North
Pacific
Anadromous
Fish
Commission

TECHNICAL REPORT 16

Roadmap to Develop the Likely Suspects Framework: Salmonscape Workshop Series

Editors: Matthew Siegle, Aline Litt, Mark Saunders, Caroline Graham, Aidan Schubert, Camille Jasinski, Scott Akenhead, Richard Erhardt, Brian Wells, Catherine Michielsens, Marc Porter, Colin Bull, and Sue Grant

Vancouver, Canada, 2021

NORTH
PACIFIC
ANADROMOUS
FISH
COMMISSION

TECHNICAL REPORT 16

Roadmap to Develop the Likely Suspects Framework: Salmonscape Workshop Series

Editors: Matthew Siegle, Aline Litt, Mark Saunders, Caroline Graham, Aidan Schubert, Camille Jasinski, Scott Akenhead, Richard Erhardt, Brian Wells, Catherine Michielsens, Marc Porter, Colin Bull, and Sue Grant

Vancouver, Canada, 2021

Roadmap to Develop the Likely Suspects Framework: Salmonscape Workshop Series

December 2020–March 2021

Location: All workshops were held virtually

Conveners: Mark Saunders (NPAFC IYS) and Matthew Siegle (ESSA Technologies)

Planning Team

Catherine Michielsens (Pacific Salmon Commission)
Scott Akenhead (Ladysmith Institute)
Brian Wells (National Oceanic and Atmospheric Administration)
Richard Erhardt (First Nations Fisheries Council)
Colin Bull (Missing Salmon Alliance)
Mark Saunders (North Pacific Anadromous Fish Commission- International Year of the Salmon)
Caroline Graham (North Pacific Anadromous Fish Commission- International Year of the Salmon)
Aidan Schubert (North Pacific Anadromous Fish Commission- International Year of the Salmon)
Minje Choi (North Pacific Anadromous Fish Commission, Intern)
Marc Porter (ESSA Technologies)
Matthew Siegle (ESSA Technologies)

NPAFC Secretariat

Vladimir Radchenko, Executive Director
Jeongseok Park, Deputy Director
Jennifer Chang, Administrative Officer
Bryon Hopper, Web /Publication Manager, interim
Mariia Artiushkina, Administrative Assistant

ISSN 1029-5917

North
***P**acific*
***A**nadromous*
***F**ish*
***C**ommission*

TECHNICAL REPORT 16

Roadmap to Develop the Likely Suspects Framework: Salmonscape Workshop Series

December 2020–March 2021

Editors: Matthew Siegle, Aline Litt, Mark Saunders, Caroline Graham, Aidan Schubert, Camille Jasinski, Scott Akenhead, Richard Erhardt, Brian Wells, Catherine Michielsens, Marc Porter, Colin Bull, and Sue Grant

Published by: North Pacific Anadromous Fish Commission
Suite 502, 889 West Pender Street
Vancouver, BC, V6C 3B2
Canada

Tel: (604) 775-5550
Fax: (604) 775-5577
E-mail: secretariat@npafc.org
Website: https://npafc.org

Acknowledgements

The North Pacific Anadromous Fish Commission Secretariat Office is located on the traditional, ancestral, and occupied shared territories of the xʷməθkʷəy̓əm (Musqueam), Skwxwú7mesh (Squamish) and səl̓ilwətaʔɬ təməxʷ (Tsleil-Waututh) Peoples. ESSA Technologies Ltd. has offices located on the traditional, ancestral, and occupied shared territory of the xʷməθkʷəy̓əm (Musqueam), Skwxwú7mesh (Squamish) and səl̓ilwətaʔɬ təməxʷ (Tsleil-Waututh) Peoples, and the Algonquin Anishnaabeg People.

The preparation of this report was led by ESSA Technologies Ltd. with guidance and support from individuals at the North Pacific Anadromous Fish Commission and input from the Salmonscape Planning Team. We also want to acknowledge Sue Grant, Michael Schmidt and Janson Wong, who were able to participate on the Planning Team during the beginning of this project but had to step away for other work priorities. We also thank Natascia Tamburello for additional graphics, and Andrew Chin and Stephanie Taylor for assisting with the workshops. The content of this report was shaped by the feedback and perspectives of the participants in the Salmonscape Workshop Series.

We thank everyone for their time and valuable contributions.

Summary

Increased variability in the abundance and productivity of Pacific salmon has been observed throughout the North Pacific in recent decades, primarily driven by climate change. For resource managers to make the best informed decisions, it is crucial that there is a solid understanding of the drivers of salmon mortality at each life history stage and how drivers in one life history stage affect survival in other stages. The Likely Suspects Framework (LSF) concept was developed in 2017 by a group of salmon researchers from the Atlantic and the Pacific basins and is a guiding process with the goal of providing practical advice to managers and decision-makers by identifying the main sources of salmon mortality and their cumulative effects across the life cycle.

The North Pacific Anadromous Fish Commission and partners, as part of the International Year of the Salmon activities, developed and hosted the Salmonscape Workshop Series as phase one of the LSF implementation in the Northeast Pacific. The workshop series involved an intital Focus Group meeting, followed by three linked workshops, with the ultimate goal of developing a roadmap to guide the process for developing Case-Use Studies (specific salmon populations/watersheds) to test and further define the LSF for future implementation in the Northeast Pacific. The workshop series brought together over 100 participants representing a diverse range of roles and expertise, from federal and provincial/state agencies, Indigenous governments and communities, NGOs, and academic institutes.

Using the outcomes from each component of the workshop series, a roadmap to guide the process for developing Case-Use Studies to test and further define the LSF for future implementation in the Northeast Pacific was developed, involving 5 steps:

1. **Establishing an LSF Oversight Committee (OC**): The OC will be responsible for identifying Case-Use Studies, assembling and supporting Working Groups to implement the Case-Use Studies, and synthesizing the results and lessons learned from the Case-Use Studies to draft the recommendations for broadscale application of the LSF.
2. **Identifying Big Questions in salmon management and conservation:** During the Focus Group meeting, 29 Big Questions and management challenges were identified by over 35 salmon managers and decision-makers, knowledge-holders, and organizational leaders. These questions and challenges will help inform the identification of Case-Use Studies by the OC.
3. **Testing the LSF Using Case-Use Studies:** Case-Use Studies will be identified by matching a salmon population/s with one or more of the Big Questions and management challenges, for which there is sufficient data and expertise for investigation.
4. **Refining the LSF:** Through synthesizing lessons learned from each of the Case-Use Studies, an organizing platform will be produced, integrating the key elements of the governance process and recommendations, guidance on data and knowledge mobilization, and a toolkit. This toolkit will link conceptual models to quantitative models, integrate quantitative modeling efforts across spatial and temporal scales, and provide decision-support tools and communications products.
5. **LSF Implementation for Broad Application:** Implementation of the LSF will be reliant on lessons learned from each of the Case-Use Studies and will need to address challenges such as bringing the LSF to data-limited systems and the complexity and scale of salmon life histories.

Table of Contents

Abbreviations

COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CSAS	Canadian Science Advisory Secretariat
DFO	Fisheries and Oceans Canada
FNFC	First Nations Fisheries Council
IK	Indigenous Knowledge
IYS	International Year of the Salmon
LSF	Likely Suspects Framework
MSE	Management Strategy Evaluation
NCEAS	National Center for Ecological Analysis & Synthesis
NPAFC	North Pacific Anadromous Fish Commission
OC	Likely Suspects Framework Oversight Committee
PNAMP	Pacific Northwest Aquatic Monitoring Partnership
PSC	Pacific Salmon Commission
RAMS	Risk Assessment Methodology for Salmon
SoK	State of Knowledge
SPT	Salmonscape Planning Team
WG	Likely Suspects Framework Working Group

Glossary

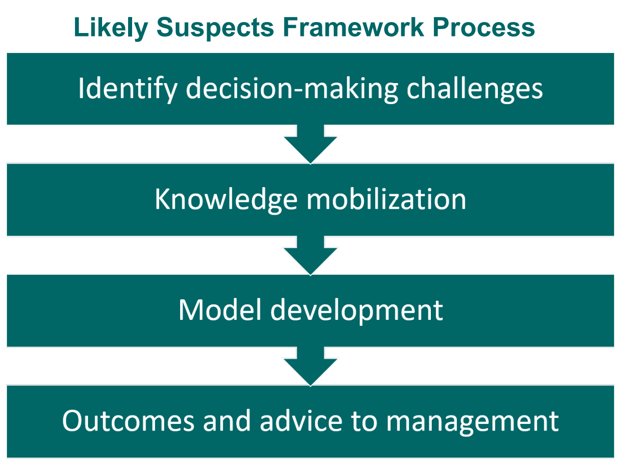
Bayesian Belief Networks	A probabilistic graphical model that represents conditional dependencies between random variables through a directed acyclic graph.
Climate Vulnerability Assessment	A quantitative assessment of a species vulnerability to climate, determined by combining the exposure of a species to a stressor and the sensitivity of that species to the stressor. (See Hare et al. 2016)
Forest Practices Code	The set of laws and policy governing forest land use and forest management practices.
Graph Theory	The study of mathematical structures used to model pairwise relations between objects.
Individual Based Models	Models of populations or systems that are composed of discrete individuals, each modeled with their own set of state variables, attributes or behaviours.
Life Cycle Models	Models that are centered around the life history and life phases of a species.
Machine Learning	A method of data analysis that automates analytical model building.
Management Strategy Evaluation	A closed-loop simulation procedure where the stock dynamics and fishery dynamics are simulated to evaluate the effect of different harvest policies and their ability to achieve desired objectives.
Mark-Selective Fisheries	Fisheries where retention is only allowed on hatchery fish identified by a mark, often the removal of the adipose fin.
Mass Marking	Large-scale marking of hatchery fish, often identified by the removal of the adipose fin.
Mixed-Stock Fisheries	Fisheries that target multiple species at the same time.
Operating Models	Models that reflect alternative states of nature for use in MSE. Often, several Operating Models are evaluated together.
Quantitative Genetic Models	Models that describe the variation in a phenotype that is determined by both genetic variation and environmental variation.
Two-Eyed Seeing	A framework for using both Indigenous and Western ways of knowing together. Developed by Mi’kmaw Elder Albert Marshall.

1 Introduction

Pacific salmon across the North Pacific have experienced widespread declines in abundance & productivity in recent decades (Grant et al. 2019; NPAFC 2019). Climate change has emerged as an overarching driver of these trends (Grant et al. 2019). Other factors including habitat changes, disease, pollution (and others) are embedded within this overarching context of climate change.

Understanding of the drivers of salmon mortality can be improved by accounting for factors across life history stages and how effects on individuals in one environment may affect survival in another (Schindler et al. 2008; Irvine and Fukuwaka 2011, MacDonald et al. 2020). Life cycle approaches can support resource management actions more effectively. They can inform annual forecasts, but also more importantly inform recovery planning, management strategy evaluations to support resource management decisions (hatchery, habitat, harvest, and ecosystems), and climate change risk assessments.

The idea to build a relatively simple conceptual model linking effects across life history stages to develop new management advice and decision support tools is currently being implemented for Atlantic Salmon, referred to as the Likely Suspects Framework (LSF, Crozier et al. 2018). The LSF concept was developed in 2017 by a group of salmon researchers from the Atlantic and the Pacific basins and is envisioned to be a guiding process to help answer Big Questions behind the decline in wild salmon and provide practical advice to managers and decision-makers. It revolves around a holistic view of the life cycle to link our understanding of salmon across life stages and environments. The LSF seeks to identify the main sources of salmon mortality (i.e., the "likely suspects") by bringing together Indigenous knowledge, local knowledge and Western science in an attempt to account for the recent observed reductions in salmon returns. Candidate mortality factors are placed in a spatial and temporal framework including the freshwater, coastal and marine life history stages. By quantifying the potential for each factor to influence survival, the cumulative effects of these factors can be estimated to account for observed variations in survival through time.



