality
- Orca
- Rivers, Streams, and Floodplains
- Salmon
- Summer Stream Flows
- Toxics in Aquatic Life

PSEMP Steering Committee Engagement

Throughout Phase 2, presentations and written updates were provided to the PSEMP Steering Committee. Meetings at which presentations and written updates were shared with the committee:

- September 10, 2019
- November 11, 2019
- January 14, 2020
- March 10, 2020

PSEMP Workgroups and Additional Group Engagement

Throughout Phase 2, presentations and written updates were provided to the PSEMP Work Groups. Presentations and written updates were also provided to Strategic Initiative and Action Agenda Leads, Watershed Leads, LIOs, Climate Action Team, and the Social Sciences Advisory Committee.

- November 7, 2019 - PSEMP Marine Waters with Forage Fish WG
- November 14, 2019 - PSEMP Toxics
- November 22, 2019 - PSEMP Salmon
- December 3, 2019 - PSEMP Nearshore
- December 9, 2019 - PSEMP Birds
- December 18, 2019 - PSEMP Marine Birds Work Group
- December 17, 2019 – PSEMP Marine Mammals

- December 18, 2019 - Climate Action Team
- January 9, 2020 - PTCC
- January 22, 2020 - Action Agenda Coordination Group
- January 23, 2020 - Salmon Recovery Council
- January 28, 2020 - Social Sciences Advisory Committee
- February 13, 2020 - Watershed Leads
- March 12, 2020 – PSEMP Toxics
- May 7, 2020 – PTCC

Board Engagement

The Partnership boards have been engaged throughout the revision process with presentations and written updates at meetings for the Science Panel, Ecosystem Coordination Board (ECB), Salmon Recovery Council, and Leadership Council (LC). Presentations and briefings included summarizing the proposed revisions to the Vital Signs and indicators as they were developed for engagement and decision making. Throughout the process, the Partnership's boards have been engaged and were asked to serve as conduits to their communities.

- July 12, 2018 Science Panel – [brief](#)
- January 31, 2019 Science Panel – [written update](#)
- February 6, 2019 Science Panel – [written update](#)
- February 21, 2019 ECB – [written update](#)
- April 18, 2019 Science Panel – [brief](#)
- April 30, 2019 Science Panel Executives – [brief](#)
- May 29, 2019 ECB – [management brief](#)
- June 12, 2019 LC – [management brief](#)
- July 18, 2019 Science Panel – [management brief](#)
- October 16, 2019 Science Panel – [management brief](#)
- November 13, 2019 ECB – [written update](#)
- December 3, 2019 LC – [written update](#)
- December 17, 2019 Science Panel – [brief](#)
- March 11, 2020 Science Panel – [brief](#)
- May 28, 2020 – [Salmon Recovery Council - brief](#)

Appendix C: Vital Signs Conceptual Models

What are conceptual models?

Conceptual models are the diagrams that describe the functional relationship among components of an ecosystem. They represent the prevailing scientific understanding of the relational hypotheses, pathways of effect, evidence and uncertainties related to physical, chemical, and biological factors controlling Vital Sign conditions and affecting outcomes, in addition to the relationships between Vital Signs and indicators. They also contain the pressures and stressors that impact factors controlling Vital Sign condition. They are, essentially, a problem statement to connect the source of pressure through to impacts on specific Vital Sign indicators. The conceptual models for Vital Signs and indicators should inform what management interventions we believe will have the most impacts. They should also connect to existing models (such as “results chains”), developed during LIO and Lead Entity-scale ecosystem planning, and Puget Sound-scale implementation strategy work to explore management interventions in detail. In short, conceptual models tell the story of “how the system works” and how restoration actions aim to alter those processes or attributes for the betterment of the system (Fischenich, 2008). This also means that the models will continually grow and change as new information is gathered.

How were conceptual models developed during the Vital Sign revision process?

As part of their review of the newly formulated indicators for Puget Sound, the Washington State Academy of Sciences (2012) criticized the absence of conceptual models during the development of the indicators. The WSAS (2012, page 84) strongly recommended the first step in an indicator selection process should be the development of “...a conceptual framework that summarizes the structural elements and processes of the ecosystem to identify the key attributes (characteristics) that should be tracked”. The models developed during the revision process incorporate that feedback and are designed to be living artifacts that evolve as new information is gathered. Updates and enhancement can be made at any time as part of adaptively managing knowledge for each Vital Sign. As Fischenich (2008) noted about the general conceptual-model-building process, we have found that the model-building process for Puget Sound was as enlightening as the models themselves. The process has revealed and will continue to reveal what is known and what is unknown about the connections and causalities in the systems under study.

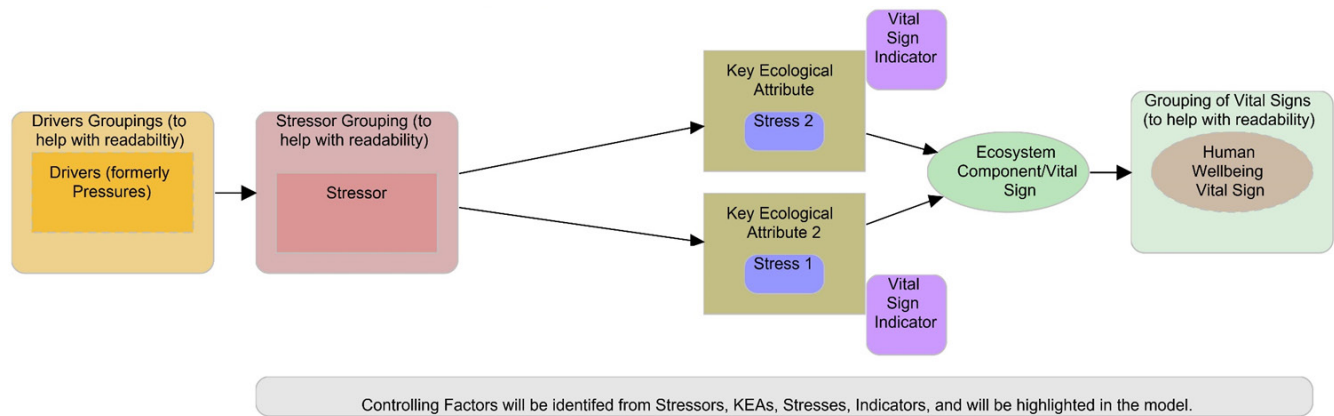
The current suite of models was built using existing models from LIOs, Implementation Strategies, reports, and scientific literature. They were then discussed and further refined by each of the Vital Sign revision small groups. The models are focused on each of the proposed new Vital Signs, except where additional detail necessitated a separate diagram (e.g., Marine waters and Marine sediment quality). Each of the conceptual models are included below (as of June 30, 2020).

Figure 1 illustrates the elements and format of the conceptual models. The models flow from left to right. That is, the pressures create the stressors, which exert influence on the KEAs. The KEAs are the items of most importance to the ecosystem components. Ecosystem components have the potential to directly affect the human wellbeing components; generally, a positive change to the ecosystem component will have a positive change on the human wellbeing components.

- *Drivers (also called pressures)* - (Yellow boxes) Drivers are the human actions that give rise to stress on the ecosystem, but also may provide benefits to humans. In some cases, related drivers are grouped for ease of analysis.
- *Stressors* - (Pink boxes) Stressors are the proximate cause of changes in the Puget Sound ecosystem. Stressors act directly on a Vital Sign, indicator, on key ecological attributes of the Vital Sign, or they act indirectly on the habitat or ecosystem processes that are necessary to support a Vital Sign or indicator. The most important stressors do not have to be acting directly on the Vital Sign or indicator; the most important stressors may be acting indirectly by impacting necessary habitats or other structures or processes (e.g., shoreline hardening might be a very important stressor for forage fish because of the way it can impair forage fish spawning habitat). Stressor definitions are from the Puget Sound Pressures Assessment and are [available here](#).
- *Key Ecological Attribute (KEA)* - (Olive boxes) Aspects of the Puget Sound ecosystem component’s biology or ecology that: (a) If present, define a healthy component; or (b) If missing or altered, would lead to the loss or extreme degradation of that component over time. KEAs often represent *controlling factors* and when they do could be associated with the Vital Sign that is the focus of the model or another related Vital Sign. In some cases, KEAs are grouped by type for ease of analysis.
- *Vital Sign or Ecosystem Component* – (Green ovals) A major characteristic of the ecosystem, such as a species or habitat. The Vital Signs dealing with water quantity, water quality, habitats, and species and food webs, which are the subjects of the conceptual models (and this revision effort), are ecosystem components.

- *Indicators* – (Light purple boxes) A measure of the condition of the ecosystem component. See above for more information on Vital Sign indicators.
- *Controlling Factors* - Controlling factors are elements that directly drive or limit Vital Sign condition. You might think of them as the necessary elements to “make” a healthy Vital Sign. Controlling factors are, generally, abiotic processes and features such as light, temperature, salinity, sediment condition, hydrology, hydrodynamics, dissolved oxygen, or pH that are required for biological processes such as productivity, growth, dispersal, and reproduction of species, and that form and maintain habitats. Biotic interactions, such as competition and predation, can also be considered controlling factors. Prey can be considered a biotic controlling factor for a predator. In turn, prey production is dependent on abiotic (e.g., temperature, salinity) and biotic controlling factors (e.g., algae). Stressors commonly directly affect controlling factors. For example, reduced water clarity caused by human-related nutrient enrichment can result in abnormally large phytoplankton blooms, which affects the light available for submerged vegetation such as kelp and seagrass. In the conceptual models, controlling factors might exist as stressors, stresses (blue boxes), KEA, or indicators. Because of this, controlling factors are represented in the models by a variety of elements rather than presented as a distinct box.
- *Human Wellbeing Vital Sign* - (tan ovals in green boxes) desirable outcomes in the human habitat and community that arise from improving the ecosystem.

Appendix C, Figure 1: Generic Miradi Model Showing Each Conceptual Model Component



Where else are they used?

Conceptual models have been utilized explicitly in large ecosystem restoration programs nationally (National Research Council 1992) including the Florida Everglades (National Academies 2018), Chesapeake Bay (Orth 1994), Missouri River (Jacobsen et al. 2017), Columbia River estuary (Krueger et al. 2017; Thom et al. 2004), and Puget Sound (Simenstad et al. 2006). The US Corps of Engineers Environmental Advisory Board of the U.S. Army Corps of Engineers recommended that: “The Corps should encourage the explicit use of conceptual models to guide ecosystem restoration planning and implementation. Conceptual models should be required as a first step in the planning process, as they provide a key link between early planning (e.g., an effective statement of problem, need, opportunity, and constraint) and later evaluation and implementation” (quote cited in Fischenich 2008). Following the Deepwater Horizon oil spill, the National Academies (2017) recommended the “Identification of well-articulated management questions that monitoring and evaluation seek to address using **conceptual system and causal models** that link ecological and socioeconomic drivers and stressors with both biophysical and ecological processes to outcomes such as populations, habitats, ecosystem, ecosystem service, and human well-being...”

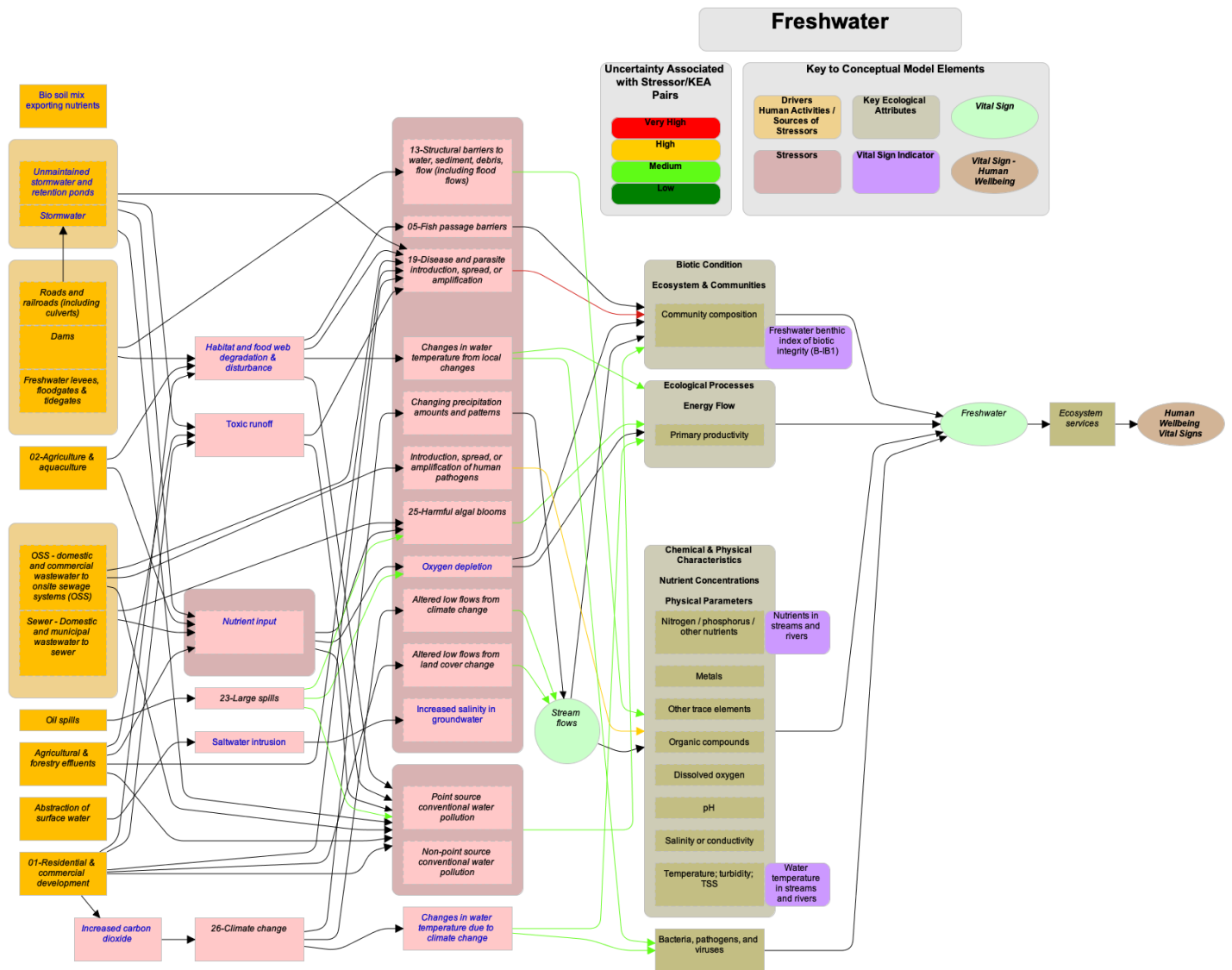
Process for Weighting Identified Stressors and Uncertainty of their Impact

As of June 2020, Partnership staff are developing a weighting scale within each conceptual model that describes the impacts of stressors and the uncertainty of the relationship between stressors and the key ecological attributes. This work is starting with the Puget Sound Pressure Assessment (PSPA) intrinsic vulnerability scores data. The PSPA does not implement the specific threat rating approach developed in Miradi, but it does crosswalk well with the Miradi approach and involves consideration of the same basic factors. In the PSPA, *scope* is evaluated directly using spatial analysis, *severity* equates to a combination of functional impact and resistance factors, and *irreversibility* equates to the recovery time factor. This work is reflected in the color-coded connections in each model (color key is included in each model). Methodology for this process will be carried forward in the Miradi project file over the summer of 2020.

Where can you find the conceptual models?

The conceptual models for revised Vital Signs are all available in the Miradi Share app (Open Standards software; www.miradishare.org), specifically [here](#). You can view the models using the pulldown menu. Updates and the full project history, including the versions presented here, will be available in Miradi moving forward. Please note that Miradi allows for multiple taxonomies. When viewing files in the Puget Sound Vital Signs update project, you should select the *Puget Sound Taxonomy*.

