SALISH SEA
MARINE SURVIVAL PROJECT

US-Canada Operating and Alignment Summary

February, 13, 2015

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Cite document as: Schmidt, M. and I. Pearsall. 2015. Salish Sea Marine Survival Project – Project Foundation, Operating, and U.S.-Canada Alignment Plan. www.marinesurvivalproject.com

Table of Contents

INDEX OF TABLES

EXECUTIVE SUMMARY

The Salish Sea Marine Survival Project is a $20 million dollar, multi-disciplinary, ecosystem-based research effort to determine the most significant factors affecting juvenile salmon and steelhead survival in the Salish Sea marine environment The project is coordinated by nonprofits, Seattle-based Long Live the Kings (LLTK) and Vancouver-based Pacific Salmon Foundation (PSF), and involves over 150 scientists and technical staff from over 40 Federal and State agencies, Tribes, academia, and nonprofit organizations. It was initiated in response to significant declines in Chinook, coho and steelhead marine survival relative to other regions in the pacific northwest; apparent changes in the Salish Sea marine ecosystem over the same time period; and increasing evidence that overall marine survival is largely dependent upon the growth and mortality rates of juvenile salmon after they first enter the marine environment.

Planning associated with this trans-boundary initiative began in 2012, and the five-year research phase began in 2014. The final year will be used to convert the research results into general conclusions and management actions. Outcomes from this extensive international effort will be instrumental in informing and prioritizing hatchery, harvest, habitat and ecosystem management decisions to increase sustainable fishing opportunities and advance the recovery of ESA-listed salmon, steelhead and southern resident killer whales.

This is the US-Canada operating and alignment summary for the Salish Sea Marine Survival Project. This document describes the foundation for the project, illustrates where and how efforts are being aligned between U.S. (Puget Sound) and Canada (Strait of Georgia) and where there will be separate tracts. It also describes how the project management, communications and data sharing activities will occur. Specific details regarding the research and the information supporting the research activities can be found in the basin-specific research plans and supporting documents on the resources page of www.marinesurvivalproject.com. The development of this plan was funded via the Pacific Salmon Commission Southern Endowment Fund, and much of the work occurred via two US-Canada Retreats, in December of 2013 and December 2014 (retreat summaries are also on the web site’s resources page).

Hypotheses

The hypotheses and conceptual frameworks that support them were established separately over the course of initial research planning. The primary hypotheses have since been merged and continue to be assessed and updated via the U.S.-Canada retreats and the ecosystem indicators process, which concentrates all of the hypotheses collected and associated indicators and metrics evaluated in this Project. At a high level, there is broad agreement that hypotheses driving the Salish Sea research effort are, in order of significance:

A. Bottom-up processes —including weather, water, and plankton—that drive Chinook, coho and forage fish prey availability have changed, and salmon aren’t able to compensate.

B. Top-down processes have changed, predominantly affecting steelhead, resident Chinook and coho, and larger forage fish. Predation is the direct cause of mortality, but fish condition (or the condition of their surrounding environment) may be compromised, increasing their susceptibility to predation.

C. Additional factors are exacerbating these ecological shifts, including toxics, disease, and the compounding effect of significant top-down and bottom-up shifts occurring simultaneously.

The Project is also targeting action-oriented management recommendations. We will build out from these hypotheses to determine whether the causes of weak Chinook, coho and steelhead survival are locally (e.g., runoff, wastewater, marine mammal management, habitat availability, hatchery production) or globally driven (climate change, ocean acidification, ocean cycles). Local impacts will result in recommendations to improve the Salish Sea ecosystem, whereas globally driven impacts will result in recommendations to adapt to our changing environment.

Research Alignment

U.S. and Canadian research is being aligned around three categories:[1]

1. **Bottom-up Sampling Program and Individual Studies -** This category includes two components:
   - A fully integrated sampling program examines the condition of salmon and steelhead as they outmigrate while simultaneously evaluating the physical and biological (plankton) characteristics of the Salish Sea: the cornerstone of the marine ecosystem. This includes identifying critical growth periods for salmon and understanding the primary mechanisms affecting their growth.

     U.S. – Canada alignment is high

   - Individual bottom-up studies build off of this sampling framework to hone our understanding of the relationship between salmon and their prey, and to build out from the fish and their prey to the factors driving prey availability, such as temperature, habitat availability, ocean acidification, runoff, and wastewater.

     Alignment is low-moderate: A distributed approach among U.S. & Canadian scientists is applied to cover more ground.

2. **Top down Studies -** Targeted studies evaluate predation (what eats salmon and steelhead) and other potential contributing factors, including disease, toxic chemicals, competition between hatchery and wild fish, harmful algae, and aquaculture impacts.

   Alignment is low-moderate: A distributed approach among U.S. and Canadian scientists is applied to address unique issues and cover more ground.

3. **Trend Analyses and Modeling -** Existing and new data are brought together to analyze and model relationships between salmon and their ecosystem, to evaluate the cumulative effects of multiple factors, and to build back to factors ultimately driving survival over time. This work establishes the platform for integrated data analyses for the entire project. The work includes survival trends, ecosystem indicators development and ecosystem modeling.

   U.S. – Canada alignment is high-moderate

[1] This represents a general framework. The effects of some factors, and affiliated research activities, do overlap categories.

Data Management and Sharing

The shared Project goal is to make ecosystem data assessed through this effort comparable across the Salish Sea and readily available and usable for a variety of analyses, with a life extending beyond this project. This is vital to project objectives such as establishing an ecosystem indicators program for salmon adult return forecasting.

A robust and transparent data management and sharing strategy continues to evolve. A password-protected, web-based project management utility is being used to support sharing among participating scientists of working datasets for each of the research activities. Protocols are being developed and shared widely to ensure consistency where it counts. Data catalogs and datasets will be established in a consistent fashion so that they can readily be connected to a variety of tools (models, web data aggregators, etc). Also, existing and up-and-coming, web-based data sharing platforms—including the Strait of Georgia Data Centre, the Regional Mark Processing Center, NANOOS, SalmonScape, the Juvenile Migrant Data Exchange, and Nearshore Data Exchange—are being considered for their utility as back-end and front-end components to the data strategy. However, the primary, shared approach for establishing long-term, useable data is to focus on critical back-end data needs, including data standardization to improve aggregation on a variety of platforms and automating data aggregation and quality control (QA/QC).

Development and Management

The PSF/LLTK management team are responsible for administration, coordination, accounting, fundraising and communications. They are facilitating the steering and technical committees that are guiding and implementing the research, providing research support, raising and administering a significant portion of the total funding, monitoring progress, aligning the effort with affiliated activities in the region, preparing a pathway for this research to affect management, and implementing a comprehensive communications and outreach strategy targeting both the science-management community and the greater public.

U.S. and Canadian steering committees oversee the project and its funding, maintain the project as a priority for the agencies involved, help coordinate the effort with other initiatives, and tie the research to management. U.S. and Canadian, multi-disciplinary technical teams have been established to ensure within-nation collaboration across disciplines and responsible parties. Relevant technical team members and supporting scientists from both U.S. and Canada also communicate as workgroups to refine and implement the activities identified in the project areas that require significant transboundary collaboration. Within this structure, task teams are being established to tackles specific research activities.

The primary tools for facilitating collaboration include: a web-based project management utility called Basecamp, to maintain communications and support data sharing, facilitated meetings and conference calls, workgroup contact management, and annual U.S.-Canada retreats to discuss progress, findings, continued alignment, and next steps.

Research development and implementation occurs slightly differently on each side of the border. In the U.S., the technical team develops and is funded to implement the research based upon a consensus approach about priorities, the ability to leverage other new funds, and final approval by the steering committee. In Canada, a proposal solicitation process is used, where the steering committee reviews and decides which proposals to fund and to not fund for a given year.

PSF and LLTK established similar fundraising strategies for the effort. The total budget for the project is $20 million in new funds and an expected match of that amount in in-kind support. 25% of the total cost was provided from Southern Fund Committee of the international body who manages the US-Canada salmon treaty, the Pacific Salmon Commission. 50% of the cost is via existing endowment funds (in Canada) and public funding, and the remaining 25% via private funding or competitive grants.

Finally, communications activities led by PSF and LLTK for this project include: a project web site and social media outlets; a media library including photos, videos, and stories; project logo and brand elements management; partnering with reporters to capture the research; coordinating with the public relations departments of all participating groups; and in-house publications to report on project progress. Participating scientists will disseminate their results at workshops and via peer-reviewed publications.

PROJECT FOUNDATION

Rationale

The Salish Sea—encompassing Puget Sound, the Strait of Georgia, and the Strait of Juan de Fuca—supports approximately 3,000 species of marine life, including all seven species of Pacific salmon. Of these salmon, Chinook, coho, and steelhead have experienced tenfold declines in survival during the marine phase of their lifecycle, and their total abundance remains well below what it was 30 years ago. By comparison, the marine survival of coastal and Columbia River Chinook, coho, and steelhead does not follow the same declining trend as the Salish Sea populations. This suggests that the problem lies within the Sea itself and not the open ocean shared by all Pacific salmonids.

Historically, our collective understanding of what drives salmon and steelhead survival in saltwater has been extremely limited, and has been acknowledged by natural resource managers as a critical information gap that must be addressed in order to make real progress toward salmon recovery and sustainable fisheries.

Objectives

The primary objective of the Salish Sea Marine Survival Project is to determine the primary factors affecting the survival of juvenile salmon and steelhead in the Salish Sea marine environment. The proposed work is solutions oriented, intended to systematically:

- identify & prioritize management actions to **increase the survival** of Salish Sea salmon and steelhead (including ESA-listed Puget Sound Chinook and steelhead)
- improve the accuracy of **adult return forecasting** for natural spawning, harvest, and hatchery management
- more accurately evaluate the success of freshwater habitat restoration and hatchery activities by **reducing uncertainty around the role of the marine environment** in overall productivity

Ultimately, the research results and subsequent management actions may also benefit other marine life in the Salish Sea food web, such as ESA-listed southern resident killer whales.

From a research perspective, this collaborative, multidisciplinary, ecosystem-based effort will improve information sharing, promote data standardization, and implement simultaneous data collection by integrating existing and proposed research and monitoring efforts into a comprehensive and hypothesis driven framework at an ecologically relevant scale – the entire Salish Sea.