There are approaches currently using this life-cycle approach, such as the Risk Assessment Methodology (RAMS) approach for salmon, which considers life-stage specific factors and linkages between life stages (RAMS, Hyatt et al. 2017). Other life-cycle approaches include integrating observations across life stages in all ecosystems to better inform survival for sockeye salmon in the upcoming year (MacDonald et al. 2020). Importantly, these holistic life cycle perspectives are consistent with how Indigenous Nations in British Columbia have advocated for fisheries to be managed. This highlights the importance of coherent, holistic strategies as a top priority for managing Pacific salmon stocks (First Nations Leadership Council 2007). By focusing research on the spatial and temporal changes in survival and the identification of the main factors affecting survival across the life cycle, the LSF will help contribute additional advice to resource managers to support hatchery, harvest, habitat, and ecosystem management decisions. The LSF also aims to improve understanding of and address socio-ecological and organizational questions and challenges in salmon management, as well as providing guidance on data standardization and sharing, and communicating salmon ecology, management, and conservation to diverse audiences.

The Salmonscape Workshop Series

The North Pacific Anadromous Fish Commission (NPAFC), as part of the International Year of the Salmon (IYS) activities, and partners, began scoping the development of the LSF in the northeast Pacific in July 2020. Supported by funding from the Pacific Salmon Commission Southern Endowment Fund, the NPAFC IYS Secretariat, with facilitation support from ESSA Technologies Ltd., hosted the Salmonscape Workshop Series as phase one of the LSF implementation plan in the northeast Pacific. It brought together individuals from a diverse suite of interested parties, including government scientists, academics, salmon managers, Indigenous knowledge-holders and decision-makers, NGOs, and organizational leaders. The Salmonscape Process was guided by a Planning Team (Appendix 1), who advised the NPAFC and ESSA on workshop content, provided recommendations for workshop participants, and reviewed the workshop structure and process.

The project was organized around four major themes and goals:

Theme	Goal
Challenges in Salmon Management	Identify the most significant scientific, management or decision-making challenges considering the impacts of rapidly changing socio-ecological conditions.
Life History Modeling Approaches and Tools	Recommend a life-history based approach to identify risk across the salmon life cycle and assess approaches to mitigation.
Data Mobilization	Determine the data mobilization conditions for success, challenges, barriers, and needs.
Development of the Roadmap and Case-Use Studies	Develop a Roadmap to pilot Case-Use Studies for developing the LSF.

2 Salmonscape Workshop Process

The Salmonscape Workshop Series occurred as four separate activities (described as a Focus Group + 3 workshops) from December 2020 to March 2021, with each workshop broken up into two, 2-hour sessions. The workshop process structure for each workshop is summarised below. Attendees and their respective affiliations for the Focus Group and each of the three workshops are listed in Appendix 3. Links for Workshop 1 and Workshop 2 presentation slide decks are provided in Appendix 4.

Focus Group: Salmon Challenges

The Salmonscape Workshop Series began with a Focus Group designed to *identify the most significant scientific, management or decision-making challenges related to salmon.* Close to 60 individuals were identified by the Salmonscape Planning Team and invited to participate. These individuals represented federal and state/provincial agencies, tribal governments and First Nations communities, academics, and NGOs. The expertise and scope of decision-making included fisheries managers, hatchery managers, habitat managers, organizational leadership, individuals with Western science backgrounds, and Indigenous Knowledge-holders. In total, 35 of these individuals were able to participate in the Focus Group, with the two sessions being largely independent, and most individuals participating in only one session.

Before the Focus Group sessions, individuals were asked to provide examples of the most significant scientific, management or decision-making challenges they face considering the impacts of rapidly changing socio-ecological conditions that are affecting salmon populations at one or more life history stages. Specifically, they were asked to provide the top challenge(s), the relevant life history stages and spatial scales to consider and describe critical uncertainties that are relevant for longer timescales (5–10+ years).

In total, the participants submitted over 110 “challenges”. The responses were compiled by ESSA and NPAFC staff, and organized into broad categories: fisheries, hatcheries, habitat, science/data, socio-ecological, ecosystem, climate change, and social. The NPAFC team reviewed these 110 submissions and, given some duplicates and overlap between “challenges” and “uncertainties”, reduced the 110 down to a list of 29 challenges (see Appendix 2).

Over each 2-hour session, participants spent the majority of their time in two different breakout groups. During the first breakout session each group was shown a different subset of 10 of the 29 challenges. Each group then selected 1–3 challenges to discuss. At the end of the first breakout session, the group submitted two challenges for a discussion about solutions during the second breakout session.

Workshop 1: Assessment Processes and Modelling Tools

Workshop 1 was held over two sessions, with the objective of *recommending a life history-based approach to identify risk across the salmon life cycle and to assess management approaches to mitigation.*

Session 1 brought together 49 participants, most of whom reconvened for Session 2, which had 43 participants in total. As with the Focus Group, participants represented a diverse range of roles and expertise from federal, and provincial/state agencies, Indigenous governments and communities, NGOs, and academic institutes.

Session 1 began with an introductory presentation by Dr. Colin Bull about the LSF. Following this introduction, five short presentations were given about assessment processes that are currently in use. These processes (and presenters) were:

1. Priority Threat Management Framework (Dr. Eric Hertz),

2. Climate Vulnerability Assessment (Dr. Lisa Crozier),
3. Risk Assessment Model for Salmon (Wilf Luedke),
4. Two-Eyed Seeing (Karli Tyance Hassell), and
5. Graph Theory (Chris Callaghan/Matt Spencer).

The process presentations described the objectives of the respective processes, their inputs and data needs, outputs, and the biggest challenges for their use. Following the presentations, participants were sent into breakout groups to discuss the following questions:

1. Are there processes, other than the ones presented today, that should be considered to shape and contribute to the LSF?
2. What can we learn from existing processes that assess risk and mitigation scenarios to help develop the LSF?
3. Can the LSF contribute to and support existing processes in place to assess risk and mitigation scenarios? If yes, how?
4. Are there emerging issues, currently not addressed by processes in use, that the LSF would be applicable to?

Summaries of responses to these question can be found in Appendix 2.

Session 2 began with a series of brief presentations to review some of the modeling tools and methods currently in use for salmon. These tools/methods (and presenters) were:

1. Ecosystem models (Greig Oldford),
2. Life history models (Dr. Mathieu Buoro),
3. Individual-based models (Dr. Mathieu Buoro),
4. Integrated population models (Dr. Mark Scheuerell),
5. Life history models (Dr. Lisa Crozier), and
6. Life cycle models (Dr. Eduardo Martins).

The presentations described the tools/methods and their current uses, their potential or actual application to management questions, required inputs and data needs, outputs, and the biggest challenges associated with the tools/methods. Following the presentations, participants were sent into breakout groups to discuss the following questions:

1. Are there other tools that should be considered for the toolkit?
2. How can these tools support the data needs for the processes discussed in the previous session? What are the limitations?
3. Is there a benefit of linking some of these tools/methods together? If so, how could they complement each other?

A second round of breakout groups then addressed the following questions:

1. Does the LSF address the management challenges identified? If not, what are we missing?
2. What are the implementation challenges for the LSF?

Summaries of responses to these questions can be found in Appendix 2.

Workshop 2: Data Mobilization

Workshop 2 was held over two sessions, with the objective of *identifying the needs, barriers, and solutions for data mobilization within the context of the LSF.*

Session 1 brought together 37 participants, and 43 participants for Session 2. Some individuals attended both sessions. The participants represented federal and provincial/state agencies, Indigenous governments and communities, NGOs, and academia.

Session 1 began with an overview of the LSF, presented by Dr. Colin Bull. This presentation focused on the LSF's data resources and database development. Following this, a second presentation was given by Matt Jones from the National Center for Ecological Analysis & Synthesis (NCEAS) on defining data mobilization. This presentation set the ground for an interactive panel discussion about winning conditions for data mobilization, with the following panel members:

- Matt Jones, NCEAS,
- Matt Deniston, Sitka Technology Group,
- Tim Van Der Stap, Hakai Institute,
- Dr. Isobel Pearsall, Pacific Salmon Foundation,
- Jen Bayer, Pacific Northwest Aquatic Monitoring Partnership (PNAMP), and
- Dr. Colin Bull, Missing Salmon Alliance

Specifically, the panel discussed past successful experiences with data mobilization tools and approaches, the conditions that led to those successes, and lessons learned. After a break, the panel reconvened for a discussion on common barriers to data mobilization, potential approaches for overcoming these barriers, and relevant lessons learned about these challenges. The workshop closed with a quick survey of participants about their own successes and challenges with data mobilization.

Session 2 began with a review and Q&A period about the feedback provided in Session 1. The conversation then continued in plenary with a brainstorming session on the key elements of a data mobilization strategy. Following this, the data mobilization strategy for the LSF was discussed in smaller breakout groups. Guiding questions for the discussion were:

- Is this the right vision for the future?
- What additional outcomes/elements are needed for a data mobilization strategy?
- What are the action items needed to achieve these long-term outcomes? And corresponding steps for a Case-Use Study?
- What are the key considerations for success?

Summaries of responses to these questions are available in Appendix 2.

Workshop 3: Developing the Roadmap and Case-Use Studies

Workshop 3 was held with the SPT over two sessions with the objective of *creating the roadmap needed to develop Case-Use Studies for the LSF.*

Session 1 brought together a small group of SPT members who reviewed and discussed the draft roadmap to further delineate its key elements. Session 2 included further refinement of the roadmap with a larger group of SPT members and several other experts, as well as a discussion on the components to include in the roadmap and the icons to use to represent them in a sample life cycle diagram. Both discussions were facilitated through use of a virtual Mural board on which participants added comments.

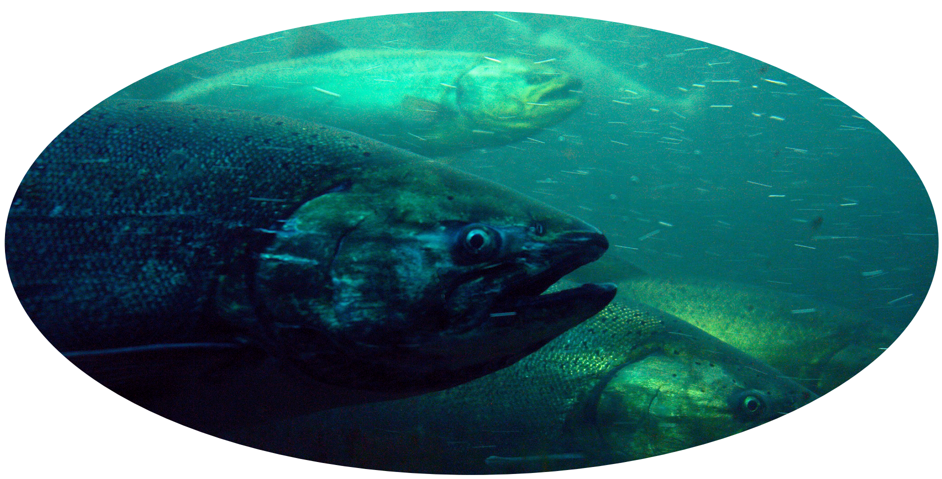
3 Roadmap for Developing the LSF

The Roadmap, outlined in Workshop 3 and further refined by the SPT following the workshop, will be used to guide the process for developing the Case-Use Studies to test and further define the LSF. The Roadmap was created based on feedback provided by dozens of participants, including salmon researchers and scientists, managers, knowledge-holders, decision-makers, and organizational leaders as part of the Salmonscape Workshop Series.

The key elements of the Roadmap fall under five broad areas:

1. Establishing an Oversight Committee
2. Identifying Big Questions in Salmon Management and Conservation,
3. Testing the LSF using Case-Use Studies,
4. Refining the LSF, and
5. LSF Implementation for Broad Application.

In this section, we provide an overview of the Roadmap elements and highlight what we learned in the Salmonscape Workshops that relates to its development. The Workshop process is described in Section 3 and high-level Workshop summaries can be found in Appendix 2.



A Roadmap for Developing

THE LIKELY SUSPECTS FRAMEWORK (LSF)

The LSF is a guiding process to help answer Big Questions behind the decline of wild salmon, and to provide practical advice to managers and decision-makers. It revolves around a holistic view of the life cycle to link our understanding of salmon across life stages and environments, as well as understand and address the socio-ecological and organizational questions and challenges in salmon management. This Roadmap will be used to guide the process for developing the LSF. It is based on feedback on key elements provided by several dozen salmon researchers, managers, decision-makers, and organizational leaders as part of the Salmonscape Workshop Series.