Appendix C, Figure 2: Conceptual Model for Freshwater Vital Sign



Appendix C, Figure 3: Conceptual Models for Marine Water Vital Sign

Figure 3a: Marine Waters

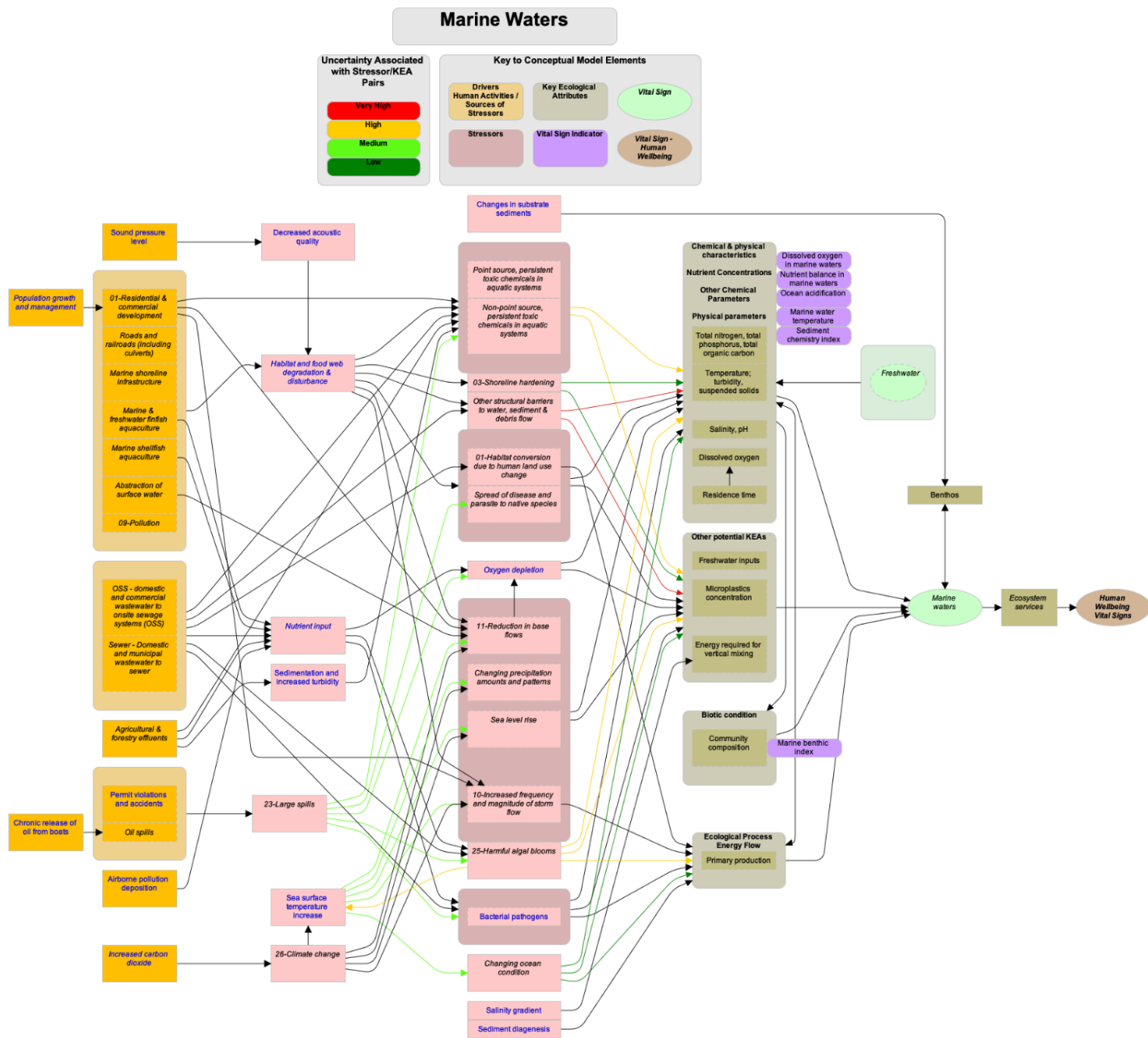
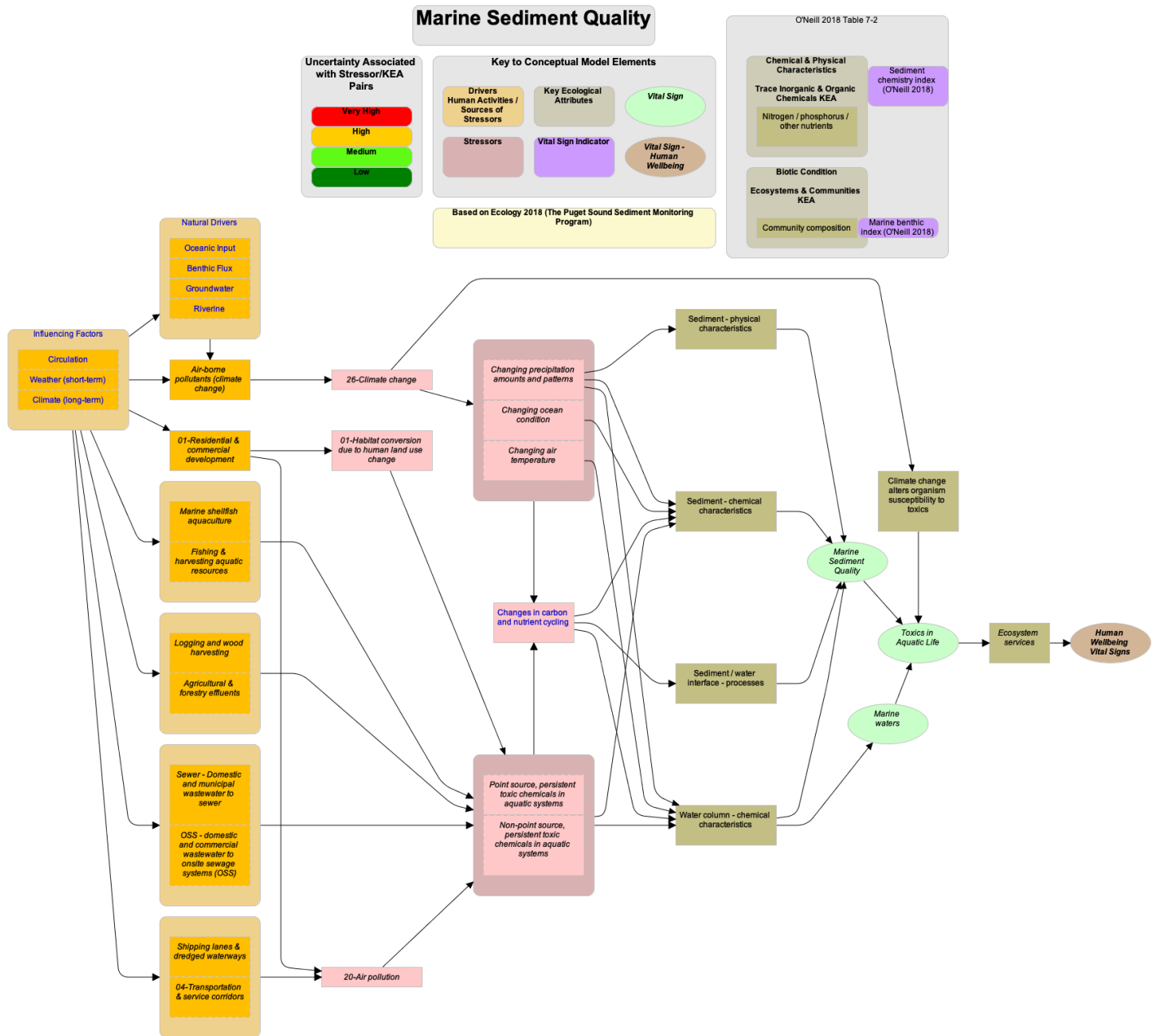
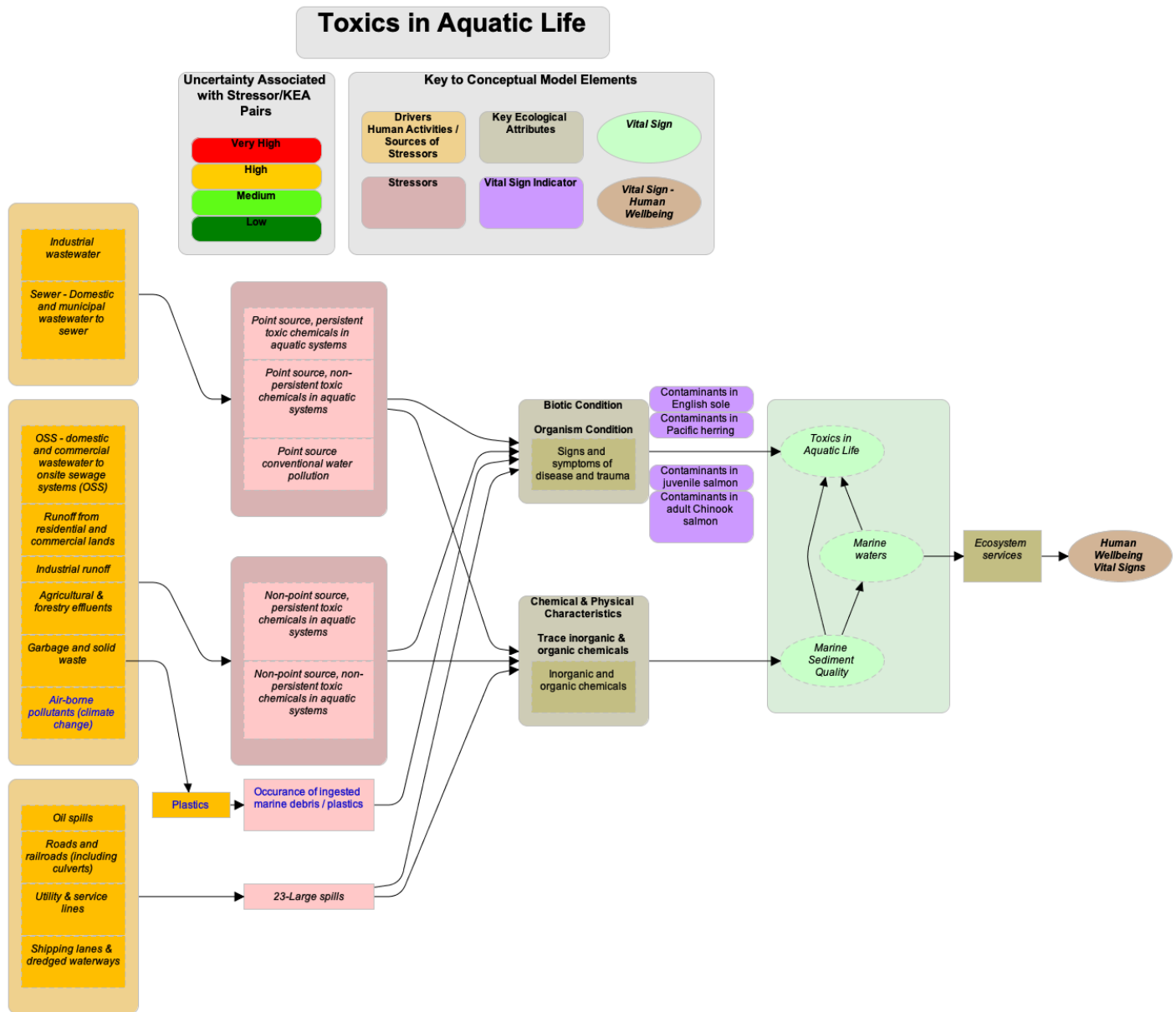


Figure 3b: Marine Sediment Quality



Appendix C, Figure 4: Conceptual Model for Toxics in Aquatic Life Vital Sign



Appendix C, Figure 5: Conceptual Models for Beaches and Marine Vegetation Vital Sign

Figure 5a: Beaches

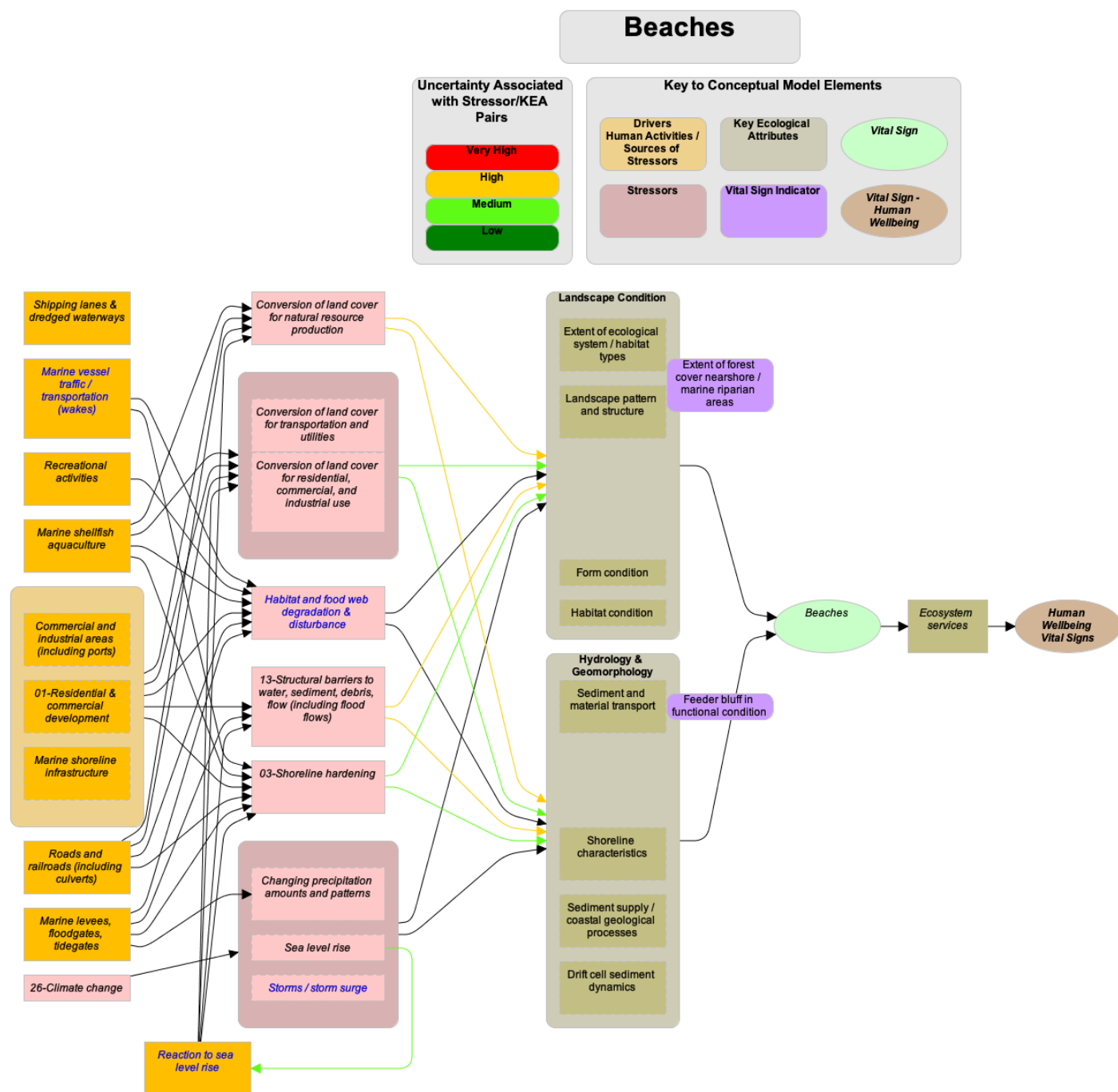
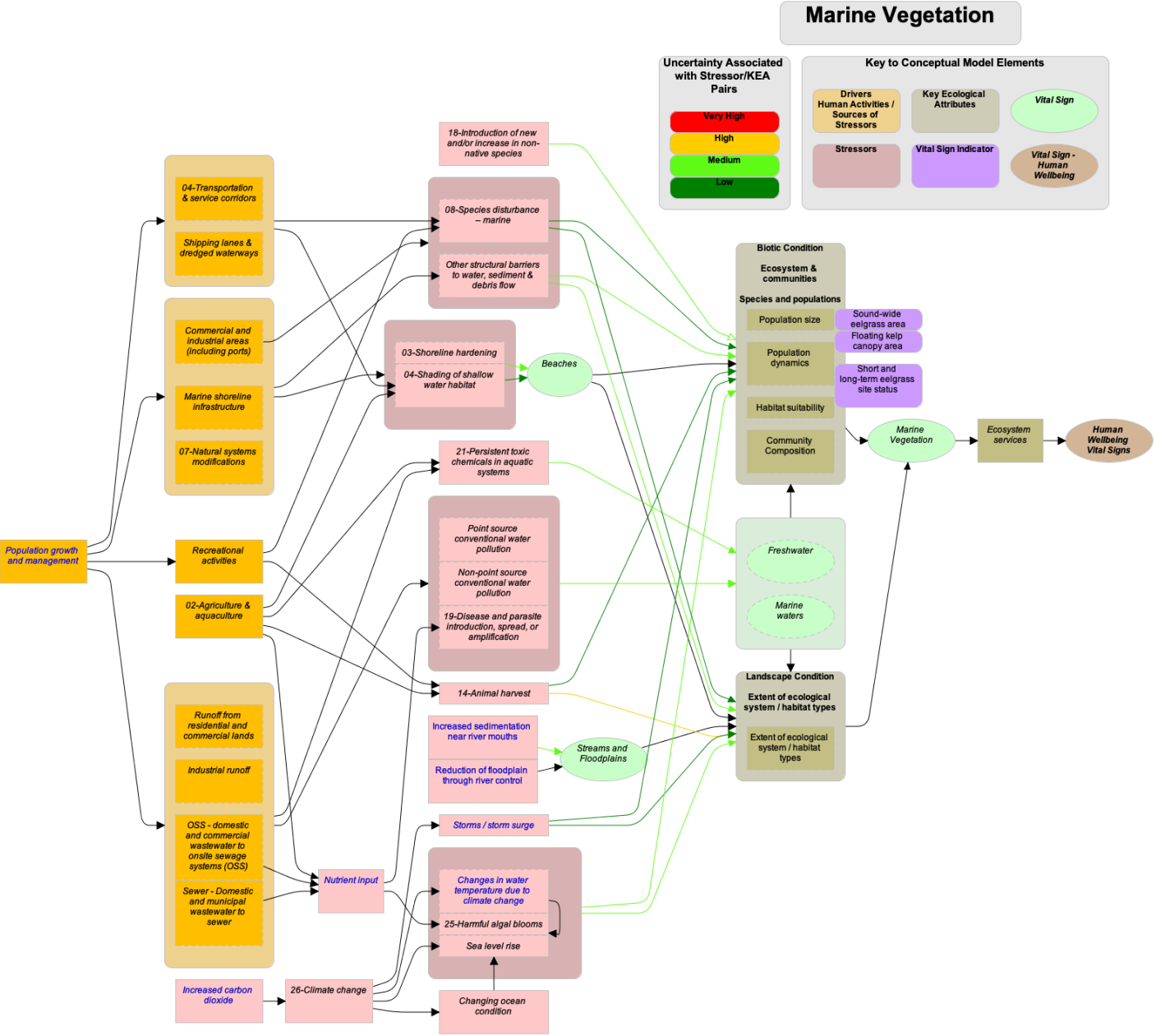
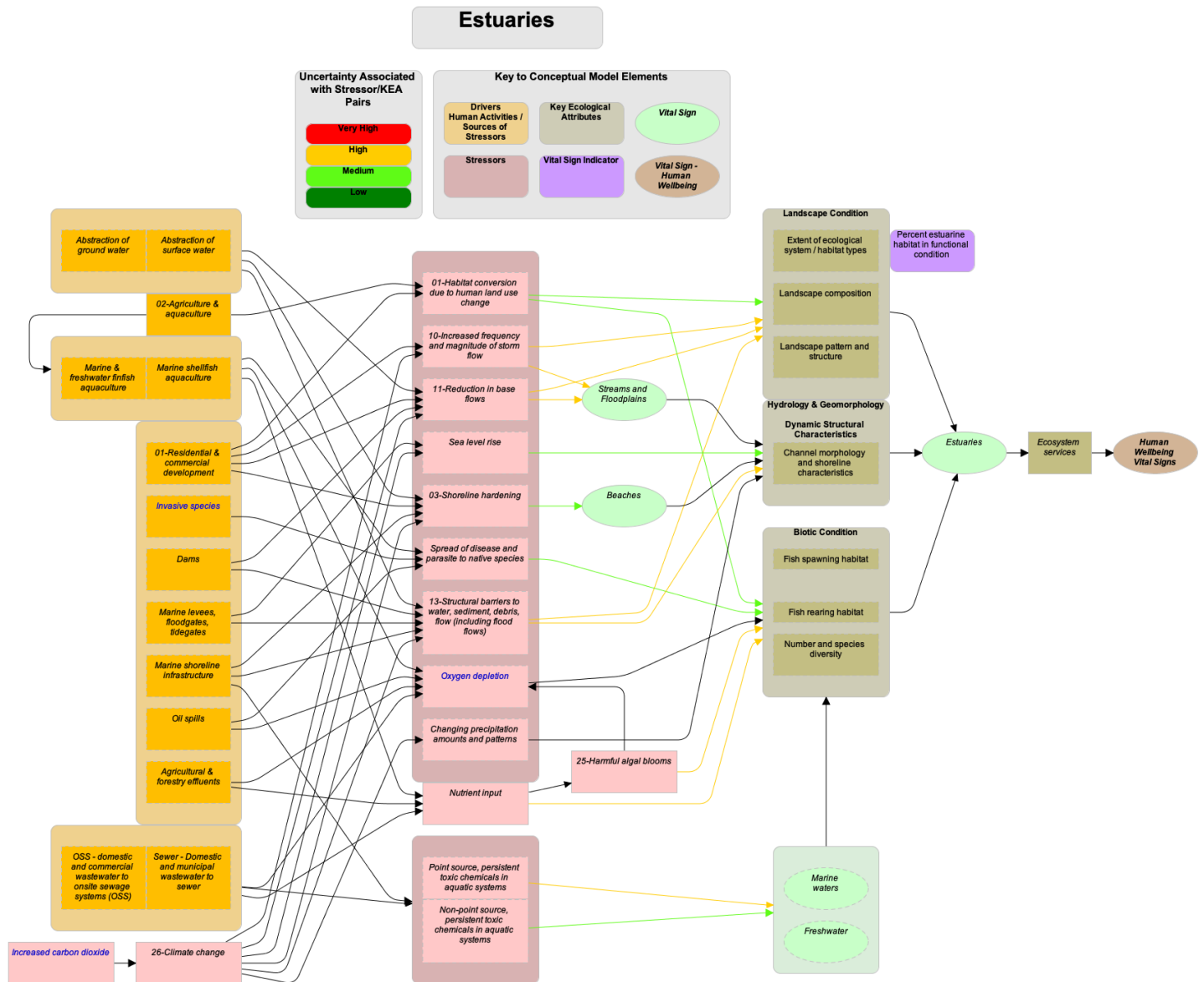