Scope and Geographic Range

The geographic range of this project includes the entire Salish Sea, the body of water that extends from the north end of the Strait of Georgia and Desolation Sound to the south end of the Puget Sound and west to the mouth of the Strait of Juan de Fuca, including the inland marine waters of southern British Columbia, Canada and northern Washington, United States[2] (Figure 1)[3].

Because the interaction between salmonids and the Salish Sea is complex, this issue will be approached from an ecosystem context, utilizing experts from multiple disciplines. Chinook, coho and steelhead are the species of greatest concern given their significant declines in smolt-to-adult survival (the primary indicator of marine survival) since the 1970s. However, chum, pink and sockeye will be included to the extent practicable in the research plan given potentially shared survival drivers; interspecies interactions; that future research methods can evaluate multiple species; and the recent, extraordinary variation in survival of these salmon species and its effects on fisheries management.

Figure 1. Topographic map of the Salish Sea

The focus is principally on issues affecting juvenile salmon and steelhead survival while they are in the Salish Sea, from the river deltas to the open ocean: spatially and temporally ranging downriver of traditional freshwater monitoring locations (e.g., smolt traps, hatcheries) to the point and time salmon and steelhead leave the Salish Sea. The resident life-history component of Chinook and coho may also be investigated as these fish stay within the Salish Sea through adulthood. Understanding the condition of fish entering the Salish Sea marine environment will be included to determine whether impacts occurring prior to their marine residence are reducing survival in the Salish Sea. However, it will more difficult to determine whether impacts occurring in the Salish Sea are reducing survival in the Pacific Ocean. Factors that do not appear to be driving survival will also be documented as both pieces of information will help inform management decisions.

HYPOTHESES

The hypotheses and conceptual frameworks that support them were established separately over the course of initial research planning. The primary hypotheses have since been merged and continue to be assessed and updated via the U.S.-Canada retreats and the ecosystem indicators process, which concentrates all of the hypotheses collected and associated indicators and metrics evaluated in this Project.

[2] http://staff.wwu.edu/stefan/SalishSea.htm

[3] Figure from, http://www.newrelationship.gov.bc.ca/success_stories/aboriginal_gov_relations.html

Conceptual Framework

Two different conceptual framework approaches have been used. The U.S. Technical Team used an organizational schema for Puget Sound that illustrates different categories/levels of biological reference: Ecosystem, Community, Population, and Individual. These differ from the top-down and bottom-up categories used to describe ecosystem interactions used by the Canadians in their original 2009 Strait of Georgia Chinook and Coho Proposal. At the November 2012 research planning workshop, the workshop Advisory Panel recommended the top-down, bottom-up structure to simplify communications about the project activities. Therefore, the U.S. Technical Team has incorporated the top-down, bottom-up nomenclature in their research descriptions to ensure synchronicity between U.S. and Canada. For more information about the conceptual frameworks and baseline assumptions, please see, the Hypotheses and Preliminary Research Recommendations for Puget Sound (2012) and the Strait of Georgia Chinook and Coho Research Plan (2009) at www.marinesurvivalproject.com.

Primary Hypotheses

At a high level, there is broad agreement that hypotheses driving the Salish Sea research effort are, in order of significance:

A. Bottom-up processes —including weather, water, and plankton—that drive Chinook, coho and forage fish prey availability have changed, and salmon aren't able to compensate.

B. Top-down processes have changed, predominantly affecting steelhead, resident Chinook and coho, and larger forage fish. Predation is the direct cause of mortality, but fish condition (or the condition of their surrounding environment) may be compromised, increasing their susceptibility to predation.

C. Additional factors are exacerbating these ecological shifts, including toxics, disease, and the compounding effect of significant top-down and bottom-up shifts occurring simultaneously.

Could the causes of mortality be shared among species in the Salish Sea?

Yes, the shared patterns of declining marine survival rates for Chinook, coho and steelhead suggest that their survival could fundamentally be dictated by similar factors. However, the pathways to affecting the survival of each species could be different. For example, changes to the timing and abundance of zooplankton (prey) may be negatively affecting Chinook salmon and steelhead in different ways. Chinook salmon may be directly responding to a change in zooplankton availability by starving, increasing their susceptibility to disease, toxics substances and/or predation. Alternatively, steelhead may be indirectly responding to changes in zooplankton production. If herring, which prey on zooplankton, also decline and subsequently aren't available for predators to eat, those predators could target steelhead more. This logic could be extended to explain similar declines in other fish species in the Salish Sea, including herring, eulachon, pacific hake, pacific cod and rockfish.

The Project is also targeting action-oriented management recommendations. We will build out from these hypotheses to determine whether the causes of weak Chinook, coho and steelhead survival are locally (e.g., runoff, wastewater, marine mammal management, habitat availability, hatchery production) or globally driven (climate change, ocean acidification, ocean cycles). Local impacts will result in recommendations to improve the Salish Sea ecosystem, whereas globally driven impacts will result in recommendations to adapt to our changing environment.

A complete list of the current hypotheses, the status of their evaluation and whether or not they are being tested in Puget Sound (US), the Strait of Georgia (Canada) or both are listed in the tables section of this document. See "Table 1. Comprehensive list of hypotheses, Strait of Georgia (SOG) and Puget Sound (PS). Assessment status color code = Underway, Planned, Concept.".

RESEARCH STRUCTURE

To address management, communications, and alignment needs, three research categories have been established for the entire Salish Sea Marine Survival Project:

1. Bottom-up Sampling Program and Individual Studies
2. Top-down Studies
3. Trend Analyses and Modeling

While top-down and bottom-up studies have been categorized separately for structural purposes, the participating scientists respect the need to look across these ecological functions simultaneously.

US-Canada ad-hoc workgroups have been established, and formal task teams within them, based upon the three research categories (see Table 2. Participants and respective groupings, at end of document). These workgroups meet periodically by conference call and annually at U.S.-Canada retreats, but communicate more often independently, facilitated by workgroup contact lists identifying who is doing what and via a web-based project management utility. Task teams meet often via facilitated conference calls. For more information regarding how project collaboration occurs, please see the "Research Development, Project Management and Coordination Strategy" Section, below.

The combined use of research elements illustrated in these categories (retrospective studies, modeling, process studies, and experiments) are founded on other large-scale, ecosystem-based, interdisciplinary research programs such as the Global Ocean Ecosystem Dynamics (GLOBEC) initiative, the estuarine and ocean salmon research program design proposed by Brodeur et al. (2000), and the Columbia River basin juvenile salmon marine ecology program (Jacobsen et. al. 2012). Finally, the approach was also appropriately influenced by PSF's 2009 Strait of Georgia Chinook and Coho Proposal, a foundational report for this effort, and the results of the November 2012 Salish Sea Marine Survival Research Planning workshop.

BOTTOM-UP SAMPLING PROGRAM AND INDIVIDUAL STUDIES

Bottom-up processes—including weather, water, and plankton—drive what is available for juvenile salmon and steelhead to eat. Bottom-up research activities fall into two categories:

- A Salish Sea-wide sampling program examines the condition of salmon and steelhead as they outmigrate while simultaneously evaluating the physical and biological (plankton) characteristics of the Salish Sea: the cornerstone of the marine ecosystem. This includes identifying critical size and growth periods for salmon and understanding the primary factors affecting growth during those periods.

- Individual bottom-up studies build off of this sampling framework: to hone our understanding of salmon growth, the relationship between salmon and their prey, and ultimately build out from the fish and their prey to the factors driving prey availability, such as temperature, habitat availability, ocean acidification, runoff, and wastewater.

Sampling programs build out from specific watersheds within Puget Sound and the Strait of Georgia. In Puget Sound, it is the Nisqually, Snohomish, Skagit and Nooksack watersheds. In Canada, work is initially focused on the Cowichan watershed, and plans are underway to build out to, Puntledge, Qualicum, and the lower Fraser. The U.S. is utilizing the capacity of their large co-management structure combined with academic and federal Principal Investigators to man the salmon and zooplankton sampling activities, and the existing buoy and water quality sampling network managed by the University of Washington and Department of Ecology to capture the physical properties of Puget Sound. The Canadians are implementing a community-based, citizen science sampling program, utilizing volunteers who will collect water quality and zooplankton data throughout the Strait of Georgia. The Canadians are also working with the academic and federal Principal Investigators for the sampling program and utilize them and others for salmon sampling. Tables at the end of this document and a sampling map at the end of this section illustrate the bottom-up sampling effort.

Juvenile salmon

U.S.-Canada Alignment: High

U.S. - Size-selective mortality provides a conceptual framework for examining and linking processes that affect growth and survival at different life stages of anadromous salmonids, and for identifying and quantifying when and where critical periods of growth and survival occur. Insufficient information exists to construct this from existing data, so a sampling program is being implemented. This work focuses on early marine life stages of Chinook and coho salmon, sampling geographically from smolt traps in the lower river, and continuing to trap and seine through the estuarine, nearshore, and offshore marine habitats. From North to South Puget Sound, this includes the Nooksack, Skagit, Snohomish and Nisqually Rivers and their nearshore and offshore areas. The San Juan Islands nearshore and offshore are also included to assess their utility for and connectedness to juvenile outmigrants.

By relating size (weight, fork length, condition) of juveniles to adult returns or smolt-to-adult survival (SARs) at regular intervals during sequential life stages (i.e., at smolt trap and/or hatchery, estuarine, nearshore marine, and offshore marine), life stages that are most influenced by size-selective marine survival (critical sizes and critical periods) will be identified. By collecting length, weight, and scale (or otolith) samples at each juvenile life stage and for returning adults, shifts in back-calculated size at specific life stages can be used to: determine the magnitude of size-selective mortality during or following a specific life stage; identify the periods of critical growth or mortality; and quantify stage-specific relationships between size and survival. Furthermore, by collecting concurrent data on diet, size, scales, and blood samples (for archival IGF-1 growth analysis), fin clips (for archival genetic & stable isotopes) for both marked and unmarked juvenile salmon and their potential competitors, biomass and numerical density of key zooplankton prey (component part of zooplankton data collection program but performed simultaneously with fish sampling), and temperature-salinity during each of these life stages, bioenergetics model simulations will be used to diagnose which factors most affect growth for specific periods, regions and stocks or species.