1 Establishing an LSF Oversight Committee (OC)

The OC helps identify Big Questions and Case-Use Studies and helps create and support the Working Groups (WG)

2 Identifying Big Questions in Salmon Management and Conservation

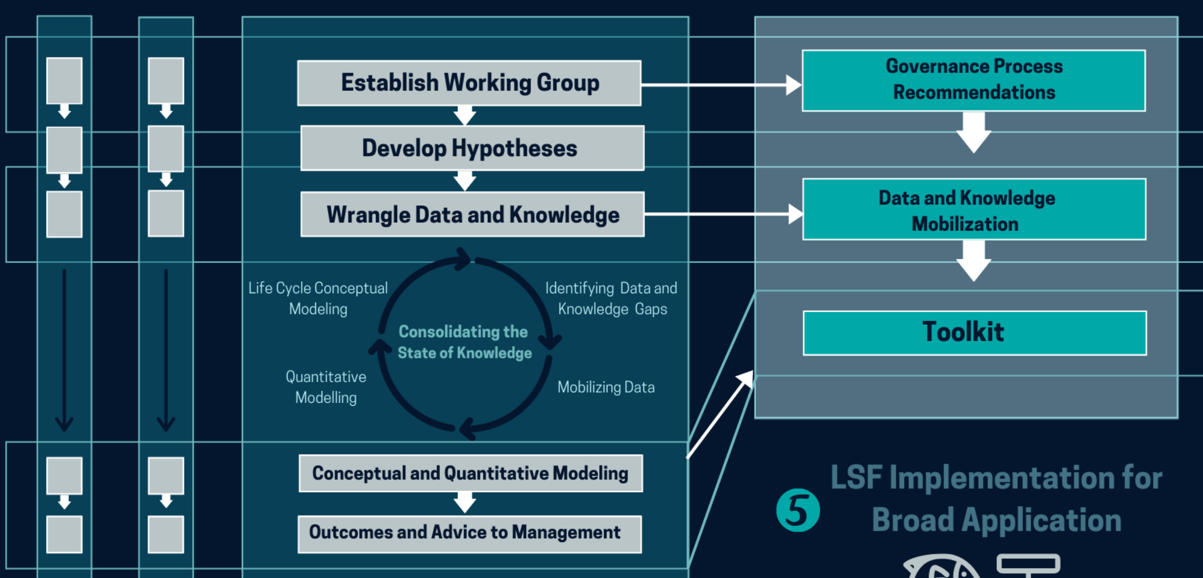
Big Questions and management challenges were identified by 35+ salmon managers and decision-makers that participated in a Focus Group as part of the Salmonscape Workshop Series. Examples of Big Questions include:

- How do carryover effects between freshwater and marine environments impact salmon?
- What are the key oceanographic drivers of salmon survival and migration?
- What are the habitat-based drivers of population status for salmon species and life history variants across populations, and how will climate change affect these?

3 Testing the LSF Using Case-Use Studies

Case-Use Studies are identified by matching a population/s with one or more of the Big Questions for which there is sufficient data and expertise for the investigation. A Working Group will be established for each Case-Use Study and will develop a series of testable hypotheses related to the Big Question/s

4 Refining the LSF



5 LSF Implementation for Broad Application

1 Establishing an LSF Oversight Committee

The LSF Oversight Committee (OC) should be composed of qualified individuals from government agencies, Indigenous communities and Nations, academia, and other organizations. The primary responsibility of members is to champion the development of the LSF in such a way that it is relevant to the needs of the organizations they represent and to ultimately promote its uptake. The LSF OC will identify Case-Use Studies that match appropriate focal populations/stocks with the appropriate Big Questions and ensure that there is sufficient information and expertise to conduct the Case-Use Study. The OC will also help assemble the Working Groups (WGs) that will implement each Case-Use Study and support the WGs as needed. The OC can support WGs by helping secure funding, and advising on governance considerations, processes, and tools to help identify population bottlenecks, knowledge, data mobilization and data sharing considerations, and approaches that are able to use multiple knowledge types to more fully address Big Questions (e.g., Two-Eyed Seeing).

The Atlantic Salmon LSF process is led by five NGOs that are part of the Missing Salmon Alliance and can serve as a model for the Pacific region. As part of the Atlantic Salmon LSF, there is an oversight body that is largely a funding body, and a technical group to oversee the science and data. Core internal groups and individuals external to the group are invited to participate and help add a range of perspectives to the project.

What we learned in the Salmonscape Workshop Series

The OC will be championing the development of the LSF, and as such will need to provide guidance on several key elements (described in Section 2) identified as important throughout the workshop series. Case-Use Studies will include developing governance and processes for the Working Groups, processes for bringing together experts to consolidate knowledge and build conceptual models to identify bottlenecks, wrangling data and creating data standards for data sharing and accessibility, linking models and bridging data and quantitative models across domains, as well as developing decision-support tools (e.g., Management Strategy Evaluation) and communications tools (e.g., infographics, workshop facilitation templates).

The OC will also need to coordinate and synthesize the results and lessons learned across the Working Groups to draft the LSF recommendations for governance and process, a data and knowledge mobilization strategy, and a toolkit that includes conceptual and quantitative modeling approaches, decision-support tools, and communications tools.

2 Big Questions and Challenges in Salmon Management and Conservation

When developing the Salmonscape Workshop Series, the Planning Team advised to start by reaching out to managers and decision-makers. The rationale for this was that it is critical to first understand the Big Questions and challenges managers, decision-makers, and organizational leaders are presently grappling with, and that their feedback would help us develop the context for the subsequent workshops.

The complex life history of salmon greatly complicates our ability to understand important drivers of mortality. As salmon grow and migrate, their competitors, prey, and predators change, and their ability to compete and evade predation is influenced by the physical environment. There are many candidate factors that are thought to influence the survival and success of salmon in different environments. However, our understanding of these factors is limited by the questions we ask and the information we can readily obtain. The LSF is meant to help us link freshwater, estuarine and marine domains, and understand how carry-over effects may also play an important role in understanding salmon mortality.

The LSF may assist management by promoting the steps needed to consider cumulative and/or non-linear effects, focus on current unknowns by quantifying uncertainty and considering alternative hypotheses, and improve communication.

What we learned in the Salmonscape Workshop Series

In total, 29 Big Questions and challenges in salmon management were identified by 35+ salmon managers, decision-makers, knowledge-holders, and organizational leaders, demonstrating the diversity and complexity of salmon management today. These questions and challenges are summarized here under rough categories of "salmon factors" and "human factors", to differentiate ecological effects from the social and organizational challenges identified by the focus group participants. General topics included in these broad categories include habitat effects, hatcheries, science and data, climate change, social challenges, and organizational challenges. Examples of associated Big Questions are:

- How do carry-over effects between freshwater and marine environments impact salmon?
- What are the key oceanographic drivers of salmon survival and migration?
- What are the habitat-based drivers of salmon survival and migration?
- How can Indigenous Knowledge be viewed as equally valid by colonial governments, and included for better decision-making using braided knowledge (e.g., Two-Eyed Seeing or others) approaches?

A full list of the 29 Big Questions and challenges can be found in Appendix 2.

Salmon factors

Habitat degradation and loss due to coastal area development was identified as a key challenge, especially when paired with shifting species ranges in response to climate change. We heard that it is exceedingly difficult for managers and organizational leaders to move from a state of acting reactively to one of proactive decision-making with regard to climate change effects, and that the ability to integrate uncertainty into our decision-making plays a role in this challenge as well.

Understanding the impacts of novel conditions in both marine and freshwater environments is a critical challenge for salmon recovery efforts. Incorporating these conditions into a quantitative modeling framework is a further challenge that needs to be addressed.

Mixed-stock fisheries are particularly challenging for management. Untangling total mortality of bycatch in mixed stock fisheries and determining stock-specific responses to environmental conditions may prove to be difficult. Both of these difficulties lead to further challenges in determining harvest opportunities for mixed stocks, particularly those that co-migrate with stocks of concern.

Broad and specific data needs were identified by participants. In terms of broad needs, participants described the importance of incorporating uncertainty throughout the science chain up to the point of decision-making. This uncertainty should be accounted for in abundance forecasts. When forecasts fail, participants also stressed the need for in-season assessment tools. Specific data needs are diverse, but more data will reduce uncertainty and better inform management by improving our understanding of focal candidate drivers of population dynamics, including:

- The impacts of Mass Marking Chinook and coho on wild populations,
- Intergenerational effects,
- Migration patterns in relation to changing oceanographic drivers,
- Marine mammal predation impacts,
- Varying sensitivity of salmon at different life stages,
- Overwintering survival of parr, and
- Marine survival (broadly defined).

Hatchery operations were also identified as a major challenge for salmon recovery. There needs to be consensus on the scale, scope, and purpose of enhancement activities. Practices must be optimized to achieve their objectives while minimizing negative impacts to wild stocks. Ideally, hatchery practices would be adaptive and responsive to the status and condition of wild populations, however implementing large-scale changes to hatchery programs entails its own set of institutional challenges.

Human Factors

Many participants attributed salmon recovery challenges to issues in legislative and regulatory frameworks. In the United States, the *Endangered Species Act* is perceived to be insufficient in its approach to harvest allocation. In Canada, weaknesses in the *Species at Risk Act* prevent some species at risk from being listed as endangered or threatened despite being designated as such by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). In both countries, there is complexity in balancing the management of salmon with non-salmon species at risk. With regards to British Columbia, participants mentioned that the Forest Practices Code was inadequate for protecting riparian areas. In general, natural river and stream function and floodplains are not perceived to be protected by regulations.

Various challenges associated with governance were identified. Firstly, prioritizing salmon recovery over competing interests (e.g., predator population recovery) is difficult. Even when salmon are prioritized, differing perspectives among different countries, states, provinces, and Indigenous groups result in long negotiations and fragmented management. The delays between problem identification and response are particularly concerning in the face of rapidly changing ecological conditions caused by climate change. Moving forward, management plans and harvest structures will need to swiftly respond to dramatic, unexpected changes. To achieve this, there is a need for clear pathways to incorporate science into policy decisions in a timely manner.

Despite hearing about the importance of Indigenous perspectives, leadership, and governance, recognition of Indigenous rights and Indigenous Knowledge (IK) regarding salmon management were highlighted by several participants as being inadequate. In most public and policy spheres, IK systems are not yet viewed as equally valid and informative as Western science. While recognizing the value of Indigenous Knowledge is a critical step, the ultimate need is for IK to be used alongside Western science, and for Indigenous governance to be upheld. Limited capacity in many Indigenous communities, however, hinders our ability to use the best available information for salmon management, and the systemic inequalities Indigenous communities continue to face affect our ability to improve salmon management.

In addition to the range of governance bodies involved in salmon recovery, there are an overwhelming number of stakeholders and partners who have complex and often competing interests. Balancing opportunities among stakeholders and partners is a major challenge that will continue to grow if salmon productivity continues to decline and more population units become listed. Decision-makers are faced with trying to maintain support and even build willingness across sectors to ease fishing pressure and to manage water usage and land-use planning. This is of particular importance, as the responsiveness of our institutions often does not meet the timeliness needed to address the causes underlying declines in wild salmon. It should be noted, however, that there are examples of our institutions moving rapidly to address major challenges, the Big Bar landslide on the Fraser River being a prime example (Province of British Columbia 2021).

Another challenge identified by participants was finding ways to meaningfully engage and communicate with the public. It has proven difficult to fully convey the complexity of salmon management. There is currently a negative perception of fish management from the public, which may impede buy-in to salmon recovery efforts. The participants conveyed that the LSF could be a tool used to help facilitate science communication across diverse audiences.

Resource limitations inhibit salmon recovery and conservation at all levels, including financial capacity for everything from maintaining monitoring programs and conducting habitat restoration activities to addressing information deficits and implementing updated policies. Resource limitations are particularly challenging in Indigenous communities that have a strong desire to contribute to salmon management and conservation activities but do not have sufficient capacity or sustainable funding sources for these activities.