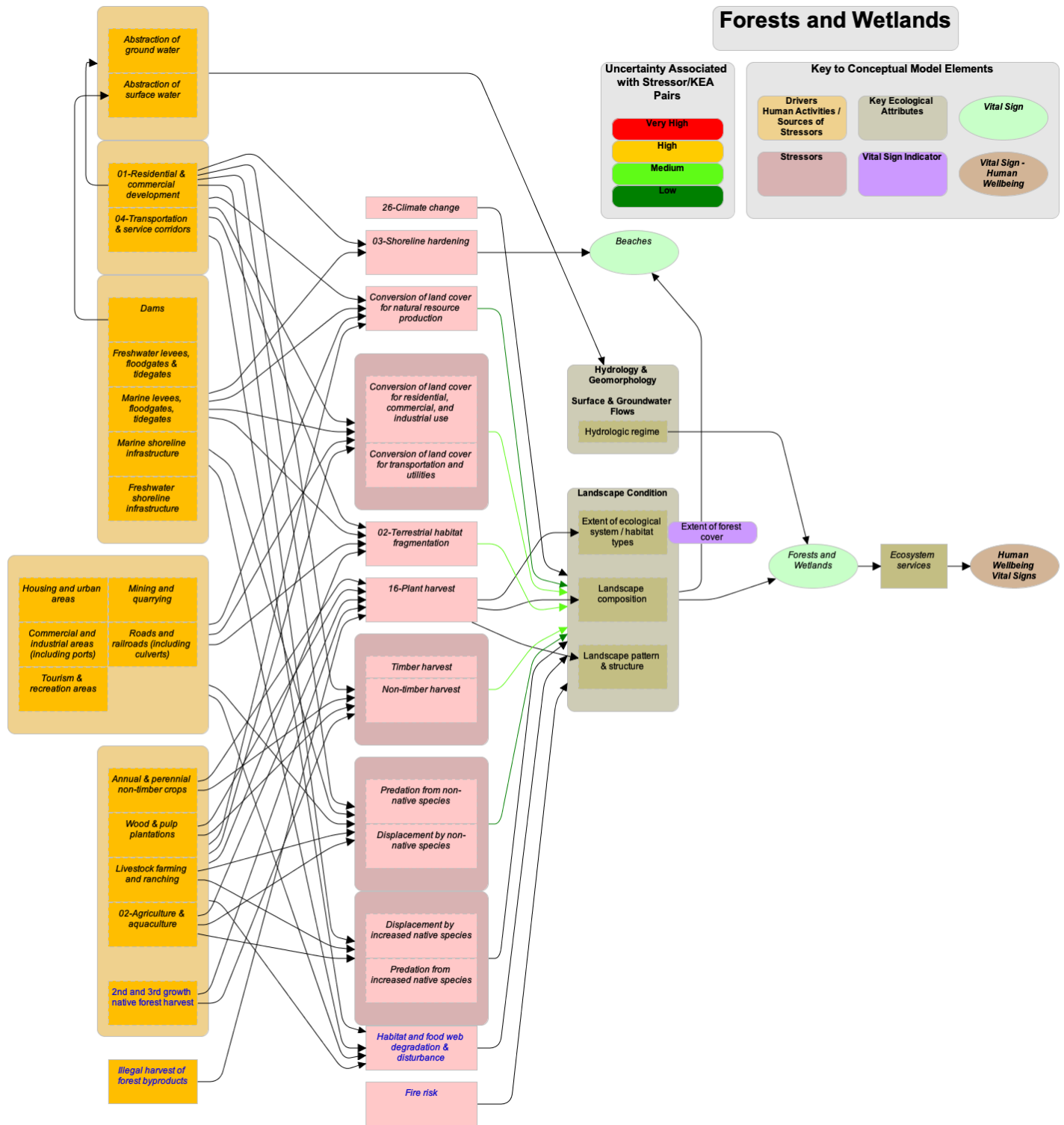
Figure 5b: Marine Vegetation



Appendix C, Figure 6: Conceptual Model for Estuaries Vital Sign

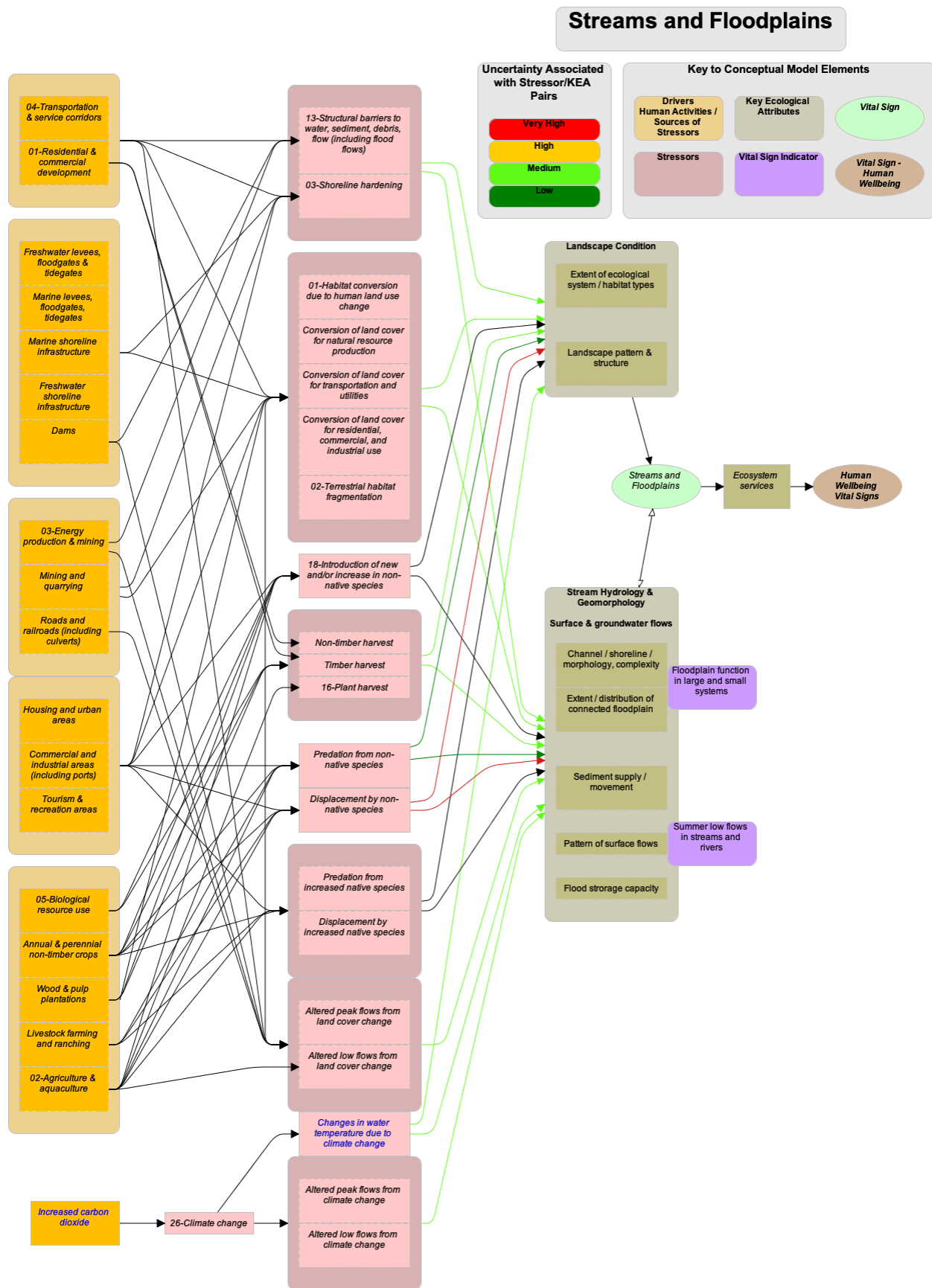


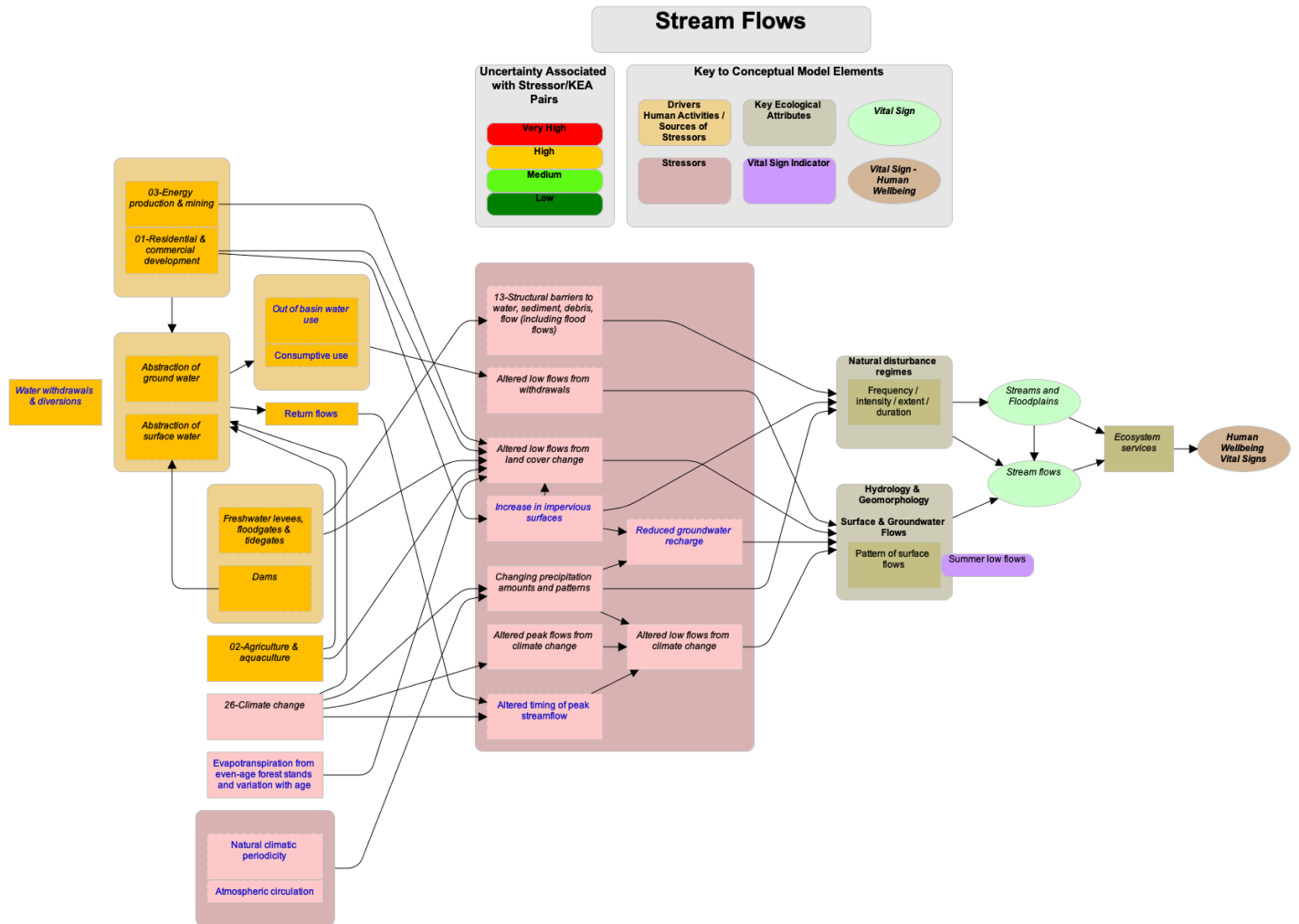
Appendix C, Figure 7: Conceptual Model for Forests and Wetlands Vital Sign



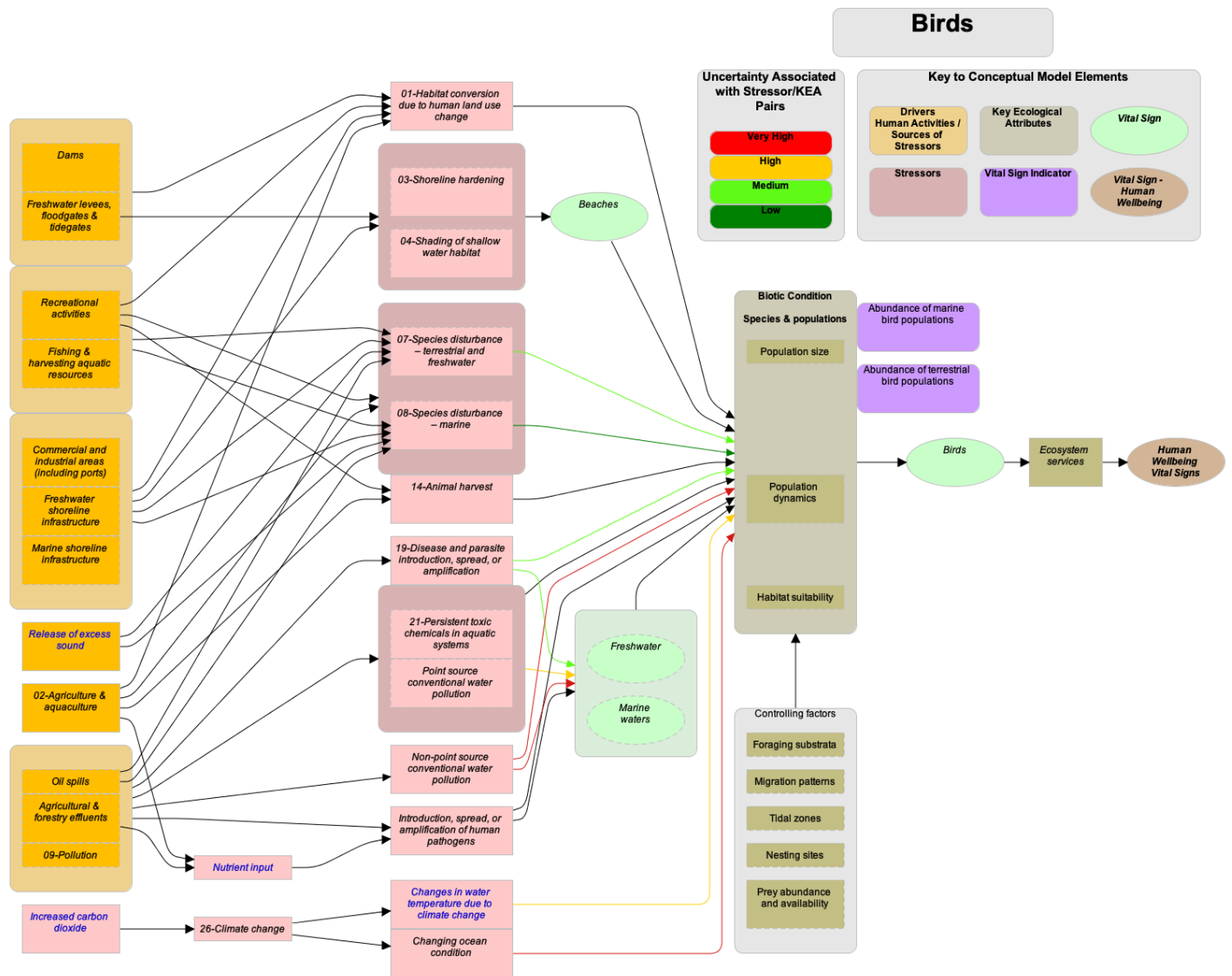
Appendix C, Figure 8: Conceptual Model for Streams and Floodplains Vital Sign