This initially is an intensive program to identify the critical periods and habitats when and where size selective mortality operates and examine the key factors that affect growth during these critical periods. The initial intensive research will identify the most valuable indicator variables for use in diagnosing factors affecting growth and survival and may potentially be useful for forecasting adult returns over time. This initial effort may ultimately transition into a more streamlined, monitoring program focused on measuring the subset of candidate indicators at the temporal frequency and spatial resolution needed to optimize efficacy and economies of scale, based on the findings from this initial phase.

CA – Both rotary screw trap and PIT tagging methods will be used to compare freshwater and marine survival at different stages in the life history of Cowichan chinook. Samples collected by both methods will be used to assess ocean entry timing, smolt size and smolt quality (using metrics such as size, NaK-ATPase, IGF, BKD). Microtrolling will be used to capture sublegal juveniles in the marine environment, and will be achieved in collaboration with the Avid Anglers as part of a second citizen science project in the Strait of Georgia. Fish sampling surveys will be implemented building out from three locations through the Strait of Georgia in 2015: in the Cowichan, around Qualicum and possibly around Puntledge and/or the lower Fraser River. Sampling will be performed with beach and purse seines, between May and July. Some hatchery and in-river or beach sampling will also occur in the Cowichan and Big Qualicum rivers to establish a baseline for size-selective mortality for hatchery and wild Chinook and coho. The focus will be on coho and Chinook salmon, but other salmon and non-salmon species will be examined to evaluate interactions. The objective is to obtain more information on young salmon before they move offshore to deeper areas. This effort will complement the ongoing July and September R/V WE Ricker mid-water trawl surveys. These studies will be used to gain information on ocean entry time and size, growth (using otoliths, RNA:DNA rations, IGF), bioenergetics, diet (using stomach contents and isotopes), fatty acids (in both zooplankton prey and juvenile salmon), presence/absence of competitors and presence of microbes. Thus, length, weight, stomach contents (diet), scales, otoliths and DNA samples will be collected. Fish will be provided to the genomics lab, blood samples will be taken, and tissues will be stored for contaminants analysis.

Protocol for the U.S. and Canadian salmon sampling efforts have been shared cross border, and the sampling teams communicate about approaches with the focus on ensuring that the results can be compared. Regarding size, growth and size-selective mortality comparisons throughout the Salish Sea: Canada is assessing the effects of size-selective mortality and ocean entry timing using otolith microstructure recorded on the otoliths taken from smolts and juvenile salmon, whereas scale samples are predominantly used for this in the U.S. That said, both scale and otolith samples are being collected on each side of the border so that results can be calibrated across the Salish Sea (otoliths less so in Puget Sound wild Chinook because they are federally protected). Unlike Puget Sound, juvenile coho and Chinook salmon appear to migrate rapidly away from the nearshore areas in the Strait of Georgia. Therefore, Canada will not rely on an intensive beach seine effort to determine the extent of size-selective mortality. Offshore/midwater sampling in the Salish Sea is occurring via trawls and purse seines from April through August. Calibrating the collection approaches is not pertinent since both sides are not using CPUE as a primary determinant of survival. The CCGS WE Ricker cruises in July and September remain a critical component of midwater sampling efforts for the Strait of Georgia and Puget Sound. Time permitting, sampling in Puget Sound will continue to occur via the Ricker.

See Table 3. Bottom-up sampling program: Juvenile salmon" in the tables section at the end of this document and the map at the end of this section for specifics about the Salish Sea juvenile salmon collection activities, including data collected and spatial and temporal extent.

Other assessment approaches are being used for steelhead and sockeye in the U.S. and Canada. A number novel methodologies (biotelemetry, biomarkers, simulation models, etc.) will be used simultaneously to examine a variety of factors influencing the migratory behaviour and survival. Using small acoustic transmitters, the behaviour and fate of Chilko sockeye (2015 and 2016) and Seymour steelhead (2016) smolts will be tracked from release through the Salish Sea. The condition of these smolts will be assessed prior to transmitter implantation and release through the use of biomarkers for pathogen presence and load, presence of immune- or stress-related responses, and growth potential, to better understand the links between condition during initial outmigration and survival and behaviour in the early marine environment. Similarly, steelhead migratory behavior, survival and interactions with predators are being assessed using acoustic telemetry in Puget Sound (2014-2016).

Zooplankton and Ichthyoplankton

U.S.-Canada Alignment: High

Zooplankton and ichthyoplankton sampling is occurring to identify the seasonal status and trends of the species composition and biomass/abundance of these animals. The sampling provides information regarding ecosystem variability and prey quantity and quality for outmigrating juvenile salmon.

Both the U.S. and Canadians are utilizing a distributed approach to achieve a zooplankton sampling program with broad spatial (throughout Salish Sea) and temporal (monthly or greater during salmon outmigration) coverage. The U.S. developed a collaborative sampling effort with March-September bi-weekly sampling that covers nearly all of Puget Sound, utilizing federal, state, academic tribal, county and nonprofit groups to do this. The Canadian program will be throughout the Strait of Georgia, leveraging existing DFO resources and programs sampling zoo/ichthyoplankton, and adding additional surveys to sample in areas and at times that are currently not covered. This is made up from existing Chandler surveys from IOS, Ricker surveys that occur June, July and September in the SOG, from additional vessels chartered by Ian Perry, and from 3-4 boats that make up part of the Mosquito Fleet in Canada.

Methodologies and protocols among the US and Canadian scientists are similar. Sampling protocols for zooplankton have been shared to ensure relative consistency, and both sides will be utilizing vertical bongo net tows (to assess zooplankton in the entire water column, from just off the sea floor to the surface) as well oblique tows (in the top 10-30m to assess the salmon prey field). Oblique tows have proven difficult off of the smaller vessels used in the distributed, multi-party approach implemented in the U.S. U.S. collaborators continue to work on refining the oblique tow approach for Puget Sound, moving to larger vessels where needed. Canadian collaborators are focused on utilizing one vessel to perform the oblique tows, with broad spatial coverage but fewer sampling events (once per month from April to September).

Ichthyoplankton are being assessed in greater detail for the Strait of Georgia at this time. Also, in Canada, the samples will be made available for biochemical analyses (e.g. of lipids, fatty acids, stable isotopes) to provide a plankton baseline for biochemical analyses of juvenile salmon being proposed by other projects.

See Table 4. Bottom-up sampling program: Zooplankton and Ichthyoplankton", in the tables section at the end of this document and the map at the end of this section for specifics about the Salish Sea plankton collection activities, including data collected and spatial and temporal extent.

Physical characteristics and phytoplankton production

U.S.-Canada alignment: High

To collect data on the physical characteristics and primary production of the Salish Sea, the U.S. and Canadians are utilizing a combined approach of buoys, CTD casts from the Canadian mosquito fleet and zooplankton sampling program, CTD casts from the U.S. and Canadian juvenile salmon sampling efforts, and data collected from ongoing monitoring efforts led by project partners (e.g., Washington Department of Ecology Puget Sound-wide CTD effort, Canada's FerryBox and FOCOS-BC Ferries program). Similar variables are collected at all sites, and both groups are focused on capturing continuous information in key areas, and time-specific information relevant to biological sampling events. Given that the physical monitoring approaches are distributed, with sampling inconsistently disbursed in space and time, circulation models will be used to help expand the data and describe physical characteristics Salish Sea wide.

See Table 5. Bottom-up sampling program: Physical Environment" in the tables section at the end of this document and the map at the end of this section for specifics about the Salish Sea physical environment sampling activities, including data collected and spatial and temporal extent.

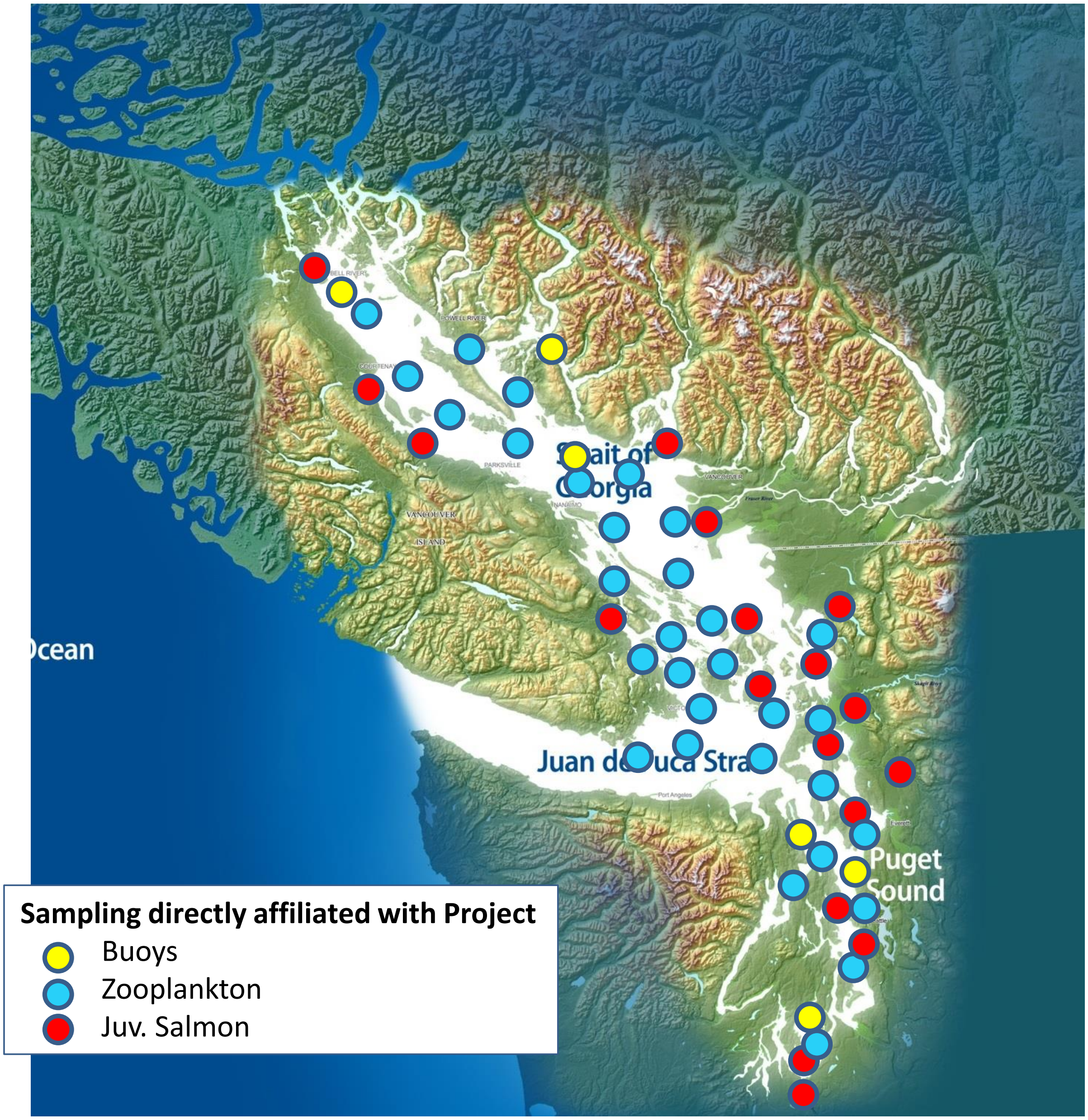

Figure 2. Rough illustration of the bottom-up sampling program in the Salish Sea. This illustrates the work directly funded via the Salish Sea Marine Survival Project. It does not include the Ricker cruise sampling sites and numerous physical environment data collection activities that feed the sampling program.