3 Testing the LSF using Case-Use Studies

Individual Case-Use Studies will involve focal populations/stocks with their relevant Big Question/s and be used to pilot the development of the LSF. A Working Group will be formed for each Case-Use Study and will focus on a population or stock (or set of populations/stocks), for which sufficient information and expertise exist. The Studies will be driven by several key elements that include Working Group governance, development of hypotheses related to the Big Questions, defining the set of processes to identify population bottlenecks, consolidating the State of Knowledge (SoK) and conducting modeling exercises, and communicating results and advice to decision-makers. Consolidating the SoK will likely be an iterative process that involves bringing together Indigenous knowledge, local knowledge, and Western scientific knowledge, developing conceptual life cycle models, identifying data needs and data gaps, wrangling data, assembling relevant quantitative models, and performing analyses. Completing an iteration of the SoK consolidation cycle may lead the Working Group to revisit and update components of the SoK and perform a new set of analyses. The lessons learned from each Case-Use Study will help the OC develop a broader set of recommendations on governance, data/knowledge sharing, and modeling approaches. These tools will provide decision-support services for managers and decision-makers and provide broad recommendations and templates for communications products that can be used in the broad application of the LSF.

What we learned in the Salmonscape Workshop Series

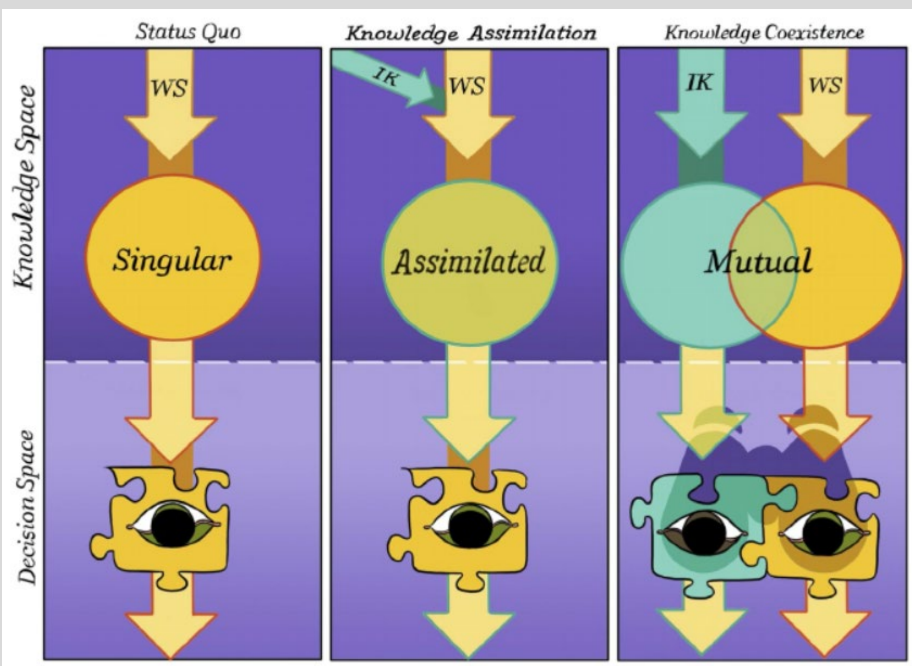
There was broad agreement across participants that for the LSF to provide tangible and actionable advice to decision-makers, the context for the Case-Use Studies needs to reflect the biggest challenges that decision-makers are currently facing. This feedback provides the context to identify the relevant Big Questions (and re-shape as needed) as the Working Group coordinates with the OC.

Assessment processes

Several processes that bring together experts to identify bottlenecks and address the Big Questions have been developed and were highlighted by participants as tools that can help shape the LSF as well as be made accessible as part of the LSF Toolkit. These processes include:

- The Risk Assessment Method for Salmon (RAMS; Hyatt et al. 2017)
- Priority Threat Assessment (Carwardine et al. 2012, 2019; Walsh et al. 2020)
- Expert-based scenario planning
- The Canadian Science Advisory Secretariat (CSAS) process
- Climate Vulnerability Assessment (Hare et al. 2016; Crozier et al. 2019)

Participants noted that inclusive processes that bring together different types of knowledge (Indigenous, local, Western science) are critical to the successful application of the LSF. Participants commented that Indigenous Knowledge used in a braided knowledge approach (e.g., Two-Eyed Seeing, Bartlett et al. 2012; Reid et al. 2021) will improve our ability to ask better questions and to better address these questions. It is critical, however, that Two-Eyed Seeing approaches are not viewed as ones where IK is simply assimilated into Western scientific paradigms but retained in a true Two-Eyed approach. Additionally, IK can also provide valuable insights into governance processes and alternative leadership paradigms, and efforts should be made for greater co-management and power sharing relationships with First Nations.



Conceptual framework showing the difference between the status quo single knowledge stream (WS is western science), how Indigenous Knowledge can be assimilated into western paradigms, and the Two-Eyed Seeing approach. Figure is from Reid et al. 2021. Artwork by Nicole Burton.

Different processes were considered to have different strengths and weaknesses that could be beneficial in developing the LSF. For example, the Risk Assessment Method for Salmon examines the full life cycle of salmon and the risks and potential management actions, but there is still a challenge with developing a process to assess risks in the marine environment. Priority Threat Assessment uses a high-level ecosystem approach to determine the overall costs and benefits of management actions but struggles to capture some of the finer details. Climate Vulnerability Assessment examines the vulnerability of species/stocks to climate change, however there is no step in the process to assess management scenarios to try and mitigate the negative impacts of climate change. Participants noted the value of drawing on the strengths of some of these processes to try and develop an inclusive and holistic approach to consolidate the SoK in the LSF.

The initial assessment of the SoK includes processes to develop life cycle and other conceptual models, identify important data and knowledge gaps, assess the feasibility to move beyond conceptual models and make use of quantitative models, create data management methods so data and model outputs can be shared more easily, and ensure model inputs and outputs can be linked as needed. Consolidating the SoK will likely be an iterative process, where conceptual models are further refined as data and knowledge are assembled and quantitative models provide initial results, at which point those results may point to the need to revisit initial hypotheses and data needs.

In order to develop the LSF, Case-Use Studies will need to focus on populations/systems that are relatively data-rich (at least initially), and for which quantitative models are being used and their inputs, outputs, strengths, and limitations are generally understood. However, as the LSF is developed, consideration for use in data-poor systems will be important, as managers and decision-makers responsible for data-poor systems are faced with making similar decisions as those in data-rich systems. The LSF should be able to provide a starting point and guidance for those decision-makers as well.

Modelling processes and tools

A variety of tools and models (e.g., those described in the first Workshop: Hierarchical Bayesian Life Cycle Model, Individual Based Models) exist that should be considered for integration into the LSF. These include monitoring of data from other species (e.g., pinniped scat data, seabird abundance, etc.) that could inform salmon food web correlates, new remote sensing of spatially explicit habitat features, and incorporation of different modeling techniques as warranted (e.g., Graph Theory, linear models, machine learning, AI, Bayesian Belief Networks, hierarchical models, multi-stock vs. individual stock models, Dynamic Energetic Budget models, and quantitative genetic models).

Data mobilization

Broader data sharing and data standardization can help create new insights. However, barriers to data sharing and data standardization are often large and can be pervasive. Providing a set of guiding principles on data sharing and standardization will be a key element of the LSF, as linking models to understand population drivers across life stages and across environments requires a high level of coordination, collaboration, and communication between partners. As Case-Use Studies are implemented, the OC will be able to provide recommendations on developing data sharing best practices. Some of the ideas and topics that were discussed during the workshops included:

- open access approaches to data
- building trust
- providing value to data providers
- protocol interoperability

- obtaining buy-in from management and securing sufficient funding
- planning interactions and timelines with partners
- shared data vocabularies
- inclusive data/knowledge collation
- metadata
- respecting reasons for private and unshared data
- technical capacity
- sustainability of data sharing approaches

More detailed summaries of the workshop outcomes related to data mobilization can be found in Appendix 2.

Generating advice to management

One of the key guiding principles of the LSF is that everything should build towards generating tactical and strategic management advice and recommended actions. What is learned from modeling exercises should translate into decision-support tools. Process models coupled with future scenario projections can provide managers with the insights they will need to deal with rapidly changing conditions. In general, we still rely on simple statistical models that are largely driven by simple assumptions of the underlying processes. Fisheries management does not depend on process models and the statistical models do not generate much insight about unexpected variations. Importantly, we heard that Management Strategy Evaluation (MSE) closed-loop simulation analysis is the current gold standard for evaluating the effects of harvest on population capacity and productivity. Case-Use Studies that build towards an MSE analysis will be important, as MSE is likely to be a key decision-support tool for evaluating fisheries management. As the LSF develops, it will likely be important for generating scenarios to be evaluated using MSE (i.e., developing Operating Models for MSE).

4 Refining the LSF

At its core, the LSF is an organizing framework to better understand the causes and impacts of salmon mortality by linking effects across life stages and environments. However, the LSF goes beyond life history conceptual modeling exercises and can provide an organizing platform that integrates key elements into one cohesive set of practices. These elements broadly include:

1. The context for critical decision-making challenges
2. Guidance on data sharing and standardization to integrate results across studies
3. A diverse toolkit including processes to conduct expert elicitation, linking conceptual models to quantitative models, integrating quantitative modeling efforts across spatial and temporal scales, decision-support tools, and communications products.

This set of practices will allow researchers to coordinate and collaborate on research efforts to address Big Questions surrounding salmon ecology and management, perform management gaming exercises to deliver advice to decision-makers, and find support for developing communications (examples of communication graphics developed so far are shown in Appendix 5).

5 LSF Implementation for Broad Application

Implementation of the LSF will be reliant on lessons learned from each of the Case-Use Studies. There are several important challenges related to the implementation of the LSF, including bringing the LSF to data-limited systems (which will be a challenge for supporting process type models), buy-in from partners/stakeholders, the inherent complexity and scale across salmon life histories, and the uncertainty around key pieces of information (e.g., hatchery effects, ocean survival, future environmental conditions). Wide implementation of sophisticated models as envisioned within the LSF likely requires development of a new set of tools, whereby individual model components can be integrated and customized to unique situations. There will be a need to effectively incorporate non-salmon information into analyses (e.g., marine environment and pelagic fisheries surveys, ecosystem surveys). Different regions within the sphere of the LSF will undoubtedly have their own set of implementation challenges and the different tools that may be developed will only be somewhat generalizable between regions, so developing flexibility around data inputs and supporting analyses will be a key element of successful LSF implementation.

4 Recommended Next Steps

Here, we outline our recommended steps to continue work towards the implementation of the LSF in the Northeast Pacific.

1. Secure funding to conduct multiple Case-Use Studies as a proof of concept of the LSF and to provide detailed recommendations for its practical implementation on a broad scale.
2. Form a Project Oversight Committee including Indigenous Knowledge holders, scientists, and federal and provincial agency representatives to provide administrative and management support and oversight for the Case-Use Studies and to ensure there are champions within management agencies to ultimately enable implementation of the LSF. International partners implementing the LSF elsewhere should also be included.
3. Form a Working Group for each Case-Use Study, comprised of local and Indigenous Knowledge holders, local scientists, and local decision makers that work within the local area to oversee Case-Use Studies and provide advice to the Project Team (see next step).
4. Establish a Project Team to conduct the Case-Use Studies. It should consist of a Principal Investigator, Postdoctoral Fellow, Data Scientist, Data Technician and Communications Coordinator. The Principal Investigator should have expertise in ecological modelling techniques recommended by the LSF Oversight Committee and specific knowledge on salmon ecology. The Postdoctoral Fellow should have expertise in bridging Indigenous Knowledge and Western science in models and data/knowledge management frameworks. The Data Scientist and Data Technician should be responsible for the Data Mobilization aspects of the project.
5. Implement the Case-Use Studies identified by the Oversight Committee that will serve as a test for broader application of the Likely Suspects Framework. These Case-Use Studies should focus on populations where there are existing data and interest in collaborative efforts between Indigenous Peoples alongside the provincial/state and/or federal government to develop management strategies. The modelling efforts should be led by the PI with assistance from the postdoc and incorporate in-person meetings with knowledge holders where possible. The Data Scientist and Data Technician should work on identifying relevant datasets for the Case-Use Studies, standardizing the data based on agreed upon standards from the Oversight Committee, making data accessible, and providing decision-support tools.
6. Once the Case-Use Studies are completed, an overview paper should be produced to describe the approach and recommend best practices for broad implementation of the Likely Suspects Framework in the Northeast Pacific.