8a: Streams and Floodplains

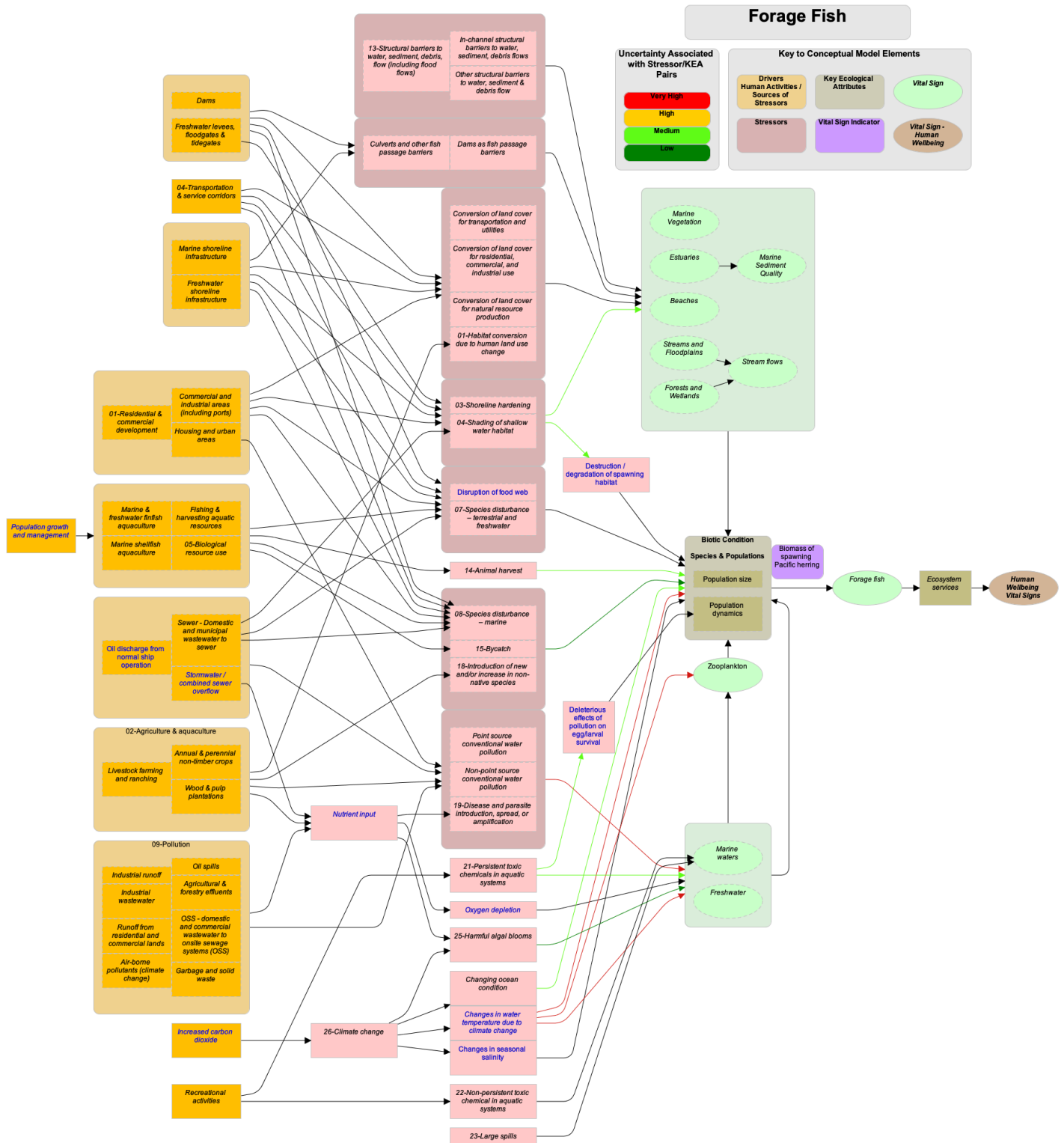




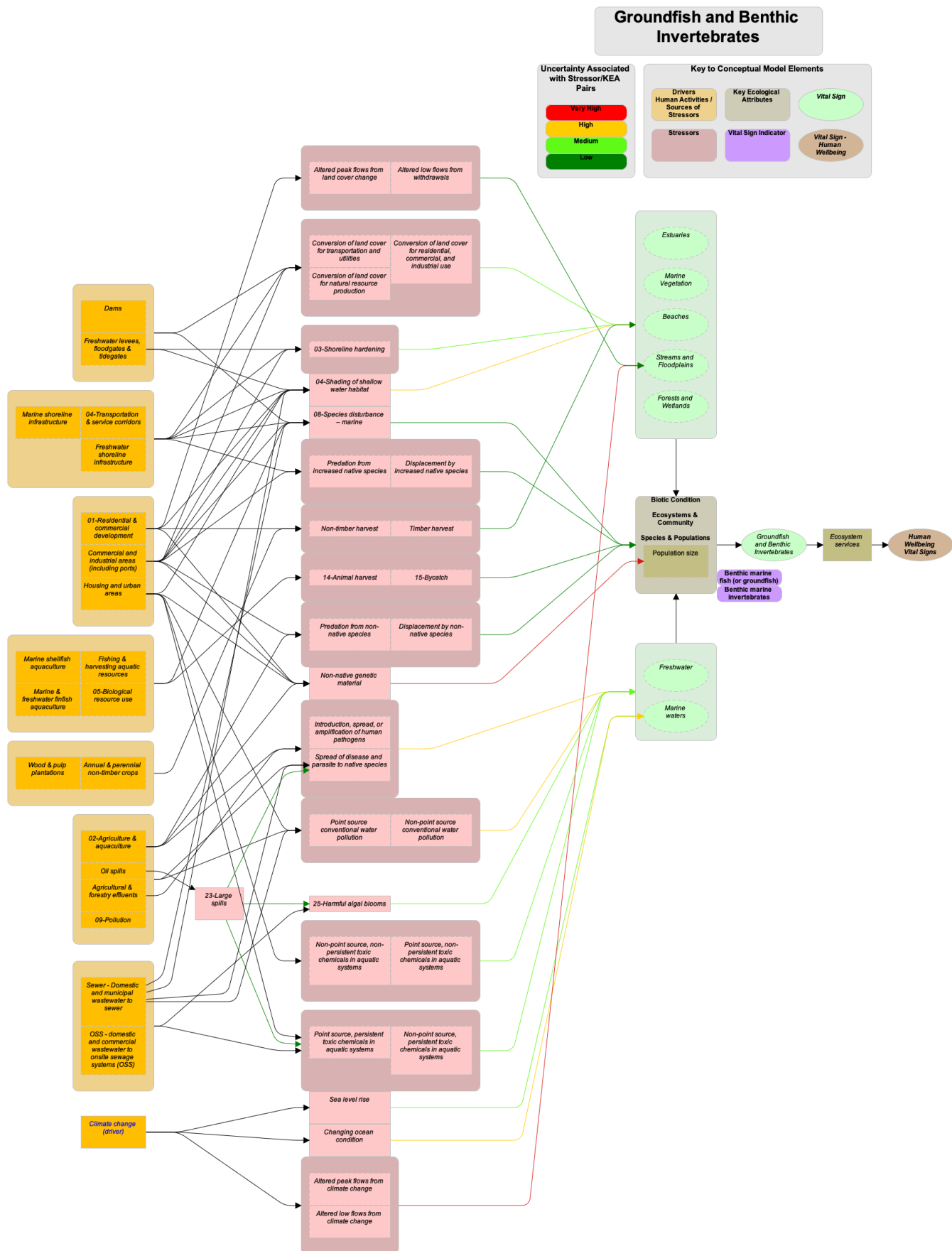
Appendix C, Figure 9: Conceptual Model for Birds Vital Sign



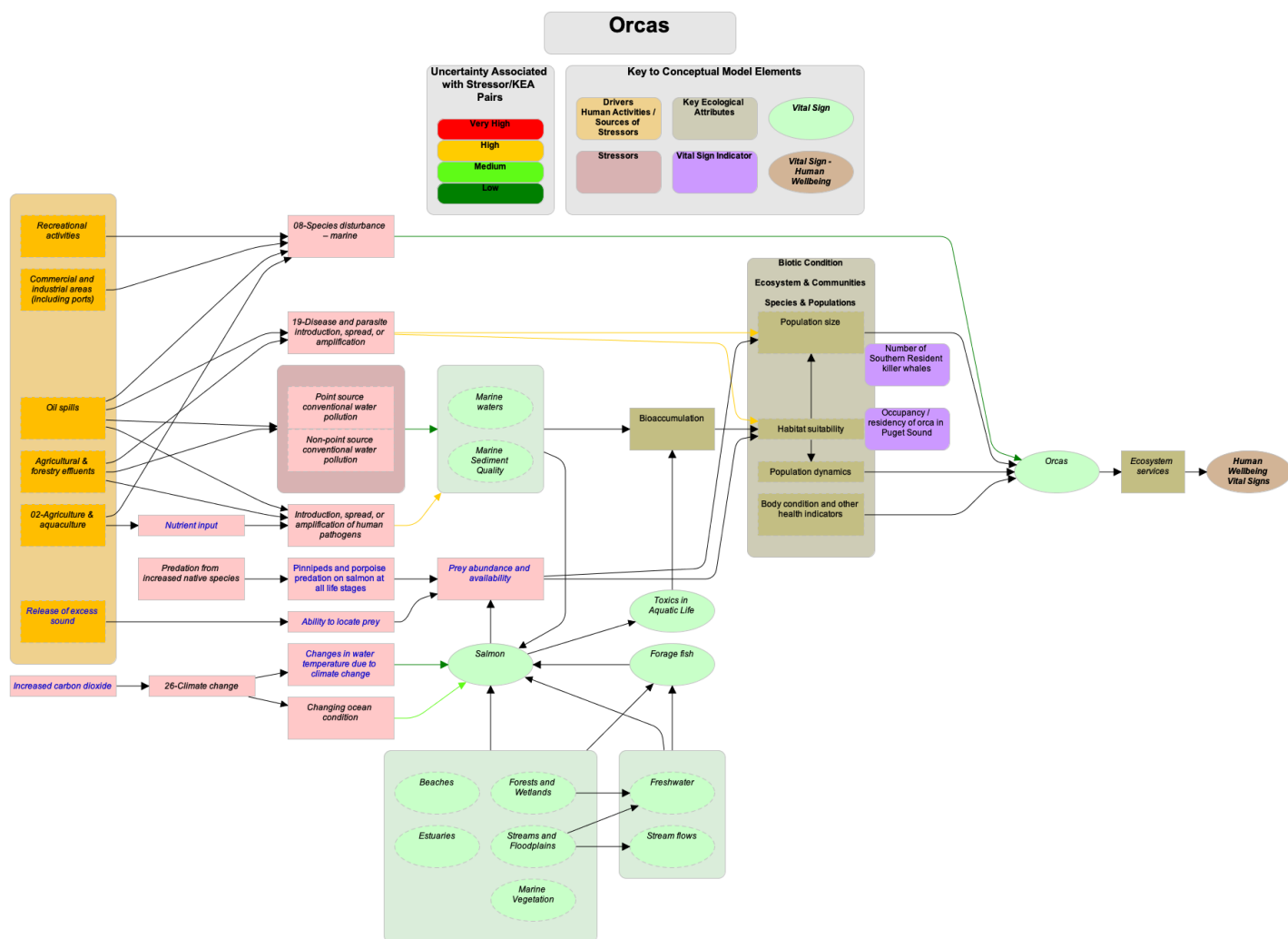
Appendix C, Figure 10: Conceptual Model for Forage Fish Vital Sign



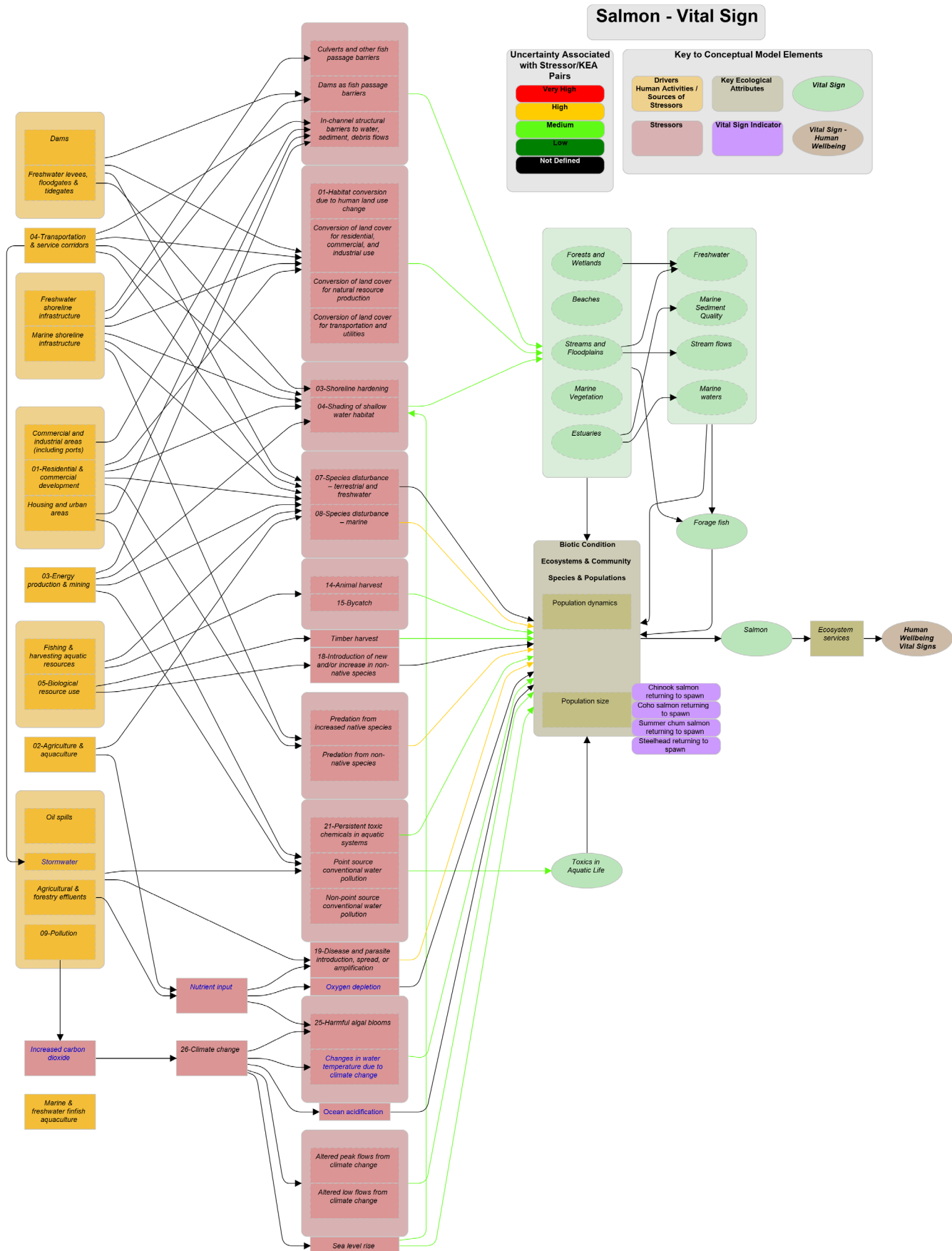
Appendix C, Figure 11: Groundfish and Benthic Invertebrates Vital Sign