TOP-DOWN STUDIES

U.S.-Canada Alignment: Low-Moderate

As illustrated above, U.S. and Canadian scientists agree that a unified understanding of the mechanistic association between Salish Sea bottom-up processes and juvenile salmon survival is vital. However, LLTK, PSF and affiliated scientists have initially determined that less U.S.-Canada alignment may be of value when investigating the multitude of other factors that may be contributing to juvenile salmon mortality in the Salish Sea. To more broadly evaluate these factors, the U.S. and Canadian scientists will have more flexibility to focus on specific species, approaches, geographic areas, and distinct survival drivers. The results will then be shared, incorporated into cumulative factors and other comprehensive analyses, and will inform next steps in research on both sides of the border.

The Canadian major top-down studies for 2015 include assessment of the impacts of seal and fish predators on juvenile coho and Chinook, analysis of the spatial and temporal occurrence of harmful algal blooms, and an examination of microbe loads on juvenile salmon. Additionally, the Canadian side will be carrying out some hatchery manipulation studies, involving alternative times of release of Chinook into the Strait of Georgia. Samples of juvenile salmon will be collected from the Strait for future contaminants analysis, but this program will be more fully developed during 2016.

The US and Canada have both pursued a technological solution to quantifying interactions between harbour seals and salmonids exhibiting poor marine survival. In Washington, steelhead were implanted with acoustic transmitters and seals were outfitted with transceivers to determine how often harbour seals encountered juvenile steelhead during their outmigration. In B.C., a development project was undertaken to create a head-mounted PIT tag scanner for harbour seals that could be used to quantify the number of PIT tagged salmon smolts consumed by pinnipeds. This coming April 40,000 hatchery coho will be released in the Strait of Georgia containing PIT tags, in conjunction with 20 seals receiving head-mounted PIT tag scanners. In addition to these novel technological approaches, the U.S. and Canadian predation projects are currently converging on a predator diet analysis approach to quantify predation rates on juvenile salmonids which combines traditional morphological identification of fish prey remains with modern genetic tools. In Canada, three important salmon bearing estuaries were targeted for two years of intensive harbour seal scat sampling, and a genetic diet analysis tool was developed to determine the species and life stage of salmon consumed by seals. The seal diet percentages generated from this effort are being integrated with bioenergetic and demographic information to estimate numbers of smolts consumed by the seal population. Similarly, the US is considering a multi-predator scat sampling design to determine the impacts of pinniped and seabird predators, informed by an extensive literature review that identified which species are probable steelhead predators.

Analysis of contaminants in juvenile Chinook and steelhead tissues has been carried out in the US only over 2013-2014. Juvenile Chinook and steelhead salmon exposure to known chemicals of concern was assessed at four major Puget Sound river/nearshore marine systems (Skagit, Snohomish, Green, Nisqually), an additional marine industrial embayment, and four offshore marine basins. Results from this work will be used to assess the role of contaminants as a contributing factor to marine mortality. The Canadian side will be collecting juvenile salmon samples for analysis during 2015, and discussions are underway on how best to align the US and Canadian programs (the latter will be more fully developed during 2016).

A significant investigation regarding whether or not the parasite, Nanophyetus, was affecting steelhead survival occurred in Puget Sound in 2014. The other Canadian top-down projects (i.e. examination of possible fish predators, harmful algal blooms and microbe loads, hatchery manipulations, and salmon habitat studies) are not being replicated in the U.S. during 2015.

U.S. and Canadian scientists continue to assess whether large-scale experiments or manipulations can be used effectively as a tool in this research project, as recommended by the November 2012 Workshop Advisory Panel and as discussed in the two subsequent Salish Sea Marine Survival Project, U.S.-Canada Retreats (2013 and 2014). These are most relevant to assessing top-down effects such as predator-prey interactions and competition, but are broadly applicable. The Canadians are currently considering future experiments to assess impacts of harmful algae and interspecific competition, and are performing kelp restoration with before and after assessments. Discussions will continue at both the international and national level regarding the applicability of this type of work. Please see the U.S.-Canada Retreat summaries, appended to this report, for more information.

TREND ANALYSES AND MODELING

Trend analyses and modeling is a priority to provide a data evaluation framework for past and future data, consolidate existing data, combine the effects of multiple factors, better identify information gaps, and help narrow the field of likely survival drivers. Historical data and modeling are being used to comprehensively evaluate survival and survival relative to life-history variation and ecosystem factors, comparing those that are natural to those that are human influenced and assessing variation throughout the Salish Sea. Historical data are also being used to look for general ecosystem regime shifts that may correlate with changes in salmon and steelhead survival since the 1980s. These activities are aligned with the proposed suite of research activities involving the collection of new data.

Each research activity in this section is being developed and implemented with significant collaboration between U.S. and Canadian scientists. There is currently significant agreement between U.S. and Canadian scientists on the value of comprehensively evaluating salmon survival trends (1) and establishing a comprehensive suite of ecosystem indicators that identify and provide a mechanism for simultaneously evaluating multiple metrics (3). There is also significant agreement that advancing ecosystem modeling is imperative to our understanding of cumulative effects (4); however, the scientists concluded that initial efforts should focus on improving the modeled relationship between physical parameters through secondary production (zooplankton). There is less agreement on the value of evaluating the effects of outmigration timing and size relative to survival (associated with the hypothesis that changes to life-history variation (2) is related to the decline in marine survival of Chinook and coho). Currently, the U.S. intends to invest more in evaluating this, while the Canadians largely reference a recent publication by Dr. James Irvine indicating no apparent difference in survival of hatchery coho with various release and outmigration times (2013)[4].

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[4] Irvine, J.R., M.O'Neill, L. Godbout, and J. Schnute. 2013. Effects of varying smolt release timing and size on the survival of hatchery- origin coho salmon in the Strait of Georgia. Progress in Oceanography (In Press), doi: http://dx.doi.org/10.1016/j.pocean.2013.05.014

Survival trends

U.S.-Canada alignment: High

Chinook, coho, and steelhead are being comprehensively analyzed to address:

- What are the marine survival trends[5] for Salish Sea Chinook and coho and Puget Sound steelhead populations? How do these trends compare to nearby populations outside of the Salish Sea (i. e., control group)?
- Does survival differ for stocks entering the Salish Sea within different sub-basins (in particular, comparing oceanographic basins of Puget Sound to the Strait of Georgia)? If so, where, when, and to what degree has it varied?
- How much does marine survival differ between hatchery stocks and naturally spawning populations?

This work is being performed retrospectively, but the datasets will be updated over the course of the project. Outmigration and adult return estimates for most Salish Sea and some Washington and B.C. coastal stocks are included, providing a comprehensive picture of marine survival in this region. Early marine abundance/CPUE data from the Ricker marine trawl surveys and from future marine trawl or seine surveys are being included to directly assess early marine survival where practical. To some extent, freshwater survival will be analyzed for wild stocks to express the degree to which freshwater vs. marine mortality contributes to salmon returns. This effort provides the framework and foundation for ongoing[6] and proposed analysis and modeling activities, listed below. Participants are also interested in using the outcome of this work as a template for a long-term assessment program.

U.S.-Canada expert task teams have been developed for coho and for Chinook (steelhead was U.S. only). To facilitate across species comparisons, an assessment format was established first by the coho survival task team and has been replicated for Chinook and steelhead.

Life-history characteristics relative to survival

U.S.-Canada Alignment: Moderate

Salish Sea Chinook and coho, and Puget Sound steelhead will be analyzed to address:

- Does variation in body size, smolt migration timing, or other life-history characteristics associated with freshwater rearing affect marine survival?
- Does outmigrant abundance affect marine survival?
- Does migration duration/residence time in the Salish Sea affect survival (comparing Strait of Georgia vs Puget Sound coho)?

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[5] Marine survival = smolt-to-adult survival, which is primarily a reflection of survival in the marine environment.

[6] For example, FRAM (Pacific Fisheries Management Council, Fisheries Regulation Assessment Model).

This work will first be performed retrospectively, but the datasets will be updated over the course of the project where it is considered appropriate. Data on wild and hatchery steelhead life-history characteristics of stocks in Puget Sound (and potentially some Strait of Georgia stocks) will be analyzed with reference to marine survival trends over time. This work will be performed to determine whether certain characteristics account for variability in the marine survival estimates and or are contributing uniquely to mortality (or are uniquely affected by the environment) in the Salish Sea. Characteristics within and among species will be compared. Hypotheses concerning spatial variation in mortality, size-selective mortality, match-mismatch, and life-history variation will be examined. This analysis will also compare changes in hatchery and wild smolt outmigrant abundance and marine survival rates to examine the marine carrying capacity hypothesis. This analysis may include developing enhanced life-cycle models that capture life-history variation better than current approaches.