References

Bartlett, C., M. Marshall, and A. Marshall. 2012. Two-eyed seeing and other lessons learned within a co-learning journey of bringing together Indigenous and mainstream knowledges and ways of knowing. J. Environ. Stud. Sci. 2(4): 331–340.

Carwardine, J., T. O'Connor, S. Legge, B. Mackey, H.P. Possingham, and T.G. Martin. 2012. Prioritizing threat management for biodiversity conservation. Cons. Let. 5(3): 196– 204.

Carwardine, J., T.G. Martin, J. Firn, R.P. Reyes, S. Nicol, A. Reeson, H.S. Grantham, D. Stratford, L. Kehoe, and I. Chadès. 2019. Priority Threat Management for biodiversity conservation: A handbook. J. Appl. Ecol. 56(2): 481–490.

Crozier L.G., M.M. McClure, T. Beechie, S.J. Bograd, D.A. Boughton, M. Carr, T.D. Cooney, J.B. Dunham, C.M. Greene, M.A. Haltuch, E.L. Hazen, D.M. Holzer, D.D. Huff, R.C. Johnson, C.E. Jordan, I.C. Kaplan, S.T. Lindley, N.J. Mantua, P.B. Moyle, J.M. Myers, M.W. Nelson, B.C. Spence, L.A. Weitkamp, T.H. Williams, and E.Willis-Norton. 2019. Climate vulnerability assessment for Pacific salmon and steelhead in the California Current Large Marine Ecosystem. PLoS ONE. 14(7): e0217711. https://doi.org/10.1371/journal.pone.0217711

Crozier, W., K. Whelan, M. Buoro, G. Chaput, J. Daniels, S. Grant, K. Hyatt, J. Irvine, N. Ó'Maoiléidigh, E. Prévost, E. Rivot, I. Russell, M. Schmidt, and B. Wells. 2018. Atlantic salmon mortality at sea: Developing an evidence-based "Likely Suspects" Framework. Atlantic Salmon Trust Likely Suspects Workshop. Edinburgh, UK. 72pp.

Grant, S.C.H, B.L. MacDonald, and M.L. Winston. 2019. State of Canadian Pacific Salmon: Responses to Changing Climate and Habitats. Can. Tech. Rep. Fish. Aquat. Sci. Fisheries and Oceans Canada, Science Branch, Pacific Biological Station, Nanaimo 3332. ix + 50 pp.

First Nations Leadership Council 2007. BC First Nations Fisheries Action Plan. First Nations Fisheries Council. 30pp. https://www.fnfisheriescouncil.ca/wp-content/uploads/2015/09/FNFC-Action-Play-full-version-2007.pdf

Hare J.A., W.E. Morrison, M.W. Nelson, M.M. Stachura, E.J. Teeters, R.B. Griffis, M.A. Alexander, J.D. Scott, L. Alade, R.J. Bell, A.S. Chute, K.L. Curti, T.H. Curtis, D. Kircheis, J.F. Kocik, S.M. Lucey, C.T. McCandless, L.M. Milke, D.E. Richardson, E. Robillard, H.J. Walsh, M.C. McManus, K.E. Marancik, and C.A. Griswold. 2016. A Vulnerability Assessment of Fish and Invertebrates to Climate Change on the Northeast U.S. Continental Shelf. PLoS ONE. 11(2): e0146756. https://doi.org/10.1371/journal.pone.0146756

Hyatt, K., L. Pearsall., and W. Luedke. 2017. A risk assessment methodology for salmon (RAMS) population conservation and management within an ecosystem context. Department of Fisheries and Oceans, Science Branch, Pacific Biological Station, Nanaimo, B.C. 38 pp.

Irvine, J.R., and M. Fukuwaka. 2011. Pacific salmon abundance trends and climate change. ICES J. of Mar. Sci. 68(6), 1122–1130.

MacDonald, B.L., S.C.H. Grant, N.Wilson, D.A. Patterson, K.A. Robinson, J.L. Boldt, J. King, E. Anderson, S. Decker, B. Leaf, L. Pon, Y. Xu, B. Davis, and D.T. Selbie. 2020. State of the Salmon: Informing the survival of Fraser Sockeye returning in 2020 through life cycle observations. Can. Tech. Rep. Fish. Aquat. Sci. 3398: v +76pp.

NPAFC. 2019. Report of the proceedings for the IYS workshop. International Year of the Salmon workshop on salmon status and trends. N. Pac. Anadr. Fish Comm. Tech. Rep. 13. 91pp. (Available at https://npafc.org/)

Province of British Columbia 2021. Big Bar Landslide Incident. Available from: <https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/fish/aquatic-habitat-management/fish-passage/big-bar-landslide-incident> [Accessed May 10th, 2021]

Reid, A., L.E. Eckert, J. Lane, N. Young, S.G. Hinch, C.T. Darimont, S.J. Cooke, N.C. Ban, and A. Marshall. 2021. "Two-Eyed Seeing": An Indigenous framework to transform fisheries research and management. Fish. Fish. 22(2): 243–261.

Schindler, D., X. Augerot, E. Fleishman, N.J. Mantua, B. Riddell, M. Ruckelshaus, J. Seeb, and M. Webster. 2008. Climate Change, Ecosystem Impacts, and Management for Pacific Salmon. Fisheries 33(10): 502–506.

Walsh, J., K. Connors, E. Hertz, L. Kehoe, T. Martin, B. Connors, M. Bradford, C. Freshwater, A. Frid, J. Halverson, J. Moore, M. Price, and J. Reynolds. 2020. Prioritising conservation actions for Pacific salmon in Canada. J. App. Ecol. 57(9): 1688-1699. https://doi.org/10.1111/1365-2664.13646

Appendix 1 – Salmonscape Planning Team

An advisory Salmonscape Planning Team (SPT) was assembled at the beginning of the project to assist the Project Lead and facilitation team in planning the Salmonscape Workshop Series. The SPT helped with the workshops in addition to participating as experts themselves. The SPT met semi-regularly to help shape workshop goals, identify individuals to invite to each workshop, and review the proposed workshop content, preparatory material, and activities.

The Salmonscape Planning Team, including the Project Lead and Facilitation team, included:

- Mark Saunders (Project Lead) currently works for the North Pacific Anadromous Fish Commission as the Director for the North Pacific Region of the International Year of the Salmon initiative. He retired several years ago from the Canadian Department of Fisheries and Oceans where he headed up a Salmon, Aquaculture and Freshwater Ecology Division at the Pacific Biological Station in Nanaimo, B.C. with staff working on salmon stock assessment, freshwater habitat, molecular genetics, fish health, and marine ecology. The early part of Mark's career focused on stock assessment of marine fishes as well as research related to hydroacoustic surveys and fisheries oceanography of the California current system.

- Caroline Graham (Project Coordinator) served as the International Year of the Salmon Coordinator for the North Pacific region. Caroline was involved with the planning, coordination, and synthesis of the first three Salmonscape meetings. She recently completed an MSc in Oceans and Fisheries at the University of British Columbia where she studied salmon trophic ecology in the high seas. Caroline is now the NPAFC IYS High Seas Expedition Coordinator.

- Aidan Schubert (Project Coordinator) began his role as the Coordinator for the International Year of the Salmon for the North Pacific region in March 2021. Aidan was involved in the planning of the third Salmonscape Workshop on Northeast Pacific Case-use studies, the synthesis of the outcomes of the Focus Group and three Workshops and assisted in the compilation of this report. Aidan recently completed an MSc at the University of Western Australia; reconstructing Kenya's historical freshwater fisheries catch data to support management and local food security for his thesis.

- Minje Choi (Project Assistant): Minje was an Intern with the NPAFC from December 2020 to May 2021 and assisted with the planning of the workshops. He is from Busan, South Korea and holds two bachelor's degrees from the Pukyong National University in Marine Business Economics and International Development, as well as a master's degree in Business Administration, writing his thesis on the Bioeconomic analysis of small yellow croaker (*Larimichthys polyactis*) for fisheries management.

- Dr. Catherine Michielsens is the Chief of Fisheries Management Science at the Pacific Salmon Commission. She co-leads the Fisheries Management Division with the Chief of Fisheries Management Programs. Her main area of expertise is in the application of Bayesian methods for fisheries stock assessment. She worked 7 years in Europe on the assessment of Atlantic salmon stocks in the Baltic Sea before joining the PSC. At the PSC, her initial role was to integrate the various pieces of information and data on Fraser River sockeye and pink salmon within the in-season assessment framework while accounting for risk and uncertainty when providing management advice. Since 2019, her role focusses on providing scientific supervision and leadership to Fisheries Management Division staff.

- Dr. Scott Akenhead was a research biologist with DFO for 15 years. He gained extensive experience in ecological models, fisheries science and management, geomatics, statistics, and numerical analysis, and led the introduction of new technologies for natural resources management. He has designed and delivered Decision Support Systems for government and utility clients: interactive maps integrated with simulation models for sustainability planning by government and corporate clients, collaborative web portals and on-line planning tools, and is an expert in data collection technology, data processing, analysis, and modeling for natural and built systems. Scott also serves on the external advisory committee for the Missing Salmon Alliance, who are developing the Likely Suspects Framework for Atlantic Salmon.
- Dr. Colin Bull is the Principal Investigator of the Likely Suspects Framework Project under the Missing Salmon Alliance and the Atlantic Salmon Trust. He is a Teaching Fellow in Biological and Environmental Sciences at the University of Stirling.
- Dr. Brian Wells is a Fisheries Researcher at National Oceanic and Atmospheric Administration (NOAA) along the California Current. His primary focus is on modeling salmon interactions with the ocean ecosystem in the hopes of developing tools for management strategy evaluation. Brian also serves on the external advisory committee for the Missing Salmon Alliance, who are developing the Likely Suspects Framework for Atlantic Salmon.
- Richard Erhardt has been providing scientific support to First Nations for over 20 years, primarily in the Northern Transboundary area of BC, to facilitate the expansion of their involvement in fish assessment, management, and conservation. His work has largely been "salmon centric", in this regard he is considered to be a technical "generalist" in terms of engaging in a wide suite of initiatives, forums and project types. Richard has had long-term involvement within the PSC. More recently he has started as Science Advisor for the new FNFC – Indigenous Technical Advisory Network (ITAN) program, and in that capacity is now a part of this IYS workshop planning team.
- Dr. Matthew Siegle (Primary Workshop Planner and Facilitator) is a Systems Ecologist at ESSA Technologies. Much of his research bears on the management of salmonids, marine groundfishes and eelgrass fish communities. His work focuses on the statistical modeling of complex ecological processes (particularly population dynamics) to inform policy, management, and conservation. Since joining ESSA, he has also been working as a technical facilitator, and has led process design for a number of different meetings and gatherings. Matthew has been the primary workshop planner and facilitator for the Salmonscape Series, working closely with the NPAFC team and the Salmonscape Planning Team.
- Marc Porter (Senior Facilitator) is a Senior Systems Ecologist at ESSA Technologies Ltd. with considerable experience in aquatic sciences, including work on ecosystem monitoring, modeling and adaptive management. He has served as a technical facilitator for many ambitious multi-agency undertakings seeking to develop monitoring plans and comprehensive management strategies to address vulnerabilities of threatened fish populations and their habitats in western Canada and the U.S.

Appendix 2 – High-Level Summary of Workshop Feedback

Focus Group: Management Challenges

Short list of Management Challenges identified and discussed by Focus Group participants.