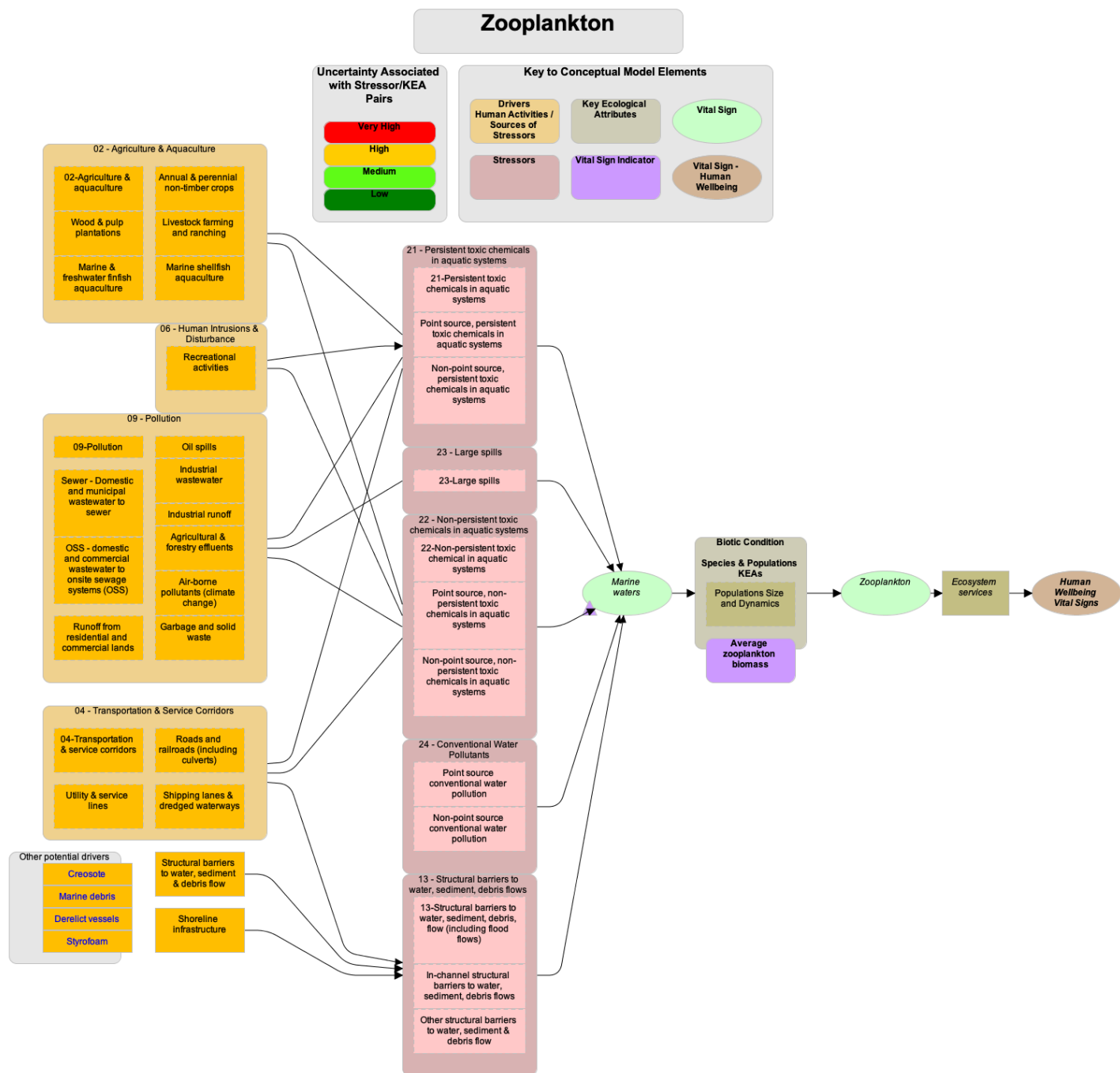
Appendix C, Figure 12: Conceptual Model for Orcas Vital Sign



Appendix C, Figure 13: Conceptual Model for Salmon Vital Sign



Appendix C, Figure 14: Conceptual Model for Zooplankton Vital Sign



Appendix D: May 2020 Focus Group Insights on Naming Vital Signs

In spring 2020, the Puget Sound Partnership commissioned the Center for Economic and Business Research at Western Washington University to convene two focus groups to understand perspectives on the ability of various Vital Sign concepts to communicate and inspire action. A first focus group convened Puget Sound residents (referred to as “public”) online on May 6, 2020. There was no interaction among the 34 participants in this first group. A second focus group convened 11 Partnership board members online on May 20, 2020. Six of the 11 participants in this second group discussed issues with the facilitator.

Reports on the focus group findings are available online: [May 6](#) and [May 20](#).

Partnership staff have summarized insights from the two focus groups in the table below. Staff used these insights to develop and evaluate the Vital Sign options presented to the Leadership Council.

OPTION 1: VITAL SIGN	FOCUS GROUP INSIGHTS
Freshwater Other names considered: Freshwater conditions Freshwater quality Clean freshwater	- Strong public preference for freshwater conditions (82%) rather than clean freshwater (15%) ~40% more public “fully” understand <u>freshwater conditions</u> than “not” <u>Freshwater conditions</u> in lower ½ of “fully” understood by board members <u>Freshwater quality</u> among bottom 5 to “inspire” public to learn more <u>Freshwater conditions</u>: among 2nd tier to “inspire” board members to learn more <u>Freshwater conditions</u>: near top scorer to “inspire” board members to take action AND expect change
Marine water Also considered: Marine conditions Saltwater conditions Marine water quality Marine sediment quality Also considered separate Vital Sign for marine sediment quality (Option 1) Also considered combining with Toxics in Aquatic Life (Option 4)	- Public preference for marine conditions (53%) rather than saltwater conditions (24%) - Public preference for combined (56%) rather than separate marine water and sediment (34%) - Strong public preference for marine water & sediment quality (79%) rather than conditions (18%) 54% more public “fully” understand <u>marine water quality</u> than “not” - Only 13% more public “fully” understand for <u>marine condition</u> than “not” <u>Marine water quality</u>: among top scoring “fully” understood by board members <u>Marine water quality</u>: among bottom 5 to “inspire” public to learn more <u>Marine water quality</u>: near-top scorer to “inspire” public to take action AND expect change in others <u>Marine water quality</u>: top scorer to “inspire” board members to take action AND expect change <u>Marine condition</u>: near top scoring to “inspire” board members to take action <u>Marine sediment quality</u>: 27% more public “not” understand than “fully” <u>Marine sediment quality</u>: among least well understood by board members <u>Marine sediment quality</u>: least “important” to board members <u>Marine sediment quality</u>: top 5 “inspire” public to learn more <u>Marine sediment quality</u>: among lowest scoring to “inspire” board members to learn more <u>Marine sediment quality</u>: among lowest scoring for public to expect & ask others to change <u>Marine sediment quality</u>: among lowest scoring for board members to expect & ask others to change
Toxics in aquatic life Other name considered: Toxics in fish Also considered combining into marine conditions (Option 4)	- Strong public preference for Toxics in Aquatic Life (91%) rather than Toxics in Fish (9%) - Slight public preference to keep separate (48%) rather than combine (42%) to marine conditions - Only 6% more public “fully” understand than “not” - Among least well understood by board members <u>Toxics in fish</u>: top scoring for public to expect & ask others to change - Near top scoring to “inspire” board members to take action AND expect & ask others to change
Forests and wetlands Other names considered: Watersheds Forests, rivers, and streams Also considered combinations with rivers, streams, and stream flows (Options 2, 3, and 4)	- Public preference for “forests, rivers, and streams” (55%) rather than separate components (42%) - Public preference for “watersheds” (50%) rather than “forests, rivers, and streams” (38%) - Rather strong public preference for forests, wetlands, rivers & streams (63%) over watersheds (32%) 96% of public “fully” understand & 0% “not” understand - Among 2nd tier as “fully” understood by board members ~70% more public “fully” understand <u>watersheds</u> than “not” <u>Watersheds</u>: among top scoring “fully” understood by board members - Among 2nd tier to “inspire” board members to learn more (as is <u>watersheds</u>) - Near top scoring to “inspire” board members to take action (as is <u>watersheds</u>) - Top scorer for board members to expect and ask other to change

OPTION 1: VITAL SIGN	FOCUS GROUP INSIGHTS
Streams and floodplains Other names considered: Rivers and streams Stream flows Watersheds Forests, rivers, and streams Also considered combinations with forests and wetlands (Options 2, 3, and 4)	<u>Rivers & streams</u>: 100% of public “fully” understand <u>Stream flows</u>: ~40% more public “fully” understand than “not” <u>Rivers & streams</u>: among top scoring “fully” understood by board members <u>Stream flows</u>: among top scoring “fully” understood by board members <u>Floodplains</u> among lowest scoring to “inspire” public to learn AND take action AND expect others <u>Rivers & streams</u>: top scoring to “inspire” board members to learn more <u>Rivers & streams</u>: near top scoring to “inspire” board members to take action AND expect others <u>Stream flows</u>: among lowest scoring to “inspire” board members to learn more <u>Stream flows</u>: among lowest scoring to “inspire” public to take action AND expect change in others <u>Stream flows</u>: among 2nd tier to “inspire” board members to take action
Estuaries Also considered combining into nearshore habitats (Option 4)	- Rather strong public preference for combined “nearshore habitats” (61%) rather than separate (33%) - Public preference for name including estuaries & beaches (57%) instead of nearshore habitat (39%) ~70% more public “fully” understand than “not” - Among top scoring “fully” understood by board members - Top 5 “inspire” public to learn more - Among 2nd tier to “inspire” board members to learn more - Near top scoring to “inspire” board members to take action AND expect & ask change in others
Beaches Other name considered: Beaches and nearshore Also considered combining with marine vegetation (Option 3) or combining all 3 into nearshore habitats (Option 4)	- Public prefers separate marine vegetation from beaches & nearshore (61%) to combined (26%) - Public preference for name including estuaries & beaches (57%) instead of nearshore habitat (39%) ~70% more public “fully” understand <u>beaches & nearshore</u> than “not” ~70% more public “fully” understand <u>marine vegetation</u> than “not” <40% more public “fully” understand <u>nearshore habitats</u> than “not” <u>Beaches & nearshore</u>: among top scoring “fully” understood by board members <u>Marine vegetation</u>: in lower ½ of “fully” understood by board members <u>Nearshore habitats</u>: in lower ½ of “fully” understood by board members <u>Marine vegetation</u>: lowest scoring to “inspire” board members -- learn AND take action AND expect <u>Eelgrass</u>: among lowest scoring to “inspire” public to take action AND expect change in others <u>Beaches & nearshore</u>: among 2nd tier to “inspire” board members to take action
Orcas	85% of public “fully” understand & 0% “not” understand - Among top scoring “fully” understood by board members - Among 2nd tier to “inspire” board members to learn more - Near-top scorer to “inspire” public to take action - Near top scoring to “inspire” board members to take action AND expect & ask change in others
Birds Also considered combining into watersheds and marine food web (Option 4)	- Strong public preference to keep birds separate (84% forest & 65% sea) from their habitats (13%, 25%) 100% of public “fully” understand & 0% “not” understand - Among top scoring “fully” understood by board members - Among lowest scoring to “inspire” public to learn more - Among lowest scoring to “inspire” board members to take action - Near-top scorer for public to expect & ask others to change
Salmon	96% of public “fully” understand & 0% “not” understand - Among top scoring “fully” understood by board members <u>Chinook salmon</u> among bottom 5 to “inspire” public to learn more 2nd highest scoring to “inspire” board members to learn more - Top scorer to “inspire” board members to action AND to expect & ask others to change <u>Chinook salmon</u>: top scorer to “inspire” public to take action <u>Chinook salmon</u>: near top scorer for public to expect & ask others to change
Seafloor fish and invertebrates Other names considered: Marine fish & invertebrates Also considered combining into marine food web (Options 3 and 4)	- Public preference to combine into marine food web (45%) rather than keep separate (29%) ~40% more public “fully” understand than “not” - In lower ½ of “fully” understood by board members - Among lowest scoring to “inspire” board members to take action

OPTION 1: VITAL SIGN	FOCUS GROUP INSIGHTS
Base of marine food web Other names considered: Marine food web Also considered separating zooplankton and forage fish (Option 1) or combining with marine fish & invertebrates (Options 3 and 4)	• Strong public preference to combine (70%) rather than separate zooplankton & forage fish (12%) • No public preference for name forage fish & zooplankton (42%) rather than marine food web (45%) • ~40% more public “fully” understand than “not” • <u>Zooplankton</u>: 30% more public “fully” understand than not • <u>Forage fish</u>: 20% more public “fully” understand than not • Among 2nd tier as “fully” understood by board members • <u>Zooplankton</u>: In lower ½ of “fully” understood by board members • <u>Forage fish</u>: Among 2nd tier as “fully” understood by board members • Among lowest scoring to “inspire” board members to learn more AND expect others to change • <u>Forage fish</u>: among lowest scoring to “inspire” board members to take action • <u>Pacific herring</u>: among lowest scoring for public to expect & ask others to change

Appendix E: Fate of Existing Biophysical Vital Signs and Indicators

There are three tables in this appendix. Table 1 describes how the existing biophysical Vital Signs relate to revised biophysical Vital Signs, highlighting changes. Table 2 provides the information for existing biophysical indicators and Table 3 describes how the revised indicators relate to the indicators recommended in O'Neill et al. (2018) with changes highlighted.

Appendix E, Table 1: Comparison of Existing Biophysical Vital Signs to Revised Biophysical Vital Signs

Existing Measure Type	Existing Measure Name	Change Analysis - Existing VS and Indicators to Revision Effort Draft Recommendations
Vital Sign	Freshwater Quality	Changed name to Freshwater. Retained B-IBI indicator; replaced freshwater quality index with indicators for individual parameters (temperature, nutrients); retired freshwater impairments.
Vital Sign	Marine Water Quality	Changed name to Marine Water. Retained indicators for dissolved oxygen but revised to measure directly; replaced marine water condition index with measures for some individual parameter (temperature); added indicators for eutrophication (i.e., nutrients balance in marine waters), ocean acidification and primary production. Included sediment chemistry index and marine benthic index.
Vital Sign	Sediments	Combined with the Marine Water Vital Sign and retired the Marine Sediment Quality Vital Sign.
Vital Sign	Toxics in Fish	Changed name to Toxics in Aquatic Life; revised indicators to be more clearly domain-based and added indicators for nearshore and riverine domains.
Vital Sign	Summer Low Flows	Changed name to Streams and Floodplains, combined with Floodplain indicators.
Vital Sign	Land Development and Cover	Changed name to "Forests and Wetlands." Moved indicators for rate of forest cover lost to development, conversion of ecologically important lands, and growth in urban growth areas to Intermediate Progress Measures; added indicators for percent forest cover by watershed, forest condition and wetlands. Moved indicator for riparian restoration to Intermediate Progress Measures. Added new indicator of riparian cover in new "Rivers and Streams" Vital Sign.
Vital Sign	Floodplains	Incorporated floodplains indicators into a new Vital Sign for "Streams and Floodplains." Retired "Floodplains" Vital Sign.
Vital Sign	Eelgrass	Changed name to "Marine Vegetation" and incorporated into proposed "Beaches and Marine Vegetation" Vital Sign. Added indicators for condition of eelgrass beds, and floating and understory kelp.
Vital Sign	Estuaries	Revised Vital Sign description to refer to estuary condition and dropped reference to the 16 largest river deltas. Moved indicator of estuarine area returned to flooding to Intermediate Progress Measures, replaced with indicator of percent potential estuary habitat in functional condition. Added indicator for pocket estuaries. Retired indicator of percent estuary habitat meeting salmon recovery goals.
Vital Sign	Shoreline Armoring	Changed name to "Beaches and Marine Vegetation." Moved indicator of change in permitted shoreline armoring to Intermediate Progress Measures; moved indicator of use of soft shore techniques to Activity Progress Measures; renamed indicator of armor on feeder bluffs to feeder bluffs in functional condition. Added indicator for marine riparian vegetation.

Existing Measure Type	Existing Measure Name	Change Analysis - Existing VS and Indicators to Revision Effort Draft Recommendations
Vital Sign	Orcas	Added indicator for occupancy/residency of orca in the Salish Sea.
Vital Sign	Birds	Added potential future indicator for Estuarine Birds.
Vital Sign	Chinook Salmon	Changed name to "Salmon" and added indicators for Summer Chum, Steelhead, and Coho
Vital Sign	Pacific Herring	Changed name to Forage Fish and added indicators for other forage fish species. In some options these indicators were placed in a new Marine Food Webs Vital Sign and retired Forage Fish Vital Sign.

Appendix E, Table 2: Comparison of Current Biophysical Indicators to Revised Biophysical Indicators

Existing Vital Sign	Existing Indicator Name	Change Analysis - Existing VS and Indicators to Revision Effort Draft Recommendations
Freshwater quality	Freshwater Benthic Index of Biotic Integrity (BIBI) in streams	No change at indicator level; refinements in coverage, monitoring, and reporting needed, consistent with O'Neill et al. 2018
Freshwater quality	Water Quality Index	Retired based on small group recommendation and in favor of reporting individual parameters (temperature, nutrients) as two separate indicators (i.e., water temperature in streams and rivers); hope to replace with Ecology's proposal for continuous monitoring.
Freshwater quality	Freshwater impairments	Retired; moving away from Vital sign indicators that are based on regulatory standards; database and assessments are not designed to track change over time; assessments are infrequent (every 5+ years); consider other measures such as clean-up plans.
Marine Water Quality	Dissolved oxygen in marine waters	Revised to measure directly instead of via modeling.
Marine Water Quality	Marine Water Condition Index	Retired based on small group recommendations and in favor of reporting individual parameters (temperature and eutrophication related) as three separate indicators (i.e., water temperature in marine waters, dissolved oxygen in marine waters, and nutrients dynamics in marine waters).
Marine Sediment Quality	Sediment Chemistry Index	No change
Marine Sediment Quality	Chemicals exceeding sediment quality standards	Retired; moving away from Vital Sign indicators based on regulatory standards
Marine Sediment Quality	Sediment Quality Triad Index	Retired; monitoring program has changed and will no longer report; benthic invertebrates will continue to be monitored and reported under the new marine benthic index indicator
Toxics in Fish	Contaminants in English Sole	No change
Toxics in Fish	Contaminants in Pacific herring	No change
Toxics in Fish	Contaminants in juvenile salmon	No change
Toxics in Fish	Contaminants in adult Salmon	Revised to add periodic reporting of toxicopathic mortality of pre-spawning adult Coho salmon
Stream Flows	Summer low flows	Revised current indicator to report different types of systems in distinct groups
Land Development & Cover	Rate of forest cover loss to development	Reclassified as an Intermediate Progress Measure
Land Development & Cover	Conversion of ecologically important lands	Reclassified as an Intermediate Progress Measure

Existing Vital Sign	Existing Indicator Name	Change Analysis - Existing VS and Indicators to Revision Effort Draft Recommendations
Land Development & Cover	Growth in Urban Growth Areas	Reclassified as an Intermediate Progress Measure
Land Development & Cover	Riparian restoration	Moved to Intermediate Progress Measure
Floodplains	Floodplain function	This indicator has been under development. Revised current indicator now reports on floodplain function in both large and small systems, by system type. Framework to identify "small" systems needs development but is being worked on through Chinook Common Indicators.
Floodplains	Restoration of floodplains	Moved to Intermediate Progress Measure
Eelgrass	Sound-wide eelgrass area	No change
Estuaries	Area of estuarine wetlands restored to tidal flooding	Moved to Intermediate Progress Measure
Estuaries	Estuary restoration meeting salmon recovery goals	Retired
Shoreline Armoring	Net change in permitted shoreline armor	Reclassified as an Intermediate Progress Measure
Shoreline Armoring	Use of soft shore techniques	Reclassified as an Activity Progress Measure
Shoreline Armoring	Armor on feeder bluffs	Changed name to feeder bluffs in functional condition and modified the description to report the percent of feeder bluffs not armored.
Orcas	Abundance of Southern Resident killer whale	No change
Birds	Abundance of marine bird populations	No change
Birds	Terrestrial bird population abundance	No change
Chinook Salmon	Chinook Salmon returning to spawn	No change
Pacific Herring	Biomass of spawning Pacific herring	No change

Appendix E, Table 3: Comparison of O'Neill et al. 2018 Indicators Recommendations to Revised Indicators

Indicator	O'Neill et al. 2018 Recommendation	Consistency between O'Neill et al. 2018 and proposed revisions	Additional Detail
Freshwater Benthic Index of Biotic Integrity (BIBI)	Keep existing indicator	Consistent	Added "in streams" to name
Water Quality Index	Keep existing indicator	Consistent but covered differently - split into multiple indicators	O'Neill et al. recommended keeping the water quality index; small groups recommended to measure parameters of temperature and nutrients as separate indicators (i.e., water temperature in streams and rivers and nutrients in stream and rivers) and retire the index.
Freshwater impairments	Retire indicator	Consistent	Database of impairments, based on opportunistic observations, is not designed for ecosystem monitoring.