The U.S.-Canada Chinook and coho survival task teams and others will work together to complete this assessment. This may be merged to occur simultaneously with the ecosystem indicators effort, described below, because of the need to evaluate both life-history characteristics and their environment simultaneously to assess hypotheses such as match-mismatch. Per the overview of the Trends Analyses and Modeling section, there is less agreement regarding the relative value of additional work in this area (U.S. greater than Canada because of Irvine 2013 findings), influencing the level of investment by each party in work in this area.

Ecosystem indicators: stoplight modeling, single & multi-variant analyses, & other approaches

U.S.-Canada alignment: High

Ecosystem indicators will be developed and analyzed for their ability to predict the marine survival of salmon and steelhead. The objectives of the indicators work are to provide a central location for organizing and compiling metrics for the project, to determine whether the indicators can be used to improve forecasts of adult returns, and to look back through time to evaluate indicators that may have correlated with the decline in survival of Chinook, coho and steelhead.

Similar to the survival datasets, this work will initially be performed retrospectively but the datasets will be updated over the course of the project where appropriate and expanded to include new data collected via the proposed sampling program. A common suite of indicators is being established for the entire Salish Sea (see Table 6. Salish Sea Marine Survival Project: Draft Indicators List", at the end of this document). This indicators list will function as the tool for compiling most of the metrics that will be utilized throughout the project: for indicators/correlative analyses, ecosystem modeling, and bottom-up data collection.

A stoplight modeling approach will be used to coarsely evaluate indicators across the Salish Sea basin and to ensure cross-talk between U.S. and Canada. However, finer-scale analyses will also be applied within this framework, to ensure the factors affecting in-basin variation are properly captured, and to provide scientists the capacity to apply their individual expertise to analyses. Furthermore, several individual studies will occur to within the ecosystem indicators category, to analyze the utility of specific datasets.

End-to-end, spatiotemporal ecosystem model for the Salish Sea

U.S.-Canada alignment: High - Moderate

End-to-end modeling (ecosystem modeling, from physical characteristics through the biotic trophic levels) alignment is focused on concurrence around key information gaps/needs and associated output. Better establishing the NPZ (nutrient-phytoplankton-zooplankton) and bio-energetics for salmon feeding and growth are top priorities throughout the Salish Sea. Establishing ecosystem models is occurring in a slightly different fashion on both sides of the border. The Canadians are currently merging two existing models for the Strait of Georgia to establish links from circulation through to the salmon, prioritizing understanding effects on feeding behavior. The Americans are focused on acquiring funding to develop a full, end-to-end Atlantis ecosystem model of Puget Sound. In the interim, the Americans are using assessing physical data for input into the Salish Sea circulation model (MoSSea), and evaluating whether atmospheric and stratification datasets illustrate ecosystem change consistent with high and low marine survival periods of coho. They are also creating the basis for incorporating zooplankton data into circulation models.

Data Management

The shared Project goal is to make ecosystem data assessed through this effort comparable across the Salish Sea and readily available and usable for a variety of analyses, with a life extending beyond this project. This is vital to project objectives such as establishing an ecosystem indicators program for salmon adult return forecasting.

The Salish Sea Marine Survival Project data management strategy is as follows:

- A password-protected, web-based project management utility (BaseCamp) is being used to support the sharing of working datasets for each of the research activities (sampling, initial analyses, etc). This allows open access to participating scientists, but data protection from the greater community.
- Data collection protocols will continue to be established for the various research activities that require significant collaboration. These protocols will be distributed and managed via the project management utility.
- Aggregated, comprehensive datasets and the associated analyses and modeling results will be shared. We envision a suite of management tools describing and evaluating ecosystem associations and indicators will be established that aid harvest (e.g., improved adult return forecasting), hatchery, and habitat decision making for wild fish recovery and sustainable fisheries. These will ultimately be managed by relevant parties participating in this effort, but may first be created independently and accessed via the project's public web site. See the Trends Analyses and Modeling section for relevant activities.
- The shared approach for establishing long-term, useable data is to focus on back-end data needs, including data standardization to improve aggregation on a variety of platforms and automating data aggregation and quality control (QA/QC). LLTK is talking to Vulcan and the Paul Allen Foundation for guidance on improving approaches to these back-end data needs.

- Existing data-sharing platforms, including the Strait of Georgia Data Centre, the Regional Mark Processing Center, NANOOS, SalmonScape, the Juvenile Migrant Data Exchange, and Nearshore Data Exchange will be utilized, referenced, and built upon where appropriate. PSF continues to evolve the Strait of Georgia Date Centre as a central access point for Strait of Georgia data, and Puget Sound scientists continue to focus on established platforms such as NANOOS and NOAA's ecosystem indicators web site as data aggregators and access points for Puget Sound data.
- Data collection, management, and sharing protocols will be integrated into the salmon and ecosystem management framework for any new activities considered necessary for long-term monitoring beyond the period of this project. Existing activities and their protocol and sharing processes will also be adapted by the project partners where appropriate.
- A comprehensive list of relevant references will be managed on the public web site. This list will extend beyond the research directly associated with this effort.

Project Development and Management

The PSF/LLTK management team are responsible for administration, coordination, accounting, fundraising and communications. They are facilitating the steering and technical committees that are guiding and implementing the research, providing research support, raising and administering a significant portion of the total funding, monitoring progress, aligning the effort with affiliated activities in the region, preparing a pathway for this research to affect management, and implementing a comprehensive communications and outreach strategy targeting both the science-management community and the greater public.

PSF and LLTK each have a full-time project coordinator devoted to the project, and organization presidents/directors', Brian Riddell and Jacques White, are serving as project directors. Associate, communications, development, and financial staff support from both organizations is also provided. The Puget Sound (LLTK) and Strait of Georgia (PSF) coordinators communicate on a weekly basis to ensure alignment is occurring where necessary. Management team meetings occur once every two to three months, predominantly focused on aligning and providing cross-border support on development and communications activities. Otherwise, members of the management team regularly communicate with one another within and across organizations in their respective areas (financial administration, development, communications).

The project development and management strategy employed by PSF and LLTK is described below.

Research Development and Contract Management

Research development is occurring via two separate processes. In the U.S., a multi-disciplinary scientific Technical Team was established to create and execute the research plan. A two-year (2014-2015) plan was completed in 2014, and planning and implementation will continue over the 5 year period. This approach is consistent with the U.S. steering committee's request to make the research iterative and informed by findings as they come in. As research and expertise gaps are identified by the Team, additional scientists have been brought in to help fill them.

Timing and funding decisions for U.S. research activities are guided by the following: the Technical Team members considerations of priority (the Team has ranked the current list of activities) and general consensus of activities to be funded for a given time period, the ability to leverage new match money or significant in-kind support, cost relative to funding available, alignment with the implementation timelines of co-dependent activities, and final consensus approval by the U.S. steering committee.

In Canada, an intensive pilot year of research was funded and implemented in the Cowichan basin in 2014, with the activities developed by a team of scientists. The Cowichan studies were aimed at defining the critical parameters for measuring early marine survival and growth to assist in development of the most cost-effective sampling program to be applied in the other areas during 2015. 2014 was also important for testing various different sampling gear and for development of different methodologies, as well as building community and First Nation partnerships, building capacity and developing sampling protocols etc. The full 2015 research program and associated budget were developed in December 2014 through a solicited proposal process, and evaluation of proposals by the Canadian steering committee.

A single proposal/research description template and reporting templates are used on both sides of the border for managing the research contracts. Canadian contracts are funded by PSF and U.S. by LLTK. For joint U.S.-Canada activities, the U.S. participants are funded by LLTK and Canadian by PSF.

Project Management and Collaboration

Project management and collaboration utilizes a multi-tiered group approach. U.S. and Canadian steering committees oversee the project and its funding, maintain the project as a priority for the agencies involved, help coordinate the effort with other initiatives, and tie the research to management. In Canada, the steering committee is also charged with evaluating proposals and helping comprehensively assess the research results. Steering committee members include chief scientists, high-level resource managers, and funding representatives. One or two technical committee members participate in each coordinating committee meeting. The steering committees meet quarterly.

U.S. and Canadian, multi-disciplinary technical teams have been established to ensure within-nation collaboration across disciplines and responsible parties. Relevant technical team members and supporting scientists from both U.S. and Canada also communicate as workgroups to refine and implement the activities identified in the project areas that require significant trans-boundary collaboration. Within this structure, task teams are being established to tackles specific research activities. These task teams have U.S., Canadian, or U.S.-Canadian representation, dictated by the task at hand. A web-based project management utility called Basecamp, tailored for team management scenarios, has been implemented for the entire Project to maintain communications and support data sharing of working datasets (sampling, initial analyses, etc). See Table 2. Participants and respective groupings”, at end of this document for the current list of higher level participants.

All participating scientists and managers will continue to convene at annual U.S.-Canada Retreats over the course of the project to facilitate alignment, promote cross talk, compare outcomes, and discuss next steps. The first retreats occurred in 2013 and 2014 (retreat summaries can be found at www.marinesurvivalproject.com). Two larger workshops will occur to ensure good communication with the broader community: 1) mid-way through the project, in 2016, to discuss progress, findings and determine whether any strategic shifts should be made in research implementation; and 2) in 2019, after the five-year research phase is complete (2014-2018).

LLTK and PSF will ensure proper coordination is occurring with other relevant initiatives, and will ensure the results of the workgroups are integrated into research and monitoring processes that are part of or relevant to the Salish Sea Marine Survival Project. In the US, for example, there will be significant alignment needed with the Puget Sound Partnership's, Puget Sound Ecosystem Monitoring Program (PSEMP). This involves attending PSEMP workgroup meetings, describing how the proposed work addresses needs identified by these workgroups, getting feedback from the workgroups, and integrated the project activities and results into their efforts.

As has been done for our standing committees and past activities (e.g., 2012 Research Planning Workshop), we will ensure that there is adequate representation of the federal, state, provincial, tribal, First Nation, and academic entities that are currently involved in relevant salmon and ecosystem research and management activities.