General Management/Decision Making
Prioritizing salmon populations for intervention with limited resources
Temporal lag between issue identification and program response
Identifying “outlier” events and incorporating effects into management
Adjusting management objectives and increasing adaptive management strategies given changing ecological conditions, increased uncertainty and stock-specific responses
Consideration of local contexts while also holistically considering the broader context of decisions
Successful incorporation of best science and knowledge in decision making
Fisheries
Maintaining and balancing harvest opportunities between all user groups
Management of mixed stock and mixed species fisheries
Understanding the impacts of fishing on salmon health and survival
Hatchery
Understanding the different roles and objectives of enhancement, realizing that different objectives may be working at cross purposes
Implementing large-scale changes in hatchery programs, such as facilitated downstream transport or trucking in response to river conditions
Understanding the totality of effects (local and global) of hatchery fish, Mass Marking and Mark-Selective Fisheries on wild populations
Habitat
Prioritizing/optimizing enhancement activities as a conservation tool based on the feasibility of rebuilding/maintaining priority salmon populations
Understanding the impact of freshwater, nearshore marine and open ocean habitat degradation/destruction
Ability to evaluate the effectiveness of regulatory frameworks to mitigate threats to ecosystem function. For example, insufficient floodplain regulation could result in net habitat loss outpacing restoration
Rapidly and accurately identifying habitat-based drivers of population status for salmon species and life history variants across populations for which specific, climate-resilient management actions can be identified, prioritized, implemented and monitored with expectation of positive effect
Ecosystem
Ecosystem based management and the challenges around the listing of non-salmon species under government conservation policies

Science/Data
Acquiring more data at all life stages to identify bottlenecks and drivers of vital rates to improve accuracy and precision of key salmon abundance forecasts
Uncertainty needs to be better propagated throughout the fisheries science chain, from data collection to science advice
Setting quantitative risk tolerance levels and recovery targets with timelines
Understanding and quantifying key oceanographic drivers of salmon survival and migration
Understanding the impact of predation on salmon populations
Incorporating changing environmental conditions across all life history stages in modelling approaches that inform decisions
Determining what cumulative effects (according to what metrics) affect salmon populations and where these are most important
Social
Having Indigenous knowledge systems be viewed as equally valid, scientific, and informative as Western scientific understandings in public and policy spheres and including Indigenous knowledge for better decision- making.
Utilizing effective communication strategies as a key tool for change
Quantifying anything other than commercial &/or recreational value of a salmon
Socio-ecological
Ability to assess the implications of funding levels to required information and management needs
Unequal technical capacity across participating groups/sectors. For example, BC First Nations are striving to increase their involvement in salmon management, but not unlike other agencies or organizations, they have limitations around capacity

Workshop 1: Modeling Processes and Tools

Summary of answers to questions posed to participants in Workshop 1.

Session 1: Processes

Are there processes, other than the ones presented today, that should be considered to shape and contribute to the LSF?
Summary: Several other processes for consideration included: Management Strategy Evaluation, expert-based scenario planning and other risk assessment processes.

What can we learn from existing processes that assess risk and mitigation scenarios to help develop the LSF?
Summary: The strengths and weaknesses from existing processes can inform the LSF. When considering lessons to be learned, make sure the process is understood in terms of objectives as well as inputs and outputs.

Can the LSF contribute to and support existing processes in place to assess risk and mitigation scenarios? If yes, how?
Summary: The LSF may support existing processes through several different ways. The LSF can be used to better understand uncertainty, and how to incorporate that uncertainty into other processes, including MSE, stock assessments, and environmental assessments. Given the holistic life-cycle approach, the LSF may also offer insight into where the greatest return on investments might be. The LSF may also be helpful as a first step that identifies a more targeted process or approach.

Are there emerging issues, currently not addressed by processes in use, that the LSF would be applicable to?
Summary: The LSF may serve as an opportunity to: consider cumulative and/or non-linear effects, bring focus to current unknowns by quantifying uncertainty and considering alternative hypotheses, and improve communication between communities, stakeholders, and Indigenous Nations/communities. More specific emerging challenges that it may be able to address include novel problems like habitat homogeneity in California's Central Valley and incorporation of phenological data.

Session 2: Tools/Methods and Challenges

Are there other tools that should be considered for the toolkit?
Summary: A variety of potential new tools/methods (optimally open source) should be considered for integration into the LSF. These include monitoring of data from other species (e.g., pinniped scat data, seabird abundance, etc.) that could inform salmon food web correlates, new remote sensing of spatially explicit habitat features, and incorporation of different modeling techniques as warranted (e.g., Graph Theory, linear models, machine learning, AI, Bayesian Belief Networks, hierarchical models, multi-stock vs. individual stock models, Dynamic Energetic Budget models, quantitative genetics). A pilot focus on using existing data from well-studied places (e.g., the Columbia River) could help in comparing models results and determining the best approaches to model integration within the LSF.

How can these tools support the data needs for the processes discussed in the previous session? What are the limitations?
Summary: There is a potential for these models to be applied to decision-making processes and help assess trade-offs, thus supporting the data needs for the processes previously discussed. These modelling tools have the potential to simulate conditions that have not been experienced yet to better plan for the future. It is important to note that these tools/models do not seem to use Indigenous Knowledge or consider socio-ecological inputs, and this is where the processes from Day 1 could be important. One major limitation of the tools is that some of the data-hungry and region-specific models are challenging to apply at a broad scale and with data-poor systems.

Is there a benefit of linking some of these tools/methods together? If so, how could they complement each other?
Summary: There is a benefit to linking these tools together. Process models coupled with future scenario projections can provide managers with the insights they will need to deal with rapidly changing conditions. We still rely on very simple statistical models that are largely driven by very simple assumptions of underlying processes. Fisheries management does not depend on process models and the statistical models do not provide much insight about unexpected variations. Linking these two together is important and we should have process models that are relatively data rich.

Does the LSF address the management challenges identified? If not, what are we missing? Please use the context of the identified challenges.

- Challenge 1: Prioritizing/optimizing restoration activities as a conservation tool based on the feasibility of rebuilding/maintaining priority salmon populations.
- Challenge 2: Utilizing effective communication strategies as a key tool for change.

Summary: There was a lack of habitat models and links between habitat and salmon abundance/productivity/diversity/distribution (including remote sensing tools). The LSF should also recognize that in some local areas we know of 1 or 2 large-effect size drivers, and the "holistic" perspective may not be as relevant. Generally, as part of the LSF, it would be helpful if all the different methods/models/tools were in one place and described with inputs/outputs/relevance. This would be helpful as a starting point for decision-makers who want to find out what resources are available.

- Challenge 1: Adjusting management objectives and increasing adaptive management strategies given changing ecological conditions, increased uncertainty, and stock-specific responses.
- Challenge 2: Management of mixed stock and mixed species fisheries.

Summary: The LSF should be explicit about uncertainties and the LSF could be used as a communications tool to address institutional and jurisdictional issues that impede the ability to address threats.

- Challenge 1: Understanding the totality of effects (local and global) of hatchery fish, Mass Marking and Mark-Selective Fisheries on wild populations.
- Challenge 2: Adjusting management objectives and increasing adaptive management strategies given changing ecological conditions, increased uncertainty, and stock-specific responses.

Summary: The LSF may be able to coordinate hatchery programs to address differences in tagging approaches and to allow for improved collection of data for understanding the cumulative effects of hatchery fish. Adjustment of management objectives is desperately needed because the current response is too slow. In adjusting management objectives, the LSF should consider cycles of resource production to make the management objectives focus on increasing resource production.

- Challenge 1: Incorporating changing environmental conditions across all life history stages in modelling approaches that inform decisions.
- Challenge 2: Uncertainty needs to be better propagated throughout the fisheries science chain, from data collection to science advice.

Summary: Incorporating environmental components into models is difficult as most relationships are not linear so hard to make extrapolated guesses. We also lack reliable retrospective models of salmon population response to environmental factors across life cycles. Best to develop very simple functional relationships and focus on where we have some ability to control/intervene to improve response. An integrated life cycle model approach is likely the best way to deal with uncertainty in terms of population response, and associated sensitivity analysis can help to define the effects of different types of error within the model.

- Challenge 1: Uncertainty needs to be better propagated throughout the fisheries science chain, from data collection to science advice.
- Challenge 2: Incorporating changing environmental conditions across all life history stages in modelling approaches that inform decisions.

Summary: Incorporating uncertainty will be a key part of the LSF and may require approaches that formalize uncertainty (e.g., Bayesian frameworks). One significant uncertainty will be future environmental conditions. A challenge will be conveying uncertainty to management in a way that aids decision-making processes.

- Challenge 1: Adjusting management objectives and increasing adaptive management strategies given changing ecological conditions, increased uncertainty and stock-specific responses.
- Challenge 2: Having Indigenous knowledge systems be viewed as equally valid, scientific, and informative as Western scientific understandings in public and policy spheres and including Indigenous knowledge for better decision making.

Summary: The LSF should ensure that Indigenous Knowledge is part of the toolkit, which could potentially be achieved through other methods, such as Bayesian belief networks.

- Challenge 1: Adjusting management objectives and increasing adaptive management strategies given changing ecological conditions, increased uncertainty, and stock-specific responses.
- Challenge 2: Utilizing effective communication strategies as a key tool for change.

Summary: The LSF has the potential to support development of management objectives and strategies. The LSF can focus our management and science on the most impactful actions across life cycle stages and ecosystem domains. It has the potential to address the non-stationarity of factors affecting productivity that cannot be accommodated in statistical models that do not have adequate power. The impacts of marine survival on the efficacy of freshwater management actions is a key challenge.

- Challenge 1: Having Indigenous knowledge systems be viewed as equally valid, scientific, and informative as Western scientific understandings in public and policy spheres and including Indigenous knowledge for better decision making.
- Challenge 2: Utilizing effective communication strategies as a key tool for change.

Summary: The LSF does not currently appear to be designed to consider Indigenous Knowledge (IK). Many of the presented tools had limited means of incorporating IK. Gathering IK and incorporating it will be a challenge. Improved communication and connecting people will be a major benefit of the LSF, however no communication strategy has been presented. Cumulative effects are a major challenge that the LSF will hopefully be able to communicate.

What are the implementation challenges for the LSF?
Summary: There are several important challenges related to the implementation of the LSF, including bringing the LSF to data-limited systems, buy-in from partners/stakeholders, the large scale at which the LSF is trying to solve problems and the lack of knowledge around key pieces of information (e.g., hatchery effects, ocean survival, future environmental conditions).

Workshop 2: Data Mobilization

Summary of the key considerations for data mobilization from Workshop 2, under several broad categories.

Open access approaches to data:

There has been increased uptake in open-source approaches to data in recent years. Open access requires clear communication protocols about data sharing, roles, responsibilities, and ownership of data. It must also be noted that it takes time for organizations to explore their options. Mandates about open access are helpful, as is legislation (e.g., federal Open Data Act) In addition, these programs require adjustments over time.

Building trust

Building trust among different organizations can be challenging. PNAMP started out with an open invitation and deliberately reached out to organizations to understand different points of view. It was demonstrated that people are collecting a lot of similar information but do not realize it — emphasizing this helped demonstrate the value of participating. In addition, PNAMP has a soft charter — there are no "must dos" and there are no formal recommendations.

Provide value to data providers:

Participation can be improved by demonstrating the value of sharing data — give people a "carrot" (i.e., something beneficial for the data providers). Data visualization is one "carrot" that can be provided. For example, Sitka Technologies Group developed an automatic fact sheet generator that was useful to data providers and therefore served as an incentive for data sharing. Another example is the Pacific Salmon Explorer (https://salmonexplorer.ca/#!/), which is a tool that visualizes salmon data for discovery and exploration.

Buy in from management and sufficient funding:

Getting science use and management use cases together to motivate organizations to participate in data sharing is important. Once there is management backing, it is easier to convince people to participate, however, funding can still be a challenge. Even with a "carrot" and eagerness to participate, the work will not happen if there is no support/funding. Data stewards often do not have time to do more to make data accessible at another scale and when data is made available, it can result in further Access to Information requests, which creates a further burden on staff. While there are significant up-front costs for establishing these approaches, open-source approaches often end up being a time saver and money saver instead of time sink because they eliminate processes associated with data requests. This can be a chicken and egg situation where showing value can only happen through participation, but then investment is needed to fund participation.