Indicator	O'Neill et al. 2018 Recommendation	Consistency between O'Neill et al. 2018 and proposed revisions	Additional Detail
Pesticides in small streams	Add new indicator	Not consistent	Small groups believe pesticides too difficult to catch without continuous monitoring and continuous monitoring would likely not be feasible; they recommended to set this measure aside.
Periphyton biomass (chlorophyll a) in streams	Add new indicator	Not consistent	O'Neill et al. recommended this metric as an indicator of primary production but also noted use of trophic diatom index by some groups in the region. Small groups considered moving forward with trophic diatom index indicator but ultimately did not move forward with this measure.
Dissolved oxygen in marine waters	Keep existing indicator	Consistent but covered differently – modified metric	O'Neill et al. recommended keeping existing indicator, which is based on modeled DO, small groups recommended changing the metric to measure DO directly instead of through modeling.
Ocean acidification	Add new indicator	Consistent but covered differently	O'Neill et al. recommended measuring pH of seawater but noted that the final metric needed TBD. Small group recommend modifying and expanding the indicator to include both water carbonate chemistry measured as 'Omega-saturation' and the ability for biological calcification in Puget Sound.
Chlorophyll A	Add new indicator	Consistent but covered differently	O'Neill recommended as a new marine water quality Vital Sign indicator to measure energy flow related to primary production; small groups did not support this measure and instead sent forward a recommendation to develop a more direct primary production measure that accounts for bottom-up and top-down processes.
Marine Water Condition Index	Keep existing indicator	Consistent but covered differently – split into multiple indicators	O'Neill et al. recommended keeping the marine water condition index that measured various changes in marine water quality parameters like temperature, oxygen, and several relevant to eutrophication; small groups recommended to measure parameters of temperature, DO, and eutrophication as separate indicators (i.e., dissolved oxygen in marine water, nutrient dynamics in marine waters, and water temperature in marine waters).
Regional Air Temperature	Add new indicator	Consistent but covered differently	O'Neill et al. recommended measuring mean annual air temperature in the Puget Sound lowland as a proxy for regional ocean temperature; small group recommended a modified metric to instead measure temperature directly in marine waters because of available data from long-term monitoring buoys.
Marine Benthic Index	Add new indicator	Consistent	
Sediment Chemistry Index	Keep existing indicator	Consistent	
Chemicals exceeding sediment quality standards	Retire indicator	Consistent	
Sediment Quality Triad Index	Retire indicator	Consistent	
Toxic chemical contaminants in English sole	Keep existing indicator	Consistent	Name changed to Contaminants in English sole. This indicator includes metrics to assess fish health and human health (i.e., seafood safety).
Toxic chemical contaminants in Pacific herring	Keep existing indicator	Consistent	Name changed to Contaminants in Pacific herring. This indicator includes metric to assess fish health and trophic transfer of contaminants to other species in the marine food web.

Indicator	O'Neill et al. 2018 Recommendation	Consistency between O'Neill et al. 2018 and proposed revisions	Additional Detail
Toxic chemical contaminants in juvenile salmon	Keep existing indicator	Consistent	Name changed to Contaminants in juvenile salmon. This indicator includes metrics to assess fish health and was intended to encompass contaminants accumulated in the transition between the freshwater and marine domain (i.e., river estuary and marine nearshore) for juvenile forms of all salmon and steelhead species. However, due to limited funding, WDFW only consistently reports on contaminant in juvenile Chinook salmon.
Toxic chemical contaminants in adult salmon	Keep existing indicator	Consistent	Name changed to Contaminants in adult salmon. This indicator includes metrics to assess human health (i.e., seafood safety) accumulated in the marine domain for adult forms of all salmonid species. However, due to limited funding, WDFW currently only reports on contaminant in resident Chinook salmon.
Toxic contaminant levels in resident fish in lakes and rivers	Add new indicator	Not consistent	Small groups preferred to set this indicator aside because of the difficulty connecting resident species in lakes and rivers to Puget Sound and in the interest of having a more manageable number of indicators focused more cleanly on Puget Sound.
Coho pre-spawn mortality	Add new indicator	Not consistent	Small groups did not support this as a stand-alone measure because of concerns about geographic coverage and ability to connect to management actions. Recommendation is to measure this periodically as part of the contaminants in adult salmon indicator in the Toxics in Aquatic Life VS.
Summer low flows in streams and rivers	Keep existing indicator	Consistent	
Snowpack	Add new indicator	Consistent but covered differently	Small groups preferred to measure as ancillary; important to understand VS and indicator condition but unlikely to be impacted significantly by management actions.
Frequency of flood events	Add new indicator	Consistent	
Timing of peak stream flow	Add new indicator	Consistent but covered differently	Small groups preferred to measure as ancillary; important to understand VS and indicator condition but unlikely to be impacted significantly by management actions.
Wetlands extent	Add new indicator	Consistent	Included as a potential future indicator; metric TBD.
Rate of forest cover loss to development	Keep existing indicator	Consistent but covered differently	This measure, described as a pressure by O'Neill et al., was maintained but will be reclassified as an IPM instead of as a Vital Sign indicator, consistent with the new Progress Measures Framework.
Conversion of ecologically important lands	Keep existing indicator	Consistent but covered differently	O'Neill et al. noted this was a pressure but kept the indicator because of high interest in this indicator. This measure was maintained but will be reclassified as an IPM instead of as a Vital Sign indicator, consistent with the new Progress Measures Framework
Growth in Urban Growth Areas	Retire indicator	Consistent	O'Neill et al. concluded this was a measure of implemented management action. Reclassified as an IPM.
Floodplain function in large and small systems	Keep existing indicator	Consistent	
Riparian restoration	Retire indicator	Consistent	This measure was maintained but will be reclassified as an Intermediate Progress Measure instead of as a Vital Sign indicator, consistent with the new Progress Measures Framework

Indicator	O'Neill et al. 2018 Recommendation	Consistency between O'Neill et al. 2018 and proposed revisions	Additional Detail
Floodplain restoration (three separate metrics)	Keep two of three existing metrics (extent of floodplain)	Consistent but covered differently	O'Neill et al. noted that indicator contained three separate metrics: extent of floodplains (a measure of landscape condition), degraded floodplains (a measure of pressure/process), and number of projects implemented to restore floodplains (a measure of management actions to restore floodplains), but only the first two metrics were retained as biophysical indicators. The measure of number of projects implemented was maintained but will be reclassified as an Intermediate Progress Measure instead of as a Vital Sign indicator, consistent with the new Progress Measures Framework.
River/stream physical habitat	Add new indicator	Not consistent	Small group preferred to cover this in an ancillary measure of habitat complexity, which includes wood abundance, instead of as a Vital Sign indicator. The habitat complexity measure is under development as part of the Chinook Common Indicators work.
Extent of forested marine shoreline	Add new indicator	Consistent	Changed the name to Extent of marine riparian vegetation.
Freshwater riparian buffer width	Add new indicator	Consistent, covered differently	Covered by new indicator (i.e., Tree cover in riparian zones) consistent with Chinook Common Indicators. The proposed indicator measures % cover and acreage greater than a specific width.
Eelgrass Area	Keep existing indicator	Consistent	
Area of estuarine wetlands restored to tidal flooding	Retire indicator	Consistent	O'Neill et al. noted the indicator metric was a measure of a management response indicator and was replaced by a newly proposed indicator, estuary area and function. Moved to be considered as IPM.
Estuary restoration meeting salmon recovery goals	Retire indicator	Consistent	O'Neill et al. concluded this was a measure of implemented management action. This measure was retired.
Estuary area and function	Add new indicator	Consistent but covered differently	Covered by indicator of percent potential estuary in functional condition, consistent with CCI measure.
Net change in permitted shoreline armor	Keep existing indicator	Consistent but covered differently	O'Neill et al. noted that this was a pressure indicator but kept because of high interest. This measure was maintained but will be re-classified as an IPM instead of as a Vital Sign indicator, consistent with the new Progress Measures Framework.
Use of soft shore techniques	Retire indicator	Consistent	O'Neill et al. concluded this was a measure of implemented best management practices. This measure was maintained but will be reclassified as an APM instead of as a Vital Sign indicator, consistent with the new Progress Measures Framework.
Armor on feeder bluffs	Retire indicator	Consistent	O'Neill et al. noted this was a focused measure of pressure on bluffs that affect sediment supply to the nearshore. In the VS revision process, this indicator was renamed to Feeder bluffs in functional condition and the metric was changed to report on of feeder bluffs not armored.
Sediment supply to rivers	Add new indicator	Not consistent	Small groups could not determine a way to measure this indicator and set it aside.
Sediment supply to the nearshore	Add new indicator	Consistent	O'Neill et. al. noted this as a measure TBD. In the VS revision process the small groups identify Drift cells in functional condition as the proposed indicator.
Number of Southern Resident killer whales	Keep existing indicator	Consistent	

Indicator	O'Neill et al. 2018 Recommendation	Consistency between O'Neill et al. 2018 and proposed revisions	Additional Detail
Abundance of marine bird populations	Keep existing indicator	Consistent	
Abundance of terrestrial bird populations	Keep existing indicator	Consistent	
Chinook Salmon returning to spawn	Keep existing indicator	Consistent	
Biomass of spawning Pacific herring	Keep existing indicator	Consistent	
Zooplankton Index	Add new indicator	Consistent	

Appendix F: Revised Vital Signs, Indicators, and Potential Future Indicators

Appendix F, Table 1: Revised Vital Signs, Indicators, and Potential Future Indicators with Measure Descriptions.*

Vital Sign names and descriptions are in **bold**. Indicators in plain type. Potential future indicators are in *italics*.

Measure Name	Measure Description
Freshwater	This Vital Sign tells us about the condition of the freshwater that is vital to people, fish, and wildlife populations and helps us understand whether efforts to reduce excessive sediments and nutrients in our rivers and streams are effective.
Freshwater Benthic Index of Biotic Integrity (B-IBI)	Biological condition of stream sites and their surrounding habitat based on the diversity and relative abundance of the benthic (bottom-dwelling) macroinvertebrates, summarized and scored on a scale from 0 to 100, with higher scores indicating better biological condition.
Water temperature in streams and rivers	Field-based discrete and continuous measurements of the seven-day rolling averages for temperature in streams and rivers, at representative spatial and temporal scales for the Puget Sound ecosystem, to determine the frequency and extent to which temperature is above biological requirements of aquatic species for survival and recovery. This will enable an understanding of current status and trends of thermal thresholds in order to provide protection and mitigation strategies for aquatic species in freshwater systems.
Nutrients in streams and rivers	Field-based measurements of nitrogen and phosphorous concentrations from discrete samples and nitrate concentrations from continuous monitoring in large rivers, at representative spatial and temporal scales for the Puget Sound ecosystem. This will enable an understanding of nutrient loading from major freshwater river systems connected to Puget Sound.
Marine Water	This Vital Sign tells us about the condition of marine waters and associated sediment and the combined impacts of global change and local human-caused stresses on Puget Sound marine waters and sediments; it helps us understand whether efforts to reduce pollutants to marine waters are effective.
Dissolved oxygen in marine waters	Direct, field-based measurements of dissolved oxygen, at representative spatial and temporal scales for the Puget Sound ecosystem (nearshore to pelagic), to determine the frequency and extent of the marine water column where dissolved oxygen is below two biologically meaningful thresholds. This will enable an understanding of the extent of low oxygen over time and space that may affect species. This also provides insights into the dynamics of low dissolved oxygen zones in response to regional and global climate-driven and human stressors.
Marine Benthic Index	Marine benthic infaunal community composition and condition to be measured by one of a suite of measures currently being evaluated, including the Benthic Quality Index (BQI), the AZTI Marine Biotic Index (AMBI), variants of AMBI, and a multimetric indicator to be developed from benthic community and habitat variables specific to Puget Sound. Before January 2022 Ecology staff will select the index that performs best for Puget Sound.

Measure Name	Measure Description
Marine water temperature	Direct, field-based measurements of water temperature, at representative spatial and temporal scales for the Puget Sound ecosystem (nearshore to pelagic, annual and seasonal). This will enable an understanding of variation in positive temperature anomalies over time and space and provide insights on the habitat quality for marine organisms.
Nutrient balance in marine waters	Direct, field-based measurements of the ratio of silicon to nitrogen, at representative spatial and temporal scales for the Puget Sound ecosystem. This will enable an understanding of whether Puget Sound has a nutrient balance that supports lipid-rich diatoms all year round, creating the base of the Puget Sound food web.
Ocean acidification	A compound indicator of (1) water carbonate chemistry measured as 'Omega-saturation' and (2) ability for biological calcification in Puget Sound.
Sediment Chemistry Index	Combines data on the concentrations of a variety of chemicals into an overall index of chemical exposure in sediments. Contaminants measured include metals, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and phthalates.
Marine Benthic Index, phase 2	<i>TBD, potentially a compound indicator comprising (1) an index of human-caused disturbance based on the relationships of the benthic invertebrate species to the habitat and (2) graphical causal modeling to elucidate interrelationships. The index of disturbance would be used to communicate biotic condition, level of disturbance, spatial extent of disturbance, and temporal or spatial trends. The graphical causal modeling would be used to hypothesize about causation and determine which direct or surrogate variables to measure to improve marine sediment monitoring.</i>
Noise in marine water	<i>TBD; Noise as an indicator of stressed condition in marine waters.</i>
Primary production in marine water	<i>TBD</i>
Toxics in Aquatic Life	This Vital Sign tells us about contaminants and the diseases they cause in indicator species that represent four major Puget Sound ecosystem habitats. Specific chemicals are selected to represent major contaminant classes.
Contaminants in adult salmon	Chemical concentrations in adult salmon. Focuses on Chinook and Coho salmon for seafood safety, reflecting periodic sampling of these species to update Dept of Health risk assessments. Periodic reporting of toxicopathic mortality of pre-spawning adult Coho salmon also will be reported.
Contaminants in English sole	Index site approach measuring chemical concentrations in English sole from Puget Sound fixed locations covering a wide range of contamination. Focuses on the benthic (seafloor) food web and contaminants that accumulate in sediments. This will enable understanding of contaminants in the marine benthic or seafloor habitat and whether our actions to prevent and reduce these contaminants are working.
Contaminants in juvenile salmon	Chemical concentrations in juvenile salmon. Focuses on river-to-Puget Sound interface in a sensitive salmon life stage, where many chemicals enter the system. This will enable understanding of contaminants in estuary habitat and whether our actions to prevent and reduce these contaminants are working.
Contaminants in Pacific herring	Chemical concentrations in Pacific herring. Focuses on the pelagic food web (food source to Chinook salmon and Southern Resident killer whales) and contaminants that are transported through the water column. This will enable understanding of contaminants in open water habitat and whether our actions to prevent and reduce these contaminants are working.
Contaminants in caged mussels	<i>Using translocation of uncontaminated mussels to nearshore locations for a set time period to measure uptake of chemicals from nearshore waters on a Puget Sound-wide basis. This will enable understanding of contaminants in nearshore habitat and whether our actions to prevent and reduce these contaminants are working.</i>
Beaches and Marine Vegetation	This Vital Sign tells us about the extent and condition of beaches and nearshore habitats in Puget Sound and helps us understand whether efforts to protect beaches and reduce shoreline hardening are working.
Eelgrass area	Areal extent (acres or hectares) of eelgrass beds calculated as a 3-year rolling average, with results reported annually.
Extent of forest cover extent in nearshore marine riparian areas	Percent and acreage of forested cover (vegetation ~8ft or taller) within 0–100-ft, 0–200-ft, and 100–200-ft riparian zones landward, from the existing shoreline, by major shore type.
Feeder bluffs in functional condition	Percent of feeder bluffs not armored, by drift cell.
Floating kelp canopy area	Areal extent (acres or hectares) of floating kelp canopies, derived from sites sampled in different geographic areas of Puget Sound.
Short and long-term eelgrass site status	The relative proportion of eelgrass sites that are increasing, decreasing, stable, or absent calculated over two time periods: (1) short-term (3 years); and (2) long-term (all data available).
Drift cells in functional condition	<i>TBD. Potentially a measure to integrate a number of attributes of drift cell function including 1) armor and overwater structures in the sediment supply and deposition zones as well as the transport reach; (2) marine riparian vegetation cover; and (3) forage fish presence/absence.</i>