Communications

The PSF/LLTK management team oversees the communications and outreach effort. The communications strategy includes the following components:

- An independent project website is utilized to describe the project as a whole, progress, ongoing activities and research findings.
- An internal communications resources website on the Basecamp Project Management Utility is utilized to facilitate communications alignment among project participants and their communications staff.
- Brand elements and brand and communications guidelines have been established to ensure consistency in presence and messaging.
- A press strategy has been implemented, including partnering with reporters to do stories on ongoing research activities, findings, and project progress.
- PSF and LLTK work with the coordinating committees and the communications staff of the participating parties to utilize their media outlets when releasing public information about the project.
- PSF and LLTK use their in-house publications and media outlets (annual reports, newsletters, Facebook, twitter) to report on project progress. They also work within their community networks to present on project progress and receive feedback.
- Participating scientists disseminate their results at workshops and via peer-reviewed publications.
- An outreach and education strategy is being considered with project partners' Seattle Aquarium, Vancouver Aquarium, and Washington Sea Grant. This may include establishing small exhibits at the aquariums describing the project and over time, project findings and outcomes.

PSF and LLTK staff will also work closely with scientists focused on utilizing newer analytical and visualization tools to help communicate the research activities and findings in an effective manner.

Fundraising

PSF and LLTK established similar fundraising strategies for the effort. An assessment was done by PSF to determine the level of private investment that may occur in a major initiative such as this. The assessment concluded that a max of 20% private investment should be targeted. From there, PSF and LLTK considered their capacity to fundraise from various sources, the funds available, an appropriate distribution of expense responsibility, and other metrics when developing their final strategies. PSF and LLTK continue to share fundraising strategies, participate in one another's major donor events, and leverage one another's fundraising progress in key areas to facilitate progress toward our fundraising objectives.

The total budget for the five-year Salish Sea Marine Survival Project is $20 million - estimated at $10 million for the U.S. work and $10 million for the Canadian work. The research itself will cost ~$17.5 million with the remaining $2.5 million for project management, coordination, communications and fundraising. This does not include significant in-kind support (up to 1:1 match of all new money) occurring on both sides of the border by the tribes, agencies and other organizations involved.

The Canadian fundraising strategy includes the following items ($8 million raised to date):

- $2.5 million from the Pacific Salmon Commission, Southern Endowment Fund (raised)
- $1.5 million from the BC Recreational Fisheries Conservation Stamp (raised)
- $1.5 million from the Pacific Salmon Endowment Fund (raised)
- $2 million appropriated from the federal government (pending)
- $2.5 million from private: individuals, corporations, and foundations (raised or pledged)

The U.S. fundraising strategy includes the following items ($4.25 million raised to date):

- $2.65 million from the Pacific Salmon Commission, Southern Endowment Fund (raised)
- $2 million from the State of Washington ($800k raised, another $800k pending)
- $2.5 million in direct allocations to the federal agencies involved, and/or the Pacific Coast Salmon Recovery Fund or EPA's Puget Sound program ($300k pending, NOAA internal)
- $1.35 million from grants targeted at specific research activities ($800k million raised)
- $1.5 million from individuals, corporations and/or private foundations.

TABLES

Table 1. Comprehensive list of hypotheses, Strait of Georgia (SOG) and Puget Sound (PS). Assessment status color code = Underway, Planned, Concept.

Name	Explanation	Prediction	Assessment Status	
			SOG	PS
Marine vs freshwater survival	Marine survival does a better job than freshwater survival in explaining productivity trends of Chinook, coho and steelhead in the Salish Sea.	Marine survival better explains long-term productivity trends, since 1980s; however, among years, populations and basins may have greater variation between fresh vs marine.	√	√
Factors operate at different levels	Ecosystem and community factors affect salmon and steelhead survival at different levels by area encountered, species, hatchery v. wild, and within species, by life-history.	Multiple species and spatial and temporal scales must be assessed to isolate primary factors that explain current vs long-term survival trends.	√	√
Critical period	Chinook and coho marine survival is thought to be set during critical periods/windows.	Total marine survival is correlated to early marine survival.	√	√
		Total marine survival is correlated to winter survival.	√	
Critical size / Smolt condition	Size-Selective mortality is an important process regulating survival at one or more life stages of Chinook and coho.	Larger body size at certain life stages, from lower river through early marine, confers higher survival to adulthood.	√	√
	Conditions in the freshwater environment affect the ability of the smolt to survive in the marine environment (additional emphasis).	Larger and fatter smolts have higher survival.	√	√
		Physiologically prepared smolts have higher survival.	√	
		Hatchery fish have lower marine survival than wild fish.	√	√
Critical growth	Growth rates regulate survival at one or more life stages of Chinook and coho.	Faster growth rates at certain life stages, from lower river through early marine, confers higher survival to adulthood.	√	√
Outmigration timing	Outmigration timing of Chinook, coho and steelhead influences the magnitude effect of competition, predation, buffering, and environmental variation on survival in the Salish Sea.	Timing of certain stocks of Chinook, coho and steelhead combined with specific environmental factors correlates with higher mortality/lower marine survival.	√	√

Name	Explanation	Prediction	Assessment Status	
			SOG	PS
Residency	Resident-type behavior and the duration of residence influence survival in the Salish Sea.	Increased residency correlates with higher overall marine survival of Chinook and coho. Likely associated with increased food availability and/or less predation.		√
Portfolio effect	Through a process known as the portfolio effect, diversity among salmonid populations confers temporal stability and long-term persistence of the species within the Salish Sea.	Populations with more genetic and/or life-history diversity have higher marine survival compared to those that don't.		√
Prey availability: Food supply	There is an insufficient food supply to meet demand by Chinook, coho and steelhead.	Timing, duration, quantity, spatial extent, and/or composition/quality of prey influences food consumption rates and growth.	√	√
Prey availability: Productivity	Fish that grow quickly during critical growth periods survive better because they can escape predators, outcompete competitors, or survive winter better.	Food consumption rates and growth increase with prey production. Marine survival increases with prey production.	√ √	√ √
Prey availability: Match-mismatch	There is a mismatch between demand (outmigrant timing and condition) and food supply.	Smolts that enter during optimum food supply conditions perform better. Smolts that don't survive worse.	√	√
Prey availability: Prey quality	Growth of juvenile salmon is affected by the nutritional content of their food.	Marine survival and growth increases with the availability of fat/nutritious prey.	√	√
Metabolic effects	Growth is limited by the metabolic effects of temperature on juvenile salmon	Growth decreases when outside a peak temperature window for metabolism.		√
Density dependence and Competition	Prey availability is reduced when competition for food increases during critical periods	Marine survival decreases with increasing smolt abundance. [e.g., changes in pink abundance between odd-even years]. Growth and food consumption rates are inversely related to the abundance of competitors .	√ √	√ √
Winter starvation	Winter is a critical period due to low food availability and low temperatures.	Fish that do not reach a critical size, growth, or lipid concentration prior to the winter will not survive.	√	
Predation: Intensity	Predation is a direct/proximate (and potentially underlying/ultimate) cause of mortality.	Mortality rates increases with the abundance of predators.	√	√

Name	Explanation	Prediction	Assessment Status	
			SOG	PS
		Mortality rates increase with increased harbor seal prey specialization targeting Chinook, coho, or steelhead.		√
		Mortality rates increase with reduced turbidity.		√
Predation: Pulse prey abundance	Predator behavior increases with large pulses juvenile salmon and/or steelhead entering the marine environment.	Mortality rates increase immediately following influxes of juvenile salmon and/or steelhead in the marine environment.		√
Predation: Buffering capacity	The probability of being detected by predators decreases with the abundance of alternative prey.	Mortality rates decreases with increasing abundance of forage fish [or other prey items such as euphausiids].	√	√
Disease - Predation	Infected fish may be more susceptible to predators or simply die from the infection.	Mortality increases with increasing parasite or pathogen loads.	√	√
		Disease leads to reduce swimming performance and increased predation.	√	√
Cont-aminants	Exposure to contaminants in freshwater habitats causes latent reductions in marine survival of juvenile salmon.	Chinook, coho and steelhead populations that obtain higher contaminant loads, above thresholds affecting health, during in river rearing have lower marine survival.		√
	Exposure to contaminants in estuarine and marine waters reduces the marine survival of juvenile salmon migrating through the Puget Sound to the Pacific Ocean.	Chinook, coho and steelhead populations that obtain higher contaminant loads, above thresholds affecting health, during outmigration have lower marine survival.		√
	Exposure to contaminants in estuarine and marine waters of Salish Sea reduces the marine survival of salmon residing in the Salish Sea.	Chinook and coho populations that obtain higher contaminant loads, above thresholds affecting health, during outmigration and Salish Sea marine residence have lower marine survival.		√
Water quality - Prey availability	Changes in circulation and water properties have altered phytoplankton and zooplankton production in ways that degraded salmon food-webs in the Salish Sea.	The timing, duration, quantity, spatial extent, and/or composition/quality of salmon prey is constrained by a different state of circulation, water properties, and boundary forces (wind, temp, open ocean conditions, river inputs) in the 2000s vs the 1970s.		√
Ocean acidification	Ocean acidification affects the productivity or nutrition quality of important zooplankton invertebrate prey for salmon (and forage fish).	The timing, duration, quantity, spatial extent, and/or composition/quality of zooplankton are constrained as the Salish Sea becomes more acidic.		√

Name	Explanation	Prediction	Assessment Status	
			SOG	PS
	Increased CO2 concentrations affect the nervous system and behavior of salmon and steelhead or affect growth.	Chinook, coho and steelhead mortality rates increase with increasing CO2 concentrations in the Salish Sea marine environment.		√
	Elevated CO2 concentrations alone and combined with increased temperatures are promoting *Heterosigma* growth, which can affect salmon survival.	Elevated CO2 concentrations and temperature have increased the prevalence and intensity of Heterosigma blooms.		√
	Synergistic responses to elevated CO2/low pH concentrations combined with low oxygen, warming, and eutrophication can occur, as well as the combined effects of ocean acidification and toxics.	Models of elevated CO2/low pH concentrations combined with lower oxygen, higher temperatures, increased nutrients, and contaminant inputs show a synergistic environmental response harmful to the salmon and/or their prey.		√
Harmful algae	Harmful algae directly affect salmon survival through acute or chronic toxicity or gill damage.	Direct mortality increases as prevalence and intensity of *Heterosigma* and other harmful algae increase.	√	√
	Harmful algae indirectly affect salmon survival through food web and salmon prey impoverishment.	The timing, duration, quantity, spatial extent, and/or composition/quality of zooplankton are constrained by competition between primary producers of high and low (i.e. harmful algae) nutritional value .		√
Reduced habitat	Reduced habitat availability and/or diversity have affected the behavior (and reduced the diversity) of salmon while in the Salish Sea.	Reductions of estuary, eel grass, and/or kelp habitat in specific sub-basins correlates with lower marine survival.	√	√