Planned interactions:

For any big initiative, interactions need to be planned with agencies to ensure respectable and effective work for all parties. Data sharing can be a huge burden, so it is better to plan carefully and ensure that the right requests are made. Often there is a temporal mismatch between when a data holder expects a return on their shared data versus when those who requested data can provide something back.

Shared vocabulary:

There's tremendous power in sharing vocabulary and resources. It is great to have web-based resources to provide access, but under the hood interoperability is also needed. Single administrative systems are rare, but if everyone uses the same vocabulary and information systems then things will be interoperable. However, there were concerns raised about the inclusivity of vocabularies when it comes to collating different types of data and knowledge (e.g., Indigenous Knowledge).

Protocol interoperability:

There is a big challenge with protocol variability across agencies that are collecting the same type of data. Sometimes this variation is planned, sometimes it is just a result of drift. This variation makes integration for larger scale re-use challenging. Some panel members spoke to the option of implementing a feature for funding sources to identify and encourage data protocols/methods for projects they fund, however, there can be a reluctance on the part of funders to tell people what to do. There needs to be bottom-up support for the approach. Showing results of an integrated dataset is a good way to show what you can get out of standardized protocols.

Metadata:

It is crucial to collect enough metadata to accurately describe data and make it more easily findable/accessible. Metadata is like doing taxes — nobody really likes collecting sufficiently rich metadata, but it is so crucial for data to be more broadly useable.

Respect reasons for unshared data:

It is important to talk to people about the value of open data but respect that there are reasons people do not release their data. Privacy considerations are one valid reason that people do not share data. Some agencies need to follow privacy legislation and are unable to release full datasets. Thus, it is important to talk to data coordinators to determine what is possible to make data useful and shareable. These challenges can be partially addressed though marking certain attributes of a dataset as private. An access control layer can also be built in, however, there is still a challenge for longer-term policy issues in making sensitive data sets available to some but not others. A curatorial role is needed.

Technical capacity

There is a wide range of technical sophistication across organizations. This needs to be recognized and there need to be ways for organizations to improve technical capacity. The approach cannot always be to send in outsiders, sometimes organizations prefer to build internal capacity.

Sustainability of the approach:

New insights based off multiple data sources are often the result of heroic efforts by people going from door to door. These heroic efforts are great for the short-term, but data's half life is short, and things quickly need to be updated. To make the process sustainable, there needs to be a continuous stream of shared data. The challenges associated with this may be more cultural than technical because researchers are time pressured and often take the shortest path to one deliverable rather than setting things up for longer-term benefits. In recent years, there has been a remarkable shift in perspectives about data sharing, however pragmatics still interfere. NCEAS has a training program for reproducible research practices that show researchers how to build reproducible workflows.

Appendix 3 – Focus Group and Workshop Attendees

Participant and Affiliation	Focus Group	Workshop 1	Workshop 2	Workshop 3
Dr. Andrea Reid (University of British Columbia)	☐			
Angela Addison (North Coast-Skeena First Nations First Nations Stewardship Society)	☐			
Anne-Marie Huang (Fisheries and Oceans Canada)	☐			
Audra Brase (Alaska Department of Fish and Game)	☐			
Dr. Ben Staton (Columbia River Inter-Tribal Fish Commission)		☐		
Beth Pechter (Fisheries and Oceans Canada)	☐			
Dr. Brendan Connors (Fisheries and Oceans Canada)		☐		
Dr. Brian Riddell (Pacific Salmon Foundation)	☐			
Brodie Cox (Washington Department of Fish and Wildlife)			☐	
Bruce Baxter (Fisheries and Oceans Canada)			☐	
Bruce Runciman (Fisheries and Oceans Canada)	☐			
Bryce Mecum (National Center for Ecological Analysis and Synthesis)			☐	
Dr. Charlotte Whitney (Central Coast Indigenous Resource Alliance)	☐			
Candace Picco (Ha'oom Fisheries Society)		☐		
Dr. Carrie Holt (Fisheries and Oceans Canada)		☐		
Chris Callaghan (Policy Spark)		☐		
Dr. Chris Jordan (National Oceanic and Atmospheric Administration)	☐			
Chris Kern (Oregon Department of Fish and Wildlife)	☐			
Dr. Daniel Schindler (University of Washington)		☐		
David Willis (Fisheries and Oceans Canada)	☐			
Diana Dobson (Fisheries and Oceans Canada)			☐	
Dr. Diego Holmgren (Tulalip Tribes)	☐			
Dr. Eduardo Martins (University of Northern British Columbia)		☐		

Dr. Eric Angel (Uu-a-thluk)	☐			
Dr. Eric Hertz (Pacific Salmon Foundation)		☐	☐	
Dr. Eric Ward (National Oceanic and Atmospheric Administration)		☐		
Dr. Geir Bolstad (Norweigian Institute for Nature Research)		☐		
Gord Sterritt (Upper Fraser Fisheries Alliance)	☐			
Graeme Diack (Atlantic Salmon Trust)			☐	
Greig Oldford (University of British Columbia)		☐	☐	
Dr. Isobel Pearsall (Pacific Salmon Foundation)		☐	☐	
Jason Parsley (Fisheries and Oceans Canada)			☐	
Jeffrey Milton (Alaska Department of Fish and Game)	☐			
Jennifer Bayer (United States Geological Survey)			☐	
Jennifer Nener (Fisheries and Oceans Canada)	☐			
Jennifer Steger (National Oceanic and Atmospheric Administration)	☐			
Dr. Jonathan Moore (Simon Fraser University)		☐		
Karli Tyance Hassell (Alaska Pacific University)		☐		
Kelsey Campbell (A-Tlegay Fisheries Society)		☐		
Dr. Kim Hyatt (Fisheries and Oceans Canada)		☐		
Kyle Adicks (Washington Department of Fish and Wildlife)	☐			
Laurent Frisson (Fisheries and Oceans Canada)	☐			
Dr. Laurie Weitkamp (National Oceanic and Atmospheric Administration)	☐			
Dr. Line E. Sundt-Hansen (Norweigian Institute for Nature Research)		☐		
Dr. Lisa Crozier (National Oceanic and Atmospheric Administration)		☐	☐	☐
Lynn DeWitt (National Oceanic and Atmospheric Administration)			☐	
Dr. Marisa Litz (Washington Department of Fish and Wildlife)	☐			
Mark Baltzell (Washington Department of Fish and Wildlife)	☐			
Mark Cleveland (Gitanyow Fisheries Authority)		☐		
Mark McMillan (Pacific Salmon Commission)			☐	
Dr. Mark Scheureull (University of Washington)			☐	☐

Dr. Mark Schildauer (National Centre for Ecological Analysis and Synthesis)			☐	
Mark Spoljaric (University of Washington Haida Fisheries Program)		☐		
Dr. Mathieu Buoro (French National Institute for Agriculture, Food, and Environment, INRAE)		☐		
Dr. Matt Baker (North Pacific Research Board)			☐	
Matt Deniston (Sitka Technology)			☐	
Matt Jones (National Center for Ecological Analysis and Synthesis)			☐	
Dr. Matthew Spencer (Policy Spark)		☐		
Michael Crowe (Fisheries and Oceans Canada)	☐			
Michael Staley (Fraser River Aboriginal Fisheries Secretariat)		☐		
Dr. Nate Mantua (National Oceanic and Atmospheric Administration)		☐		
Dr. Neala Kendall (Washington Department of Fish and Wildlife)			☐	
Dr. Nicolas Bailly (University of British Columbia)			☐	
Dr. Oliver Miler (Northwest Indian Fisheries Commission)		☐		
Pat Matthew (Shuswap Nation Tribal Council)	☐			
Dr. Peter Dudley (National Oceanic and Atmospheric Administration)		☐		
Dr. Peter Westley (University of Alaska Fairbanks)		☐		
Pierre Yves Hernvann (National Oceanic and Atmospheric Administration /University of California, Santa Cruz)			☐	
Roger Dunlop (Uu-a-thluk)		☐		
Sabrina Crowley (Uu-a-thluk)		☐	☐	
Sam Wilson (Simon Fraser University)		☐		
Dr. Stephen Gregory (Game and Wildlife Conservation Trust)		☐		
Steve Gotch (Fisheries and Oceans Canada)	☐			
Stu Barnes (First Nations Fisheries Council)	☐			
Susan Bishop (National Oceanic and Atmospheric Administration)	☐			
Dr. Teresa Ryan (University of British Columbia)		☐		
Terri Bonnet (Fisheries and Oceans Canada)	☐			
Tim van der Stap (Hakai Institute)			☐	

Valerie Berseth (University of British Columbia)			☐	
Dr. Walter Crozier (Missing Salmon Alliance)		☐	☐	
Wilfe Luedke (Fisheries and Oceans Canada)		☐		
Dr. Will Satterthwaite (National Oceanic and Atmospheric Administration)	☐			
Salmonscape Planning Team/Additional Meeting Support				
Aidan Schubert (North Pacific Anadromous Fish Commission-International Year of the Salmon)				☐
Aline Litt (ESSA Technologies)	☐	☐	☐	
Andrew Chin (North Pacific Anadromous Fish Commission-International Year of the Salmon)	☐	☐	☐	
Dr. Brian Wells (National Oceanic and Atmospheric Administration)	☐	☐	☐	☐
Camille Jasinski (North Pacific Anadromous Fish Commission-International Year of the Salmon)	☐	☐	☐	☐
Caroline Graham (North Pacific Anadromous Fish Commission-International Year of the Salmon)	☐	☐	☐	☐
Dr. Catherine Michielsens (Pacific Salmon Commission)	☐	☐	☐	☐
Dr. Colin Bull (Missing Salmon Alliance)	☐	☐	☐	☐
Janson Wong (First Nations Fisheries Council)	☐			
Marc Porter (ESSA Technologies)	☐	☐	☐	☐
Mark Saunders (North Pacific Anadromous Fish Commission-International Year of the Salmon)	☐	☐	☐	☐
Dr. Matthew Siegle (ESSA Technologies)	☐	☐	☐	☐
Minje Choi (North Pacific Anadromous Fish Commission-International Year of the Salmon)	☐	☐	☐	☐
Richard Erhardt (First Nations Fisheries Council)	☐	☐	☐	☐
Dr. Scott Akenhead (The Ladysmith Institute)	☐	☐	☐	☐
Stephanie Taylor (North Pacific Anadromous Fish Commission-International Year of the Salmon)	☐	☐	☐	
Sue Grant (Fisheries and Oceans Canada)	☐			

Appendix 4 – Workshop Presentation Slide Decks

Workshop 1

https://npafc.org/wp-content/uploads/technical-reports/Tech-Report-16/Salmonscape-Workshop-1-Presentation.pdf

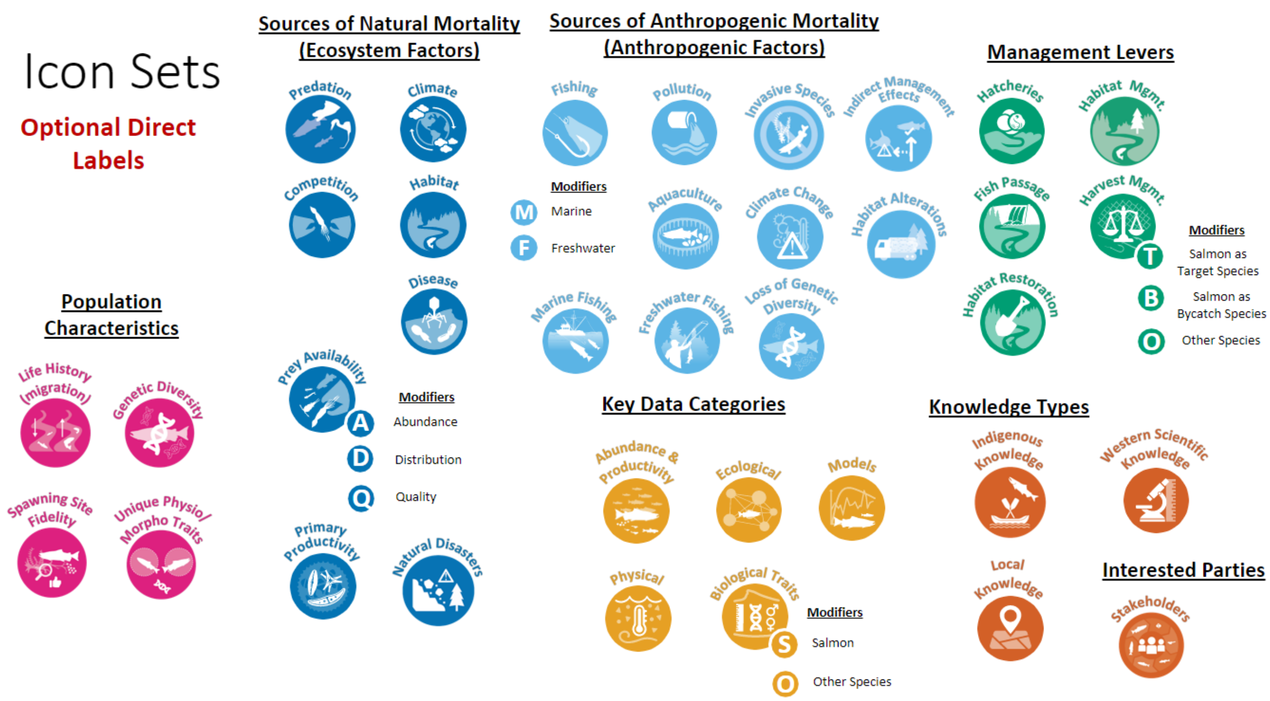
Workshop 2

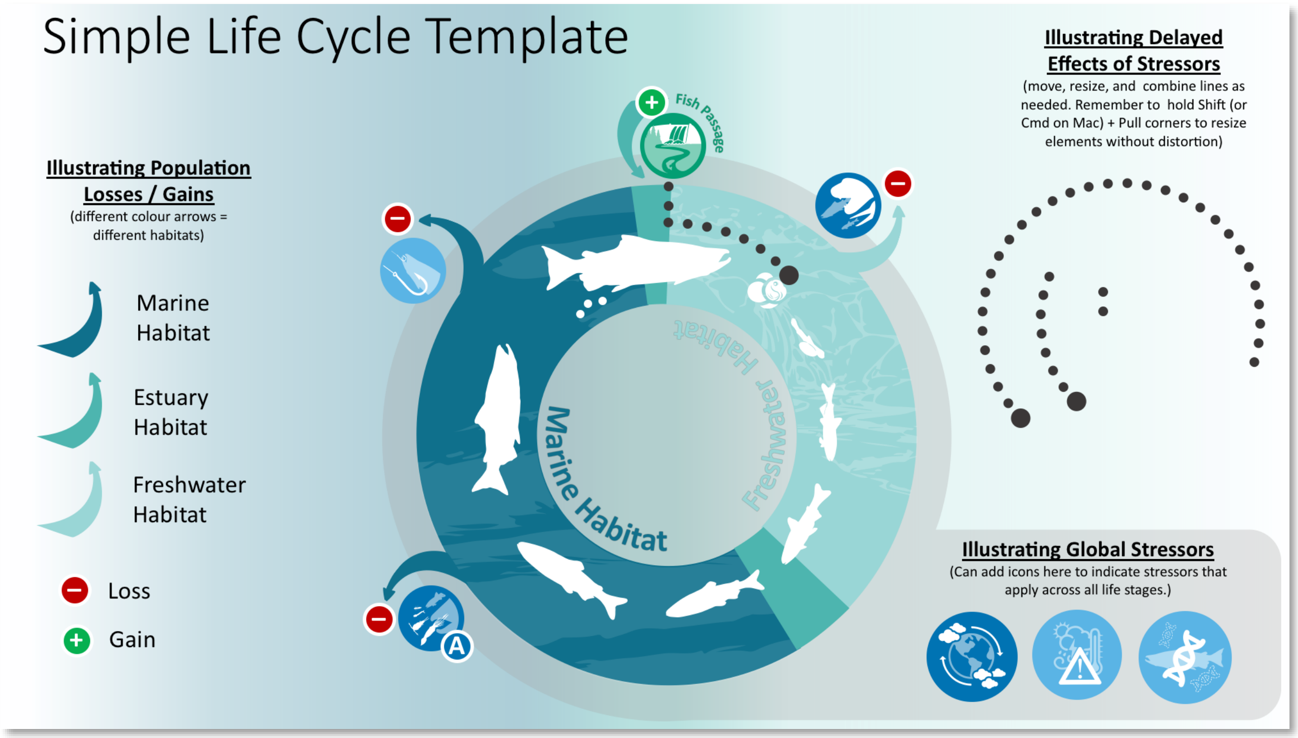
https://npafc.org/wp-content/uploads/technical-reports/Tech-Report-16/Salmonscape-Workshop-2-Presentation.pdf

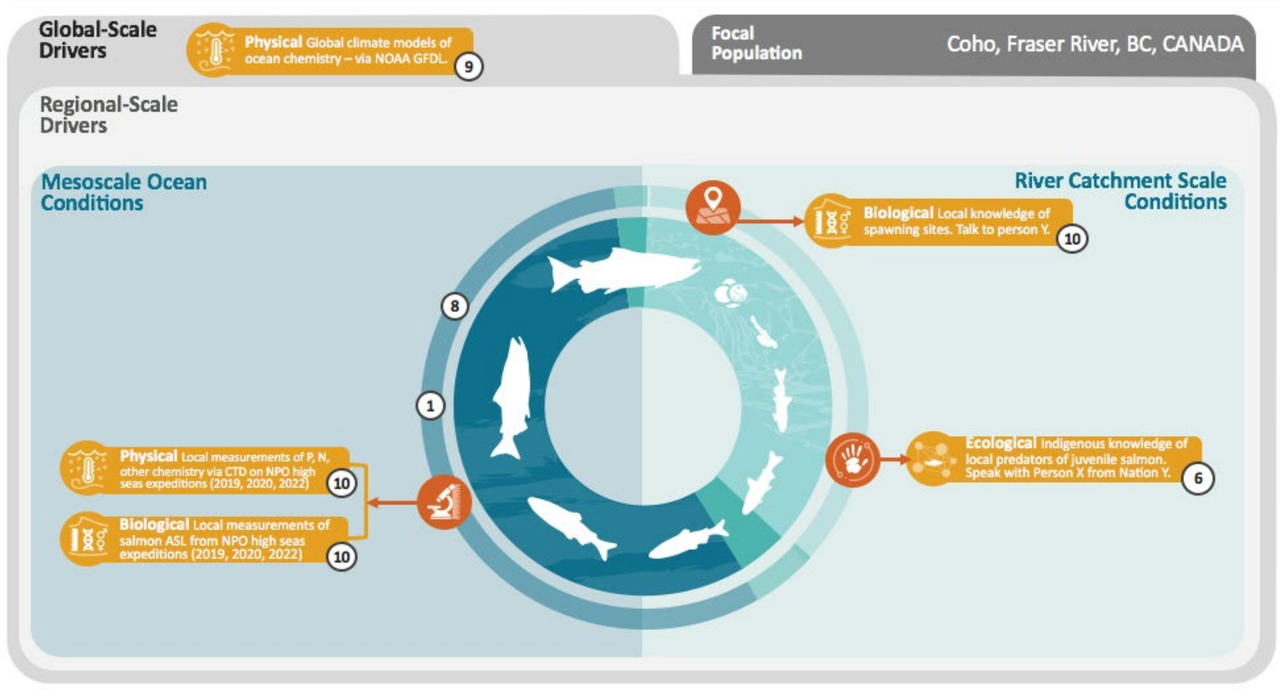
Appendix 5 – Life Cycle and Management Graphics

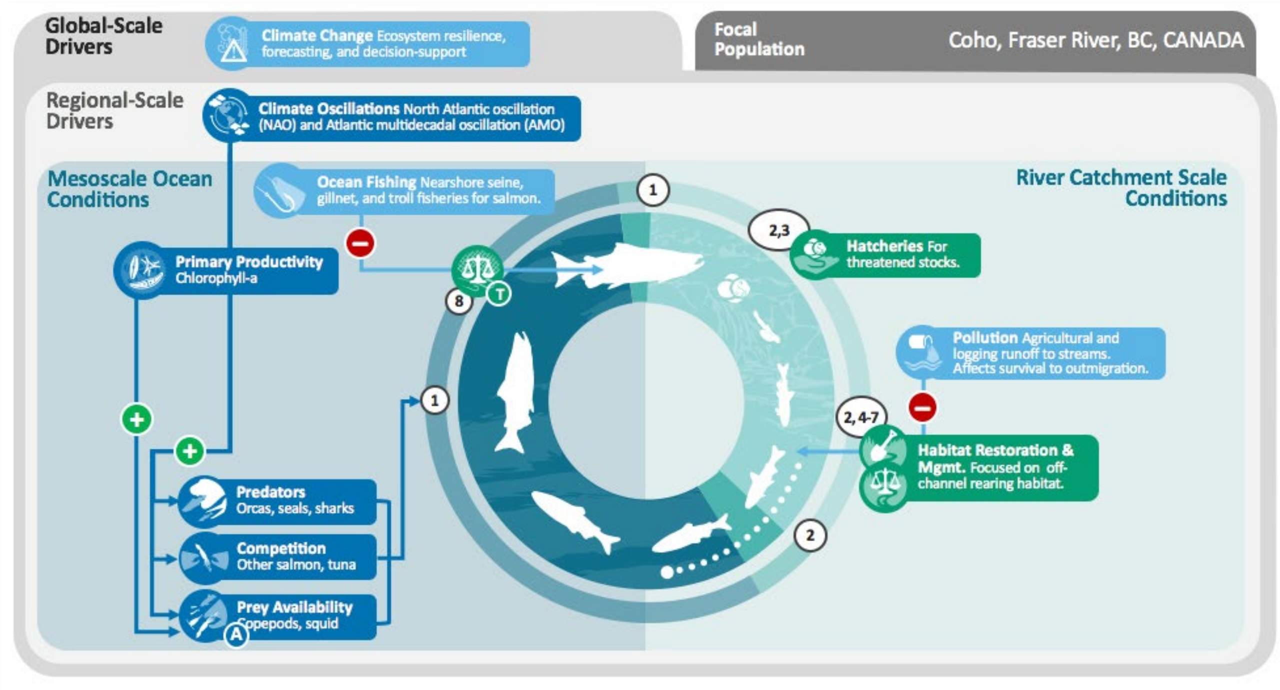
In collaboration with the NPAFC, ESSA has produced a series of graphic elements focused on icons and life cycle templates intended to help users illustrate key concepts and scenarios within the Likely Suspects Framework.

These icons and templates are modular and intended to be recombined in different ways to suit different purposes and audiences, from simple one-way communication in documents or posters to use in facilitated workshop settings. Icons can also be used to provide visual cues and 'anchors' in detailed tables supporting life cycle graphics. Examples of the icon sets and how they can be used are shown below.




Simple Life Cycle Template
Illustrating Population Losses / Gains
(different colour arrows = different habitats)
Marine Habitat
Estuary Habitat
Freshwater Habitat
Loss
Gain
Fish Passage
Marine Habitat
Freshwater Habitat
A
Illustrating Delayed Effects of Stressors
(move, resize, and combine lines as needed. Remember to hold Shift (or Cmd on Mac) + Pull corners to resize elements without distortion)
Illustrating Global Stressors
(Can add icons here to indicate stressors that apply across all life stages.)


Global-Scale Drivers
Physical Global climate models of ocean chemistry – via NOAA GFDL.
9
Focal Population
Coho, Fraser River, BC, CANADA
Regional-Scale Drivers
Mesoscale Ocean Conditions
River Catchment Scale Conditions
Biological Local knowledge of spawning sites. Talk to person Y.
10
8
1
Physical Local measurements of P, N, other chemistry via CTD on NPO high seas expeditions (2019, 2020, 2022)
10
Biological Local measurements of salmon ASL from NPO high seas expeditions (2019, 2020, 2022)
10
Ecological Indigenous knowledge of local predators of juvenile salmon. Speak with Person X from Nation Y.
6



Icons in Accessory Tables – **Example of Visual Anchoring in Tables**

- Icons can also be used to provide visual cues for tables supporting life cycle summary graphics. Generic