Measure Name	Measure Description
<i>Miles of intertidal beach in functional condition</i>	<i>TBD. Potentially a measure to integrate a number of attributes of intertidal beach function, including potentially armor absence and placement (e.g., above the intertidal zone), overwater structures, and other attributes.</i>
<i>Understory kelp abundance and condition</i>	<i>Marine survey of understory kelp species' distribution, community composition, and trends. Indicator under development, candidates: areal extent, density, proportion of sites increasing/decreasing/stable/absent.</i>
Estuaries	This Vital Sign tells us about the condition of estuaries in Puget Sound and helps us understand whether efforts to protect and restore estuaries are working.
Percent of estuaries habitat area in functional condition	Amount of estuarine surface area in functional condition, defined by the extent of connected tidal wetlands and the extent of functional tidal channels based on aerial photography. Reported as a compound indicator for two estuary types: (1) the 16 large river deltas and (2) small estuaries.
<i>Number of accessible pocket estuaries and embayments</i>	<i>Number of pocket estuaries and embayments that are accessible to juvenile salmon at all tidal cycles. Calculated and reported as the sum of all mapped habitat features for all identified pocket estuaries and embayments.</i>
Forests and Wetlands	This Vital Sign tells us about the extent and condition of terrestrial habitats important to freshwater quality and the overall health of Puget Sound.
Extent of forest cover in the upper, middle, and lower areas of watersheds	Extent of forest cover (vegetation ~8ft or taller) by watershed, reported in the upper, middle, and lower watershed areas, but not freshwater or marine riparian zones, based on 1-meter aerial imagery updated every 2-3 years.
<i>Forest condition</i>	<i>TBD, potentially watershed area with low road density, e.g., road density below X amount, particularly in upper watersheds; effective impervious surface/area below X percent throughout the watershed; unfragmented areas, particularly in upper watersheds; natural disturbance related to fire.</i>
<i>Wetlands extent and condition</i>	<i>TBD, potentially freshwater wetland area, by type (or class), but not floodplain, estuarine, or salt marsh wetlands.</i>
Streams and Floodplains	This Vital Sign tells us about the extent and condition of streams, rivers, and associated floodplain and riparian habitats that are important to salmon recovery and overall Puget Sound health.
Floodplain function in large and small systems	An assessment of floodplain function is based on connectivity, land cover, and land use for the rivers of Puget Sound. Floodplain areas with natural land cover and unrestricted access by the river at all flow levels are expected to be functional and provide the most ecosystem services. Floodplain areas with land use in place and/or impeded river flow to the area due to roads, railroads, or levees will have impaired or loss of floodplain function. Report as a compound indicator by system type: (1) the 16 large river systems; and (2) remaining small river systems.
Summer low flows in streams and rivers	Seven-day minimum summer flows based on continuous discharge records at selected gauges throughout Puget Sound watersheds. Reported as a compound indicator, by drainage basin size, elevation, and the land use and cover within the drainage basin. Long-term trends will be assessed over 30-year moving windows, and seasonal rainfall and temperature will be explored as explanatory factors.
<i>Extent of forest cover in freshwater riparian zones</i>	<i>Percent forest cover and acreage (vegetation ~8ft or greater) in defined riparian zones.</i>
<i>Changes in hydrologic regime in streams and rivers</i>	<i>Amount of time each year the current hydrologic regime is different from the historic regime.</i>
<i>Frequency of flood events</i>	<i>TBD, Potentially number of annual flood events.</i>
Birds	This Vital Sign tells us about the abundance and distribution of populations of native resident and migratory species of birds and about Puget Sound ecosystem health and ecosystem change. The Vital Sign takes a community-based approach to indicators of species in marine and terrestrial habitats.
Abundance of marine bird populations	Compound indicator reported as: (1) Biannual spring/summer at-sea densities of rhinoceros auklet, pigeon guillemot, and marbled murrelet. These species are highly dependent on the marine environment, and breed in Puget Sound and Strait of Juan de Fuca. (2) Yearly population abundance and trends of three bird species that over-winter in the Puget Sound marine environment, which provides an integrative view of the health of species that depend upon the Puget Sound for survival. (Surf, black, and white-winged scoter).
Abundance of terrestrial bird populations	Compound indicator reported as: (1) Yearly breeding abundance of resident species associated with interior conifer forests, which measures the size of terrestrial bird populations that reside most, if not all, of the year in Puget Sound watersheds (golden-crowned kinglet, varied thrush, and brown creeper); and (2) yearly breeding abundance of human-associated resident species (American crow, rock pigeon, house sparrow, house finch, and European starling).

Measure Name	Measure Description
Estuarine birds	<i>TBD. An indicator of estuarine birds would help us understand whether estuaries are functioning to support the species which depend on them and the overall population trends for estuarine bird species that are important in their own right and as part of the Puget Sound food web.</i>
Forage Fish	This Vital Sign tell us about the abundance of forage fish in Puget Sound.
Biomass of spawning Pacific herring	The spawning biomass of Pacific herring, estimated as the annual tonnage of spawning herring in Puget Sound.
<i>Regional index of the stock presence and health of forage fish such as Sand Lance, Surf Smelt, and Anchovy</i>	<i>Index of presence and estimate of stock health for specific locations within Puget Sound. Example: age and condition factor. Methods may differ by species and will not be reported as a single rolled-up indicator (e.g. species may come online at different times).</i>
Groundfish & Benthic Invertebrates	This Vital Sign tells us about the abundance and distribution of resident marine fish that live on or near the seafloor, as well as crabs, shrimp, and other invertebrates, species which make up the majority of the food in the Puget Sound food web.
Abundance and biomass of groundfish	Abundance and biomass of marine fish that live on or near the seafloor. Reported as (1) yearly abundance and biomass of ratfish; (2) yearly abundance and biomass of round fish; (3) yearly abundance and biomass of flat fish.
Abundance and biomass of benthic marine invertebrates	Abundance and biomass of invertebrates that live on or near the seafloor reported as (1) yearly abundance and biomass of crab; (2) yearly abundance and biomass of shrimp; (3) yearly abundance and biomass of other invertebrates (urchin, sea stars, sea cucumbers, octopus, and others).
Orcas	This Vital Sign tells us about the abundance and distribution of orcas, how orcas are using Puget Sound, and whether the population of local killer whales is growing or continuing to decline.
Number of Southern Resident killer whales	Abundance of all individuals in the Southern Resident killer whale population, based on photo-id of individuals.
Occupancy/residency of orcas in Puget Sound	Number of days orcas are in Puget Sound and the balance of occupancy between SRKW and transient orcas reported as (1) number of days of the year that each SRKW is seen in Puget Sound and (2) number of days of the year that Biggs transients are seen in Puget Sound.
Salmon	This Vital Sign tells us about the abundance and distribution of salmon populations and helps us understand whether efforts to improve salmon habitat and coordinated management of harvest and hatcheries are having the desired effect of improving salmon populations.
Number of natural-origin Chinook salmon on spawning grounds	Chinook Salmon returning to spawn, as measured by the number of natural-origin adult fish returning to spawn. Chinook population abundance is reported here two ways: the number of natural-origin spawners and the number of natural-origin recruits (by population). Estimates the abundances of the 22 Chinook salmon populations from five Puget Sound regions as measured by the number of natural-origin adult fish on the spawning grounds. Reported by population, not as an aggregate of all populations.
Number of natural-origin Coho salmon on spawning grounds	Estimates the abundances of the Coho salmon populations from Puget Sound regions as measured by the number of natural-origin adult fish on the spawning grounds. Reported by population.
Number of natural-origin Steelhead salmon on spawning grounds	Estimates the abundances of the Steelhead populations from Puget Sound regions as measured by natural-origin adult fish on the spawning grounds. Reported by population.
Number of natural-origin Summer Chum salmon on spawning grounds	Estimates the abundances of the Summer Chum salmon populations from Puget Sound regions as measured by the number of natural-origin adult fish on the spawning grounds. Reported by population.
Zooplankton	This Vital Sign tells us about the abundance and distribution of zooplankton populations in Puget Sound.
Average zooplankton biomass	Average annual zooplankton biomass at sixteen locations in Puget Sound.
<i>Integrated annual zooplankton biomass</i>	<i>TBD. Potentially a more robust indicator of the health of zooplankton in marine waters, which would integrate sampling data from multiple sites and across multiple sampling periods per year to provide a single estimate of biomass and could replace average annual zooplankton biomass.</i>
<i>Zooplankton index</i>	<i>TBD. Potentially a new indicator of community composition of open waters of marine systems. The parameters to be measured will be determined based on current monitoring and may include changes in composition or frequency and distribution of jellyfish, Noctiluca miliaris, and other flagellate zooplankton.</i>

* Two potential future indicators related to salmon harvest and the extent and frequency of drought emergencies are recommended as measures of human wellbeing and not included in this table. Drought emergencies are declared by Ecology based on a combination of water availability (looking at storage and flows) and an economic hardship factor, reflective of water demand not being met.

Appendix G: Mapping of Recommended Measures to Puget Sound KEAs

The following tables provide additional information for how proposed indicators, potential future indicators, and ancillary measures map to the biophysical framework described in [O'Neill et al 2018](#). Table 1 provides the description of the KEAs defined in O'Neill et. al (2018) that more fully assess the proposed Vital Signs against the Puget Sound recovery goals and objectives. Table 2 provides a detailed mapping of each proposed indicator, potential future indicator, and ancillary measure to the biophysical framework.

Appendix G, Table 1: O'Neill (2018 Table 4-3) Recommendations of KEAs to More Fully Assess the Vital Signs and the Puget Sound Recovery Goals and Objectives.

	Attribute Category	Definition	Vital Sign KEA
Biotic Conditions	Ecosystems & Communities	Assemblage of species/taxa that inhabit an area and are tied together by similar ecological processes (e.g., fire, hydrology), underlying environmental features (e.g., soils, geology) or environmental gradients (e.g., elevation, temperature), and form a cohesive, distinguishable unit.	Community Composition
	Species & Population	Measures of the condition or viability of populations of species in an area are important indicators of biotic condition, yet monitoring the status of all species is impossible from a practical standpoint.	Population Size
			Population Dynamics
			Habitat Suitability
	Organism Condition	Health of individuals (e.g., for focal species or for species imperiled or vulnerable to extinction or extirpation from an area).	Signs and Symptoms of Disease or Trauma
Chemical & Physical Characteristics	Nutrient Concentrations	Measurements of nutrients related to the chemistry and productivity of streams and marine environments. Excess= trouble	Nitrogen/ Phosphorus/ Other Nutrients
	Trace Inorganic & Organic Chemicals	Baseline information on a broad spectrum of metals and organic chemicals in environmental samples is an important step in ecological assessments, whether their concentrations are elevated by pollutant discharges.	Metals/Other Trace Elements/ Organic Compounds
	Other Chemical Parameters	Other chemical parameters that should be reported will differ depending on the environmental compartment (water, air, soil, and/ or sediment) being assessed. In soils and sediments, for example, measures such as total organic matter, cation exchange capacity, and pH will be important. In aquatic environments, measures might include alkalinity, biochemical oxygen demand (BOD), dissolved organic carbon (DOC), and water transparency.	Dissolved Oxygen
			pH, Salinity
	Physical Parameters	Physical measures, many of which have been routinely collected for years, are an important complement to other measures of physical habitat.	Temperature, Turbidity, Suspended Solids
Ecological Processes	Energy Flow	The flow of energy between trophic levels and the interaction between heterotrophic and autotrophic components are universal features of ecosystems.	Primary Production

	Attribute Category	Definition	Vital Sign KEA
Hydrology and Geomorphology	Surface & Groundwater Flows	Surface and groundwater flows determine which habitats are wet or dry and when, and water flows transport nutrients and contaminants.	Pattern of Surface and Groundwater Flows
			Water Storage
	Dynamic Structural Characteristics	Maintenance of the diversity of natural habitats in aquatic systems is a dynamic process involving variations in water flow, erosion and deposition of sediments, and transport of other materials.	Channel / Shoreline / Morphology and Complexity
			Extent/ Distribution of Connected Floodplains
	Sediment & Material Transport	A wide variety of underwater and nearshore habitats (e.g., wetlands, early successional states in riparian areas) is maintained by the pattern of sediment and debris movement, and native species have adapted accordingly.	Sediment Supply/ Movement
Landscape Condition	Extent of Ecological System/Habitat Types	The areal extent of each habitat type within a landscape is important because a decrease in the total area of habitat available often is correlated with species decline (Wilson,1988; Saunders et al., 1991). Extent may be reported for broad land cover classes, for finer subunits, or both. In addition to area, the shape of habitat patches is an important consideration for many (e.g., edge-sensitive) species.	Extent of Ecological System/Habitat Types
	Landscape Composition	Landscape composition can be measured by several metrics. The number of land cover or habitat types can serve as a discrete measure but requires a clear definition of each type in such a way that they are not overlapping (e.g., forested land, agricultural lands, and edges between the two).	Landscape Composition
	Landscape Pattern and Structure	While some minimum area of native habitats in a landscape is necessary for maintaining population viability of native species, the spatial pattern of habitat also is important. Changes in pattern can occur either by natural processes (e.g., wildfires, windthrows), or as a result of human activities (e.g., urbanization, agricultural expansion). Natural fragmentation generally results in habitat patches with more irregular edges than human-created patches	Landscape Pattern and Structure
Natural Disturbance Regimes	Frequency / Intensity / Extent / Duration	Effects of the disturbance on the biota, rather than the energy released or force exerted by the disturbance, and it includes both the severity and magnitude of impact, temporal scale of the disturbance event, which may range from minutes/hours (e.g., earthquakes and some weather events) to days/weeks (e.g., some fire events) to months or years (e.g., some insect outbreaks).	Flood Events

Appendix G, Table 2: Recommended Indicators, Potential Future Indicators, and Ancillary Measures Mapped Against the Biophysical Framework*

Indicators that are sufficiently developed that they can be ready to monitor and report on within a year are noted in blue, the additional coverage provided if potential future indicators are added are noted in green, and ancillary measures are noted in yellow. Definitions for each of the categories are provided in Table 1 above.

Key to text colors: Recommended NEW measures are blue text.

		Biotic Condition						Chemical & Physical Characteristics					Ecological Processes
	Category	Ecosystems & Communities	Species & Populations				Organism Condition	Nutrient Concentrations	Trace Inorganic & Organic Chemical	Other Chemical Parameters		Physical Parameters	Energy Flow
Name	Sub-category (where applicable)	Community Composition	Population Size	Population Structure	Population Dynamics	Habitat Suitability	Signs and Symptoms of Disease or Trauma	Nitrogen/ phosphorus/ other nutrients	Metals, other trace elements, and organic compounds	Dissolved oxygen	pH and salinity or conductivity	Temperature, turbidity, susp. solids	Primary production
Vital Sign: Freshwater													
Freshwater Benthic Index of Biotic Integrity (BIBI) in streams	Indicator												
Water temperature in streams and rivers	Indicator												
Nutrients in streams and rivers	Indicator												
Fine sediment biotic index	Ancillary												
Vital Sign: Marine Water													
Dissolved oxygen in marine water	Indicator												
Stratification													
Marine water temperature	Indicator												
Nutrient balance in marine waters	Indicator												
Ocean acidification	Indicator												
Sediment Chemistry Index	Indicator												
Marine Benthic Index	Indicator												
Marine Benthic Index, phase 2	Potential future indicator												
Noise in marine water	Potential future indicator												
Primary production in marine water	Potential future indicator												
Chlorophyll A	Ancillary												
Turbidity	Ancillary												

		Hydrology & Geomorphology					Landscape Condition			Natural Disturbance Regimes
	Category	Surface & Groundwater Flows		Dynamic Structural Characteristics		Sediment & Material Transport	Extent of Ecological System/Habitat Types	Landscape Composition	Landscape Pattern & Structure	Frequency/Intensity/Extent/Duration
Name	Sub-category (where applicable)	Pattern of surface flows	Water storage	Channel / shoreline / morphology, complexity	Extent / distribution of connected floodplain	Sediment & material transport	Extent of ecological system / habitat types	Landscape composition	Landscape pattern & structure	Flood Events
Vital Sign: Freshwater										
Freshwater Benthic Index of Biotic Integrity (BIBI) in streams	Indicator									
Water temperature in streams and rivers	Indicator									
Nutrients in streams and rivers	Indicator									
Fine sediment biotic index	Ancillary									
Vital Sign: Marine Water										
Dissolved oxygen in marine water	Indicator									
Stratification										
Marine water temperature	Indicator									
Nutrient balance in marine waters	Indicator									
Ocean acidification	Indicator									
Sediment Chemistry Index	Indicator									
Marine Benthic Index	Indicator									
Marine Benthic Index, phase 2	Potential future indicator									
Noise in marine water	Potential future indicator									
Primary production in marine water	Potential future indicator									
Chlorophyll A	Ancillary									
Turbidity	Ancillary									