Table 2. Participants and respective groupings

Participant			Trend Analysis and Modeling				Bottom-up Sampling & Individual Studies				Top-Down Studies
			Workgroup	Teams			Workgroup	Teams			
Country	Name	Affiliation		Survival & Life History	Ind-icators	Eco. Model		Phys -ical	Zoo / Ich plankton	Juv. Salmon	
US	Alan Chapman	Lummi Nation	•	•	•	•	•	•	•	•	
US	Andrew Trites	UBC									•
CA	Angelica Pena	DFO/IOS Sidney	•		•	•	•	•			
US	Austen Thomas	UBC / U.S. ind.									•
US	Barry Berejikian	NOAA									•
CA	Ben Nelson	UBC									•
CA	Brian Beckman	NOAA					•			•	
CA	Carl Walters	UBC	•				•			•	
US	Chris Ellings	Nisqually Tribe	•	•	•	•	•	•	•	•	•
US	Chris Harvey	NOAA	•		•	•					
US	Chrys Neville	DFO	•	•	•	•	•	•	•	•	
CA	Correigh Greene	NOAA	•	•	•	•	•	•	•	•	
CA	Dave Beauchamp	UW	•	•	•	•	•	•	•	•	•
CA	Dave Preikshot	Independent	•	•	•	•	•			•	
US	Dick Beamish	DFO/PBS (retired)	•	•			•			•	•
CA	Eddie Carmack	DFO/IOS (retired)	•		•		•	•	•		
US	Erik Neatherlin	WDFW	•				•				•
US	Evelyn Brown	Lummi Nation	•				•		•	•	
US	Frances Juanes	UVIC					•			•	
US	Ian Perry	DFO	•		•	•					
US	James Irvine	DFO	•	•			•			•	
US	Jan Newton	UW	•			•	•	•	•		
CA	John F. Dower	UVIC					•		•		
US	John Mickett	UW									
CA	Joseph Anderson	WDFW	•	•			•			•	
CA	Josh Chamberlain	NOAA	•				•			•	
CA	Joy Wade	Fundy Aqua									•
CA	Julie Keister	UW			•		•	•	•	•	
CA	Ken Denman	U Vic	•			•	•	•			

Participant			Trend Analysis and Modeling				Bottom-up Sampling & Individual Studies				Top-Down Studies
			Workgroup	Teams			Workgroup	Teams			
Country	Name	Affiliation		Survival & Life History	Ind-icators	Eco. Model		Phys -ical	Zoo / Ich plankton	Juv. Salmon	
CA	Ken Warheit	WDFW	•	•			•			•	
CA	Kevin Pellett	BC Cons. Found					•			•	
US	Kristi Miller	DFO					•			•	•
CA	Karia Kaukinen	DFO (alt. Kristi M)					•			•	•
US	Lance Campbell	WDFW	•	•	•		•			•	
US	Madi Gamble	UW					•			•	
US	Mara Zimmerman	WDFW	•	•	•						
CA	Marc Trudel	DFO	•	•	•		•	•	•	•	•
US	Megan Moore	NOAA									•
CA	Mel Sheng	DFO					•			•	
US	Mike Crewson	Tulalip Tribes	•	•	•	•	•	•	•	•	
CA	Mike Foreman	DFO	•	•	•	•					
CA	Nathan Furey	UBC					•			•	•
US	Neala Kendall	WDFW	•	•	•		•			•	
CA	Neil Banas	UW	•			•		•	•		
US	Parker MacCready	UW	•			•	•	•	•		
US	Paul Hershberger	USGS									•
US	Pete Lawson	NOAA	•		•						
CA	Peter Ross	Van. Aquarium									•
US	Robie Macdonald	DFO/IOS Sidney	•				•	•			
US	Sandie O'Neil	WDFW									•
US	Scott Hinch	UBC					•			•	•
US	Sophia Johannessen	DFO/IOS Sidney	•		•	•	•	•	•		
US	Stewart Johnson	DFO	•	•			•			•	
CA	Susan Allen	UBC	•			•					
CA	Svein Vagle	DFO					•				
CA	Terry Curran					•					
CA	Tony Farrell	UBC									•
US	Wendi Ruef	UW (alt Jan N)						•			

Table 3. Bottom-up sampling program: Juvenile salmon

Activity	Loc-ation	Target Species	Data*	Spatial Extent	Temporal Extent
Hatcheries (in river)	Can	Chinook, coho	Count Length (lab) Weight (lab) Scales and otoliths Muscle sample Tissue samples	Hatcheries - Big Qualicum, Cowichan, possibly Puntledge and others	Immediately before release
Beach seine (nearshore)	Can	Chinook, coho	Count Length (field) Weight (lab) DNA + wand for CWT + PIT-tag Stomach contents Muscle sample Otoliths + Scales Tissue samples	Cowichan Bay, Big Qualicum, Baynes Sound and possibly Puntledge	1-2 times per month between April- July
Purse seine (offshore)	Can	Chinook, coho	Count Length (field) Weight (lab) DNA + wand for CWT + PIT-tag Stomach contents Muscle sample Otoliths + Scales Tissue samples	Cowichan Bay, Big Qualicum, and possibly Puntledge and Baynes Sound	1-2 times per month between April- July
Neocaligus seine (offshore)**	Can	Chinook, coho, sockeye, chum, pink	Count Length (field) Weight (lab) DNA + wand for CWT + PIT-tag Stomach contents Muscle sample Otoliths + Scales Tissue samples	Cowichan Bay and Fraser River plume	Monthly April- August
Microtroll (offshore)	Can	Chinook, coho	Count Length (field) DNA + wand for CWT + PIT-tag	Mostly around Cowichan Bay	3 times per week Spring -summer
Ricker trawl** (offshore)	Can + US	Chinook, coho, steelhead, sockeye, chum, pink	Count Length (field) Weight (lab) DNA + wand for CWT + PIT-tag Stomach contents Muscle sample Otoliths + Scales IGF-1 – No in 2015*** Tissue samples	Transects throughout the Strait of Georgia and	10-14 days in June, July, September for Strait of Georgia. Limited sampling throughout Puget Sound opportunistically in July and September.

Activity	Loc-ation	Target Species	Data*	Spatial Extent	Temporal Extent
Purse seine (offshore)	US	Chinook, coho (steelhead for 2014 fish health assessment only)	Count Length (field) Weight (lab) DNA + Wand for CWT Stomach contents Scales and limited otolith IGF-1 (North Puget Sound only) Tissue samples (steelhead in 2014 only)	Bellingham Bay, San Juan Islands/Rosario Strait, Whidbey Basin, Central Puget Sound (limited), South Puget Sound	May-Aug/Sept purse seine trips (once every 2-4 weeks)
Beach Seine (estuary and nearshore)	US	Chinook, coho (steelhead for 2014 fish health assessment only)	Count Length (field) Weight (lab) DNA + Wand for CWT Stomach contents Scales and limited otolith IGF-1 (North Puget Sound only) Tissue samples (steelhead in 2014 only)	Nooksack River/Bellingham Bay, San Juan Islands, Skagit River/North Whidbey Basin, Snohomish River/South Whidbey Basin, Nisqually River/South Puget Sound	Weekly-monthly, March-October, depending upon salmon outmigration peak
Smolt Trap (in river)	US	Chinook, coho (steelhead for 2014 fish health assessment only)	Count Length (field) Weight - hatchery fish only (lab) DNA + Wand for CWT Stomach contents - hatchery fish only Scales and limited otolith Tissue samples (steelhead in 2014 only)	Nooksack River, Skagit River, Snohomish River, Nisqually River	Daily March-August, when fish are present
Hatcheries (in river)	US	Chinook, coho (steelhead for 2014 fish health assessment only)	Count Length (lab) Weight (lab) Scales and limited otolith	Hatcheries in Nooksack River, Skagit River, Snohomish River, Nisqually River	Immediately before release

*Data collection for target species + limited sampling of other fish in offshore to characterize competition, etc.

**Not funded via SSMSP but significant data source.

*** No IGF-1 sampling in 2015 from Ricker due to lack of funds.

Table 4. Bottom-up sampling program: Zooplankton and Ichthyoplankton

Activity	Loc-ation	Data	Spatial Extent	Temporal Extent
Chandler Survey - Vertical tows*	Can	Species composition of entire water column	Throughout Strait of Georgia	3-4 trips per year
Ricker Survey - Vertical tows*	Can	Species composition of entire water column	Throughout Strait of Georgia	June, July and September
Purse seine-Vertical tows	Can	Species composition (max 50m depth)	Throughout Strait of Georgia	May-July
Perry surveys-Vertical and Oblique tows	Can	Species composition of entire water column & prey field	Throughout Strait of Georgia	February-October
Mosquito Fleet collections - Vertical tows	Can	Species composition of entire water column	Throughout the Strait of Georgia. A portion of total stations sampled by 3-4 of the more capable boats.	18-20 collections bi-weekly, Feb-Oct
Collaborative sampling effort - Vertical tows	US	Species composition of entire water column	12-15 stations throughout Puget Sound	15 collections bi-weekly, late March-October. A few stations also do October-March monthly.
Collaborative sampling effort - Oblique tows	US	Species composition of salmon prey field in upper 30m of water column	12-15 stations throughout Puget Sound	15 collections bi-weekly, late March-October. A few stations also do October-March monthly.

*Not funded via SSMSP but significant data source.