		Biotic Condition						Chemical & Physical Characteristics					Ecological Processes
	Category	Ecosystems & Communities	Species & Populations				Organism Condition	Nutrient Concentrations	Trace Inorganic & Organic Chemical	Other Chemical Parameters		Physical Parameters	Energy Flow
Name	Sub-category (where applicable)	Community Composition	Population Size	Population Structure	Population Dynamics	Habitat Suitability	Signs and Symptoms of Disease or Trauma	Nitrogen/ phosphorus/ other nutrients	Metals, other trace elements, and organic compounds	Dissolved oxygen	pH and salinity or conductivity	Temperature, turbidity, susp. solids	Primary production
Frequency of High Bloom Events	Ancillary												
Vital Sign: Toxics in Aquatic Life													
Contaminants in English sole	Indicator												
Contaminants in Pacific herring	Indicator												
Contaminants in juvenile salmon	Indicator												
Contaminants in adult salmon	Indicator												
Contaminants in caged mussels	Potential future indicator												
Vital Sign: Beaches and Marine Vegetation													
Feeder bluffs in functional condition	Indicator												
Extent of forest cover in nearshore marine riparian area	Indicator												
Eelgrass area	Indicator												
Short and long-term eelgrass site status	Indicator												
Floating kelp canopy area	Indicator												
Understory kelp abundance and condition	Potential future indicator												
Drift cells in functional condition	Potential future indicator												
Miles of intertidal beach in functional condition	Potential future indicator												
Eelgrass in areas of concern	Ancillary												
Vital Sign: Estuaries													
Percent estuarine habitat area in functional condition	Indicator												

		Hydrology & Geomorphology					Landscape Condition			Natural Disturbance Regimes
	Category	Surface & Groundwater Flows		Dynamic Structural Characteristics		Sediment & Material Transport	Extent of Ecological System/Habitat Types	Landscape Composition	Landscape Pattern & Structure	Frequency/Intensity/Extent/Duration
Name	Sub-category (where applicable)	Pattern of surface flows	Water storage	Channel / shoreline / morphology, complexity	Extent / distribution of connected floodplain	Sediment & material transport	Extent of ecological system / habitat types	Landscape composition	Landscape pattern & structure	Flood Events
Frequency of High Bloom Events	Ancillary									
Vital Sign: Toxics in Aquatic Life										
Contaminants in English sole	Indicator									
Contaminants in Pacific herring	Indicator									
Contaminants in juvenile salmon	Indicator									
Contaminants in adult salmon	Indicator									
Contaminants in caged mussels	Potential future indicator									
Vital Sign: Beaches and Marine Vegetation										
Feeder bluffs in functional condition	Indicator									
Extent of forest cover in nearshore marine riparian area	Indicator									
Eelgrass area	Indicator									
Short and long-term eelgrass site status	Indicator									
Floating kelp canopy area	Indicator									
Understory kelp abundance and condition	Potential future indicator									
Drift cells in functional condition	Potential future indicator									
Miles of intertidal beach in functional condition	Potential future indicator									
Eelgrass in areas of concern	Ancillary									
Vital Sign: Estuaries										
Percent estuarine habitat area in functional condition	Indicator									

		Biotic Condition						Chemical & Physical Characteristics					Ecological Processes
	Category	Ecosystems & Communities	Species & Populations				Organism Condition	Nutrient Concentrations	Trace Inorganic & Organic Chemical	Other Chemical Parameters		Physical Parameters	Energy Flow
Name	Sub-category (where applicable)	Community Composition	Population Size	Population Structure	Population Dynamics	Habitat Suitability	Signs and Symptoms of Disease or Trauma	Nitrogen/ phosphorus/ other nutrients	Metals, other trace elements, and organic compounds	Dissolved oxygen	pH and salinity or conductivity	Temperature, turbidity, susp. solids	Primary production
Number of accessible pocket estuaries and embayments	Potential future indicator												
Vital Sign: Forests and Wetlands													
Extent of forest cover in the upper, middle, and lower areas of watersheds	Indicator												
Wetlands extent and condition	Potential future indicator												
Forest condition	Potential future indicator												
Vital Sign: Streams and Floodplains													
Floodplain function in small and large systems	Indicator												
Summer low flows in streams and rivers	Indicator												
Extent of forest cover in freshwater riparian zone	Potential future indicator												
Changes in hydrologic regime in streams and rivers	Potential future indicator												
Frequency of flood events	Potential future indicator												
Instream habitat complexity	Ancillary												
Estimated shade hours	Ancillary												
Snowpack	Ancillary												
Timing of peak stream flow	Ancillary												
High pulse count	Ancillary												
Vital Sign: Birds													
Abundance of marine bird populations	Indicator												
Abundance of terrestrial bird populations	Indicator												
Estuarine Birds	Potential future indicator												
Marine bird prey quality	Ancillary												

		Hydrology & Geomorphology					Landscape Condition			Natural Disturbance Regimes
	Category	Surface & Groundwater Flows		Dynamic Structural Characteristics		Sediment & Material Transport	Extent of Ecological System/Habitat Types	Landscape Composition	Landscape Pattern & Structure	Frequency/Intensity/Extent/Duration
Name	Sub-category (where applicable)	Pattern of surface flows	Water storage	Channel / shoreline / morphology, complexity	Extent / distribution of connected floodplain	Sediment & material transport	Extent of ecological system / habitat types	Landscape composition	Landscape pattern & structure	Flood Events
Number of accessible pocket estuaries and embayments	Potential future indicator									
Vital Sign: Forests and Wetlands										
Extent of forest cover in the upper, middle, and lower areas of watersheds	Indicator									
Wetlands extent and condition	Potential future indicator									
Forest condition	Potential future indicator									
Vital Sign: Streams and Floodplains										
Floodplain function in small and large systems	Indicator									
Summer low flows in streams and rivers	Indicator									
Extent of forest cover in freshwater riparian zone	Potential future indicator									
Changes in hydrologic regime in streams and rivers	Potential future indicator									
Frequency of flood events	Potential future indicator									
Instream habitat complexity	Ancillary									
Estimated shade hours	Ancillary									
Snowpack	Ancillary									
Timing of peak stream flow	Ancillary									
High pulse count	Ancillary									
Vital Sign: Birds										
Abundance of marine bird populations	Indicator									
Abundance of terrestrial bird populations	Indicator									
Estuarine Birds	Potential future indicator									
Marine bird prey quality	Ancillary									

		Biotic Condition					Chemical & Physical Characteristics					Ecological Processes	
	Category	Ecosystems & Communities	Species & Populations			Organism Condition	Nutrient Concentrations	Trace Inorganic & Organic Chemical	Other Chemical Parameters		Physical Parameters	Energy Flow	
Name	Sub-category (where applicable)	Community Composition	Population Size	Population Structure	Population Dynamics	Habitat Suitability	Signs and Symptoms of Disease or Trauma	Nitrogen/ phosphorus/ other nutrients	Metals, other trace elements, and organic compounds	Dissolved oxygen	pH and salinity or conductivity	Temperature, turbidity, susp. solids	Primary production
Burrow occupancy and reproductive success	Ancillary												
Vital Sign: Forage Fish													
Biomass of spawning Pacific herring	Indicator												
Regional index of the stock presence and health of forage fish such as Sand Lance, Surf Smelt, and Anchovy	Potential future indicator												
Age and size structure of Pacific herring	Ancillary												
Vital Sign: Groundfish and Benthic Invertebrates													
Abundance and biomass of groundfish	Indicator												
Abundance and biomass of benthic marine invertebrates	Indicator												
Vital Sign: Orcas													
Number of Southern Resident killer whales	Indicator												
Occupancy/residency of orcas in Salish Sea	Indicator												
Body condition of Southern Resident killer whale	Ancillary												
Fecundity of Southern Resident killer whale	Ancillary												
Vital Sign: Salmon													
Number of natural-origin Chinook salmon on spawning grounds	Indicator												
Number of natural-origin Coho salmon on spawning grounds	Indicator												

		Hydrology & Geomorphology					Landscape Condition			Natural Disturbance Regimes
	Category	Surface & Groundwater Flows		Dynamic Structural Characteristics		Sediment & Material Transport	Extent of Ecological System/Habitat Types	Landscape Composition	Landscape Pattern & Structure	Frequency/Intensity/Extent/Duration
Name	Sub-category (where applicable)	Pattern of surface flows	Water storage	Channel / shoreline / morphology, complexity	Extent / distribution of connected floodplain	Sediment & material transport	Extent of ecological system / habitat types	Landscape composition	Landscape pattern & structure	Flood Events
Burrow occupancy and reproductive success	Ancillary									
Vital Sign: Forage Fish										
Biomass of spawning Pacific herring	Indicator									
Regional index of the stock presence and health of forage fish such as Sand Lance, Surf Smelt, and Anchovy	Potential future indicator									
Age and size structure of Pacific herring	Ancillary									
Vital Sign: Groundfish and Benthic Invertebrates										
Abundance and biomass of groundfish	Indicator									
Abundance and biomass of benthic marine invertebrates	Indicator									
Vital Sign: Orcas										
Number of Southern Resident killer whales	Indicator									
Occupancy/residency of orcas in Salish Sea	Indicator									
Body condition of Southern Resident killer whale	Ancillary									
Fecundity of Southern Resident killer whale	Ancillary									
Vital Sign: Salmon										
Number of natural-origin Chinook salmon on spawning grounds	Indicator									
Number of natural-origin Coho salmon on spawning grounds	Indicator									

		Biotic Condition					Chemical & Physical Characteristics					Ecological Processes	
	Category	Ecosystems & Communities	Species & Populations				Organism Condition	Nutrient Concentrations	Trace Inorganic & Organic Chemical	Other Chemical Parameters		Physical Parameters	Energy Flow
Name	Sub-category (where applicable)	Community Composition	Population Size	Population Structure	Population Dynamics	Habitat Suitability	Signs and Symptoms of Disease or Trauma	Nitrogen/ phosphorus/ other nutrients	Metals, other trace elements, and organic compounds	Dissolved oxygen	pH and salinity or conductivity	Temperature, turbidity, susp. solids	Primary production
Number of natural-origin Puget Sound Steelhead on spawning grounds	Indicator												
Number of natural-origin Summer Chum salmon on spawning grounds	Indicator												
Chinook Salmon Marine Survival	Ancillary												
Chinook Salmon freshwater survival	Ancillary												
Coho Salmon Freshwater Survival	Ancillary												
Fall Chum population abundance	Ancillary												
Pink/Sockeye population abundance	Ancillary												
Bull Trout population abundance	Ancillary												
Vital Sign: Zooplankton													
Average zooplankton biomass	Indicator												
Integrated annual zooplankton biomass	Potential future indicator												
Zooplankton Index	Potential future indicator												
Timing (late year/early year biomass timing)	Ancillary												
Peak zooplankton biomass	Ancillary												

		Hydrology & Geomorphology					Landscape Condition			Natural Disturbance Regimes
	Category	Surface & Groundwater Flows		Dynamic Structural Characteristics		Sediment & Material Transport	Extent of Ecological System/Habitat Types	Landscape Composition	Landscape Pattern & Structure	Frequency/Intensity/Extent/Duration
Name	Sub-category (where applicable)	Pattern of surface flows	Water storage	Channel / shoreline / morphology, complexity	Extent / distribution of connected floodplain	Sediment & material transport	Extent of ecological system / habitat types	Landscape composition	Landscape pattern & structure	Flood Events
Number of natural-origin Puget Sound Steelhead on spawning grounds	Indicator									
Number of natural-origin Summer Chum salmon on spawning grounds	Indicator									
Chinook Salmon Marine Survival	Ancillary									
Chinook Salmon freshwater survival	Ancillary									
Coho Salmon Freshwater Survival	Ancillary									
Fall Chum population abundance	Ancillary									
Pink/Sockeye population abundance	Ancillary									
Bull Trout population abundance	Ancillary									
Vital Sign: Zooplankton										
Average zooplankton biomass	Indicator									
Integrated annual zooplankton biomass	Potential future indicator									
Zooplankton Index	Potential future indicator									
Timing (late year/early year biomass timing)	Ancillary									
Peak zooplankton biomass	Ancillary									

* Two potential future indicators related to salmon harvest and the extent and frequency of drought emergencies are recommended as measures of human wellbeing and not included in this table.

Appendix H: Ancillary Measures, Intermediate Progress Measures, and Activity Progress Measures Identified During the Revision Effort

Appendix H, Table 1: Ancillary Measures Identified in the Revision Effort

Proposed Measure Name	Proposed Measure Description
Eelgrass in areas of concern	Proportion of sites in increasing/decreasing/stable condition in sensitive areas and areas where management actions are taking place. Locations would change over time in response to ongoing research findings and management actions.
Marine bird prey quality	Measures weight/calories of bill-loads of fish fed to rhinoceros auklet chicks & provisioning rates for pigeon guillemot chicks as an indicator of habitat suitability.
Burrow occupancy and reproductive success	Rhinoceros auklet and pigeon guillemot: Measures burrow occupancy and reproductive success (hatching success and or fledging success) for pigeon guillemot (Whidbey Island) and rhinoceros auklet (Protection Island).
Age and size structure of Pacific herring	Frequency of age and sizes classes of Pacific herring populations sampled on the spawning grounds.
Fine sediment biotic index	Measure using the fine sediment biotic index--this indicates chronic fine sediment deposition and is relevant to habitat quality for salmon spawning. Fine sediment is one of the major stressors for stream health. Does not measure sediment loads, transport, or supply.
Chlorophyll A	Chlorophyll-a (Chl-a), at surface and at depth, monitored by Dept. of Ecology to be reported as a proxy for primary production (final metric to be determined).
Turbidity	TBD
Frequency of high bloom events	TBD
Fecundity of Southern Resident killer whale	Pregnancy and birth rate estimates from hormone levels in fecal samples
Body condition of Southern Resident killer whale	TBD
Chinook Salmon Marine Survival	Population-specific estimates of the number of Chinook smolts from a specific brood year and the number of adults returning from that same brood year. (i.e., an estimate of marine survival).
Chinook Salmon freshwater survival	Population-specific estimates of the number of Chinook smolts per spawner from a specific brood year (i.e., an estimate of smolt production or freshwater survival).
Coho Salmon Freshwater Survival	Population-specific estimates of the number of Coho smolts per spawner from a specific brood year (i.e., an estimate of smolt production or freshwater survival).
Fall Chum population abundance	Estimates the abundances of the XX Fall Chum salmon populations from XX Puget Sound regions as measured by the number of natural-origin adult fish on the spawning grounds.
Pink/Sockeye population abundance	Estimates the abundances of the XX populations from XX Puget Sound regions as measured by <need measurement>
Bull Trout population abundance	Estimates the abundances of the XX populations from XX Puget Sound regions as measured by <need measurement>
High pulse count	Number of days each water year that discrete high flow pulses occur. High pulses are a daily average flow that is equal to or greater than a threshold set at twice the long-term daily average flow rate.
Estimated shade hours	From Chinook Common Indicators. Protocols are still under development.
Snowpack	Snowpack (April 1st Snow Water Equivalent) indicator measures water storage as snow which is projected to decline with warming climate. [suggested in O'Neill as a climate change indicator]
Timing of peak stream flow	Timing of peak steam flows in snowmelt-influenced rivers in the Pacific Northwest
Instream Habitat complexity	A remote-sensed indicator that looks at the "roughness" of streams and rivers, incorporates LWD, frequency of pools and riffles, and other factors.

Proposed Measure Name	Proposed Measure Description
Timing (late year/early year zooplankton biomass timing)	TBD
Peak zooplankton biomass	TBD

Appendix H, Table 2: Vital Signs and Indicators Proposed for Reclassification to Intermediate Progress Measures

Proposed Measure Name	Proposed Measure Description
Net change in permitted shoreline armor	Net change in permitted shoreline armor (new armor minus armor removed), measured using shoreline armor permit data. The Aquatic Protection Permitting System (APPS), managed by the Washington Department of Fish and Wildlife to document and track Hydraulic Project Approval permits, provides our best information about the location and nature of armor-related projects across the region.
Area of estuarine wetlands restored to tidal flooding	Area of estuarine wetlands restored to tidal flooding in Puget Sound's 16 largest river deltas.
Rate of forest cover loss to development	Conversion of forested cover, including coniferous, deciduous, and mixed forest classes, to developed land cover by using four classes of development intensity, based on Landsat satellite imagery with a 30-meter resolution. Loss of forested land cover to developed land cover, reported as an annual average loss, in acres, for a five-year period.
Conversion of ecologically important lands	Proportion of vegetated cover on undeveloped lands, identified as both ecologically important and under high pressure from development, that is converted to developed cover.
Growth in Urban Growth Areas	The proportion of population growth occurring within Urban Growth Areas (UGAs).
Riparian restoration	The amount of riparian corridor restored to vegetated cover is measured through collection of acreage or linear riparian shoreline restoration reported for Puget Sound restoration projects. Riparian restoration efforts are being measured instead of riparian condition due to the difficulty in assessing riparian condition Sound-wide and the length of time necessary to call a specific location successfully restored.
Restoration of floodplains	Metrics are assessed via aerial photography/lidar. Tracks the number and acreage of projects that improve or restore floodplain function in the 17 major river floodplains in Puget Sound.
Inventory, inspection, and repair of onsite sewage systems (relates to the Healthy Humans goal)	Tracks and advances the proper use and care of onsite sewage systems (septic systems) in sensitive and high-risk areas of Puget Sound, in order to protect public health and water quality. The indicator consists in three distinct measures: inventory, inspection, and repair of onsite sewage systems in designated areas.

Appendix H, Table 3: Vital Signs and Indicators Proposed for Reclassification to Activity Progress Measures

Proposed Measure Name	Proposed Measure Description
Proposed Measure Name	Proposed Measure Description
Use of soft shore techniques	Understanding how soft shore techniques are used on Puget Sound is based on review of previous studies and guidance documents, along with review of relevant regulations, restoration programs, and outreach efforts. Data on recent armor projects, including the use of soft shore techniques, was obtained from APPS but there is not monitoring.
Miles of historic habitat open to Chinook*	From Chinook Common Indicators



Revisions to Puget Sound Vital Signs and Indicators