Table 5. Bottom-up sampling program: Physical Environment

Activity	Loc-ation	Data	Spatial Extent	Temporal Extent
Moorings – Cowichan Bay	Can	Temperature, salinity, nitrate concentration and fluorescence	Cowichan Bay only	continuous
Moorings- Halibut Bank, Sentry Shoal and Egmont	Can	Temperature, salinity, pressure and fluorescence	Northern Strait of Georgia	continuous
Mosquito Fleet collections	Can	Temperature, salinity, oxygen, fluorescence, nutrients, turbidity, phytoplankton	Full coverage- 120 stations throughout the Strait of Georgia	18-20 collections bi-weekly, Feb-Oct
Purse Seine, Trawl*	Can	Temperature, salinity, dissolved oxygen	Localized purse seine trips- Cowichan Bay, Biq Qualicum, Puntledge, Neocaligus in Fraser River Plume and Cowichan Bay, Ricker throughout SOG, Chandler IOS surveys in SOG	Apr-Jul purse seine, Apr-Aug Neocaligus, June, July and Sept Ricker, 3-4 times a year for Chandler trips
Moorings - ORCA buoys*	US	Air and water temperature; salinity; solar radiation; wind speed and direction; nutrient, oxygen, and chlorophyll concentrations; turbidity; gas exchange parameters; currents	Admiralty Inlet (Hansville), Central Puget Sound (Pt. Wells), South Puget Sound (Carr Inlet). Considering Whidbey Basin and Bellingham Bay additions. 5 additional locations exist in Hood Canal.	continuous
Purse Seine - CTD casts	US	Temperature, salinity, pH, dissolved oxygen	Purse seine set locations in Bellingham Bay, San Juan Islands, Whidbey Basin, Central Puget Sound and South Puget Sound	May-Aug/Sept purse seine trips (once every 2-4 weeks)
Department of Ecology CTD casts**	US	Temperature, salinity, pH, dissolved oxygen, light transmissivity	Stations throughout Puget Sound	Monthly, year round

*Partially funded by SSMSP and a significant data source.

**Not funded via SSMSP but significant data source.

Table 6. Salish Sea Marine Survival Project: Draft Indicators List

Indicators Red = SOG, Blue = Puget Sound, Green=Coast/Open Water, Black = All		**Salmon Species**			**Temporal Extent**	**Spatial Extent** (L = limited)			
Variable/Indicator Type	Indicators/Variables	Chinook	Coho	Steelhead	(None, 1-5, 5-10, 10-20, 20+ years)	Individual Pop	Sub basin	Salish Sea	Northwest
Pop Identification	• CWT	🔴🔵🟢	🔴🔵🟢		20+				
Survival - Wild	• Smolt to Adult	🔴🔵🟢	🔴🔵🟢	🔴🔵🟢	10-20	L			
	• Adult to Adult	🔴🔵🟢	🔴🔵🟢	🔴🔵🟢	20+				
	• Early Marine		🔴	🔵	10-20, 1-5	L			
Survival - Hatchery	• Smolt to Adult	🔴🔵🟢	🔴🔵🟢	🔴🔵🟢	20+				
	• Adult to Adult	🔴🔵🟢	🔴🔵🟢	🔴🔵🟢	20+				
	• Early Marine		🔴	🔵	10-20, 1-5	L			
Abundance - Estuarine	• Cumulative density	🔴🔵	🔵		1-5, 1-10	L			
Abundance - Nearshore	• Shoreline counts								
	• Beach seining density	🔴🔵	🔵		1-5, 1-10	L			
Abundance - Offshore	• Neritic density	🔵			?		L		
	• Midwater CPUE	🔴🔵	🔴🔵		10-20				
	• Purse seine CPUE	🔴🔵	🔵		1-5				
Abundance - SJDF & Coast	• Pelagic CPUE	🔴🔵	🔴🔵		?		L	L	
Abundance - In River/At Release	• Juvenile Outmigrants (Hatchery)	🔴🔵🟢	🔴🔵🟢	🔴🔵🟢	20+				
Abundance - In River	• Juvenile Outmigrants (Wild)	🔴🔵🟢	🔴🔵🟢	🔴🔵🟢	10-20	L			
Abundance	• Adults (Parent Spawners - Wild)	🔴🔵🟢	🔴🔵🟢	🔴🔵🟢	20+				
Migration Timing and Patterns	• Outmigration timing (lower river to ocean)	see abd	see abd	see abd	1-20+				
	• Outmigration pattern (lower river to ocean)	🔵	🔴	🔵	1-5				
	• Residence duration in Salish Sea (indicated by growth, otolith biochemistry, or mark recapture in N & O)	🔵	🔴	🔵	1-5				
	• Pattern and timing of offshore (outside Salish Sea) migration	🔴🔵	🔴🔵	🔵	?	L	L	L	

Indicators Red = SOG, Blue = Puget Sound, Green=Coast/Open Water, Black = All		**Salmon Species**			**Temporal Extent**	**Spatial Extent** (L = limited)			
Variable/Indicator Type	Indicators/Variables	Chinook	Coho	Steelhead	(None, 1-5, 5-10, 10-20, 20+ years)	Individual Pop	Sub basin	Salish Sea	Northwest
Growth and Condition - Salish Sea Freshwater (F), Nearshore (N), Offshore (O)	• Size structure - Individual size and size change	● Red ● Blue	● Red ● Blue	● Blue	1-20	L	L		
	• Growth	● Red ● Blue	● Red ● Blue		1-20+	L	L		
	• Body condition (F,N,O)	● Red		● Blue	1-5	L	L	L	
	• Disease (F,N,O)	● Red		● Blue	1-5	L	L	L	
Boundary - Freshwater	• River Discharge - Average river flow				20+				
	• River Discharge -Low flows				20+				
	• River Discharge -Peak flows				20+				
	• Temperature (winter & summer?)				20+				
	• Turbidity				20+ (frgmntd)				
	• Snowpack				20+				
Boundary - Climate & weather	• Pacific Decadal Oscillation				20+				
	• Oceanic Nino Index				20+				
	• Date of spring transition				20+				
	• Upwelling Index				20+				
	• Sea level				20+				
	• Sea surface temperature				20+				
	• Precipitation				20+				
	• Wind speed and direction				20+				
	• Salish Sea surface wind				1-5				
	• Cloud cover				20+				
	• Length of Day (LOD)				20+				
	• Pacific Circ. Index (PCI)				20+				
	• Atmospheric Forcing Index (AFI)				20+				
	• Aleutian Low Pressure Index (ALPI)				20+				

Indicators Red = SOG, Blue = Puget Sound, Green=Coast/Open Water, Black = All		**Salmon Species**			**Temporal Extent**	**Spatial Extent** (L = limited)			
Variable/Indicator Type	Indicators/Variables	Chinook	Coho	Steelhead	(None, 1-5, 5-10, 10-20, 20+ years)	Individual Pop	Sub basin	Salish Sea	Northwest
Boundary - Climate & weather (cont'd)	• Multivariate ENSO Index (MEI)				20+				
	• Trenberth and Hurrell North Pacific Index (NP)				20+				
	• ENSO Precipitation Index (EPI)				20+				
	• North Pacific Gyre Oscillation (NPGO)				20+				
Boundary - Oceanography	• Water temperature				20+				
	• Sea level				20+				
	• Hypoxia / Dissolved oxygen				10-20 (fragmented)				
	• PAR (solar radiation)				1-5				
	• Salinity				20+				
Salish Sea - Estuary, Nearshore, Offshore	• Water temperature				20+				
	• Dissolved oxygen				20+				
	• Salinity				20+				
	• Turbidity / Transmissivity				10+				
	• Chlorophyll				10+ (limited)				
	• SiO_4:Nox				?				
	• pH				?				
	• Stratification				20+ (frgmntd)				
	• HABs & Noctiluca (Diatoms vs Dinoflagellates)				?				
	• Nutrients				20+				
	• Chlorophyll (contributions by taxa)				?				
	• Phytoplankton sedimentation rate				?				
Satellite datasets	• Sea surface temperature				20+				
↓	• Turbidity				20+				
	• Chlorophyll				20+				

Indicators Red = SOG, Blue = Puget Sound, Green=Coast/Open Water, Black = All		**Salmon Species**			**Temporal Extent**	**Spatial Extent** (L = limited)			
Variable/Indicator Type	Indicators/Variables	Chinook	Coho	Steelhead	(None, 1-5, 5-10, 10-20, 20+ years)	Individual Pop	Sub basin	Salish Sea	Northwest
Prey	• Coastal Copepod biodiversity				10-20				
	• Coastal Copepod community structure				10-20				
	• Coastal Winter ichthyoplankton				?				
	• (Summer & fall?) pelagic herring abundance				20+				
	• Salish Sea Zooplankton density, biomass, abundance, peak timing, community structure				10-20, 20+				
	• Quality - Lipid and fatty acids of zooplankton				None				
	• Salmon Stomach Contents				10-20				
Competitors (OR prey, OR buffer)	• Odd/even pink (Parent spawner abundance)				20+				
	• Odd/even pink (Midwater CPUE)				10-20				
	• herring abundance (see above.. Can be pos. or neg. relation… may be prey, competitor, buffer)				20+				
	• Other salmon abundance (midwater CPUE)				10-20				
	• Other salmon abundance (total relevant timed outmigrants for basin, region, or Salish Sea in total)				20+				
	• hake abundance				20+				
	• Dominant Fraser sockeye cycles				20+				

Indicators Red = SOG, Blue = Puget Sound, Green=Coast/Open Water, Black = All		**Salmon Species**			**Temporal Extent**	**Spatial Extent** (L = limited)			
Variable/Indicator Type	Indicators/Variables	Chinook	Coho	Steelhead	(None, 1-5, 5-10, 10-20, 20+ years)	Individual Pop	Sub basin	Salish Sea	Northwest
Predators	• Orcas abundance				20+				
	• Harbor porpoise				20+ (rough)				
	• Pinniped (harbor seal and sea lion) abundance				20+				
	• Winter seabird predators abundance				20+				
	• Fish predators abundance (e.g., hake)				20+ ?				
Other - Ecosystem	• Oyster condition				20+				
	• Crab CPUE, abundance				?				
	• Habitat availability (e.g., estuary, eelgrass, kelp)				?				
	• Core Samples				20+				
	• Geoduck growth rates				20+				
Anthropogenic Inputs	• Runoff - fertilizer				?				
	• Stormwater				?				
	• Wastewater				?				
	• Contaminant loads, occurrence				1-5 (fragmented)	L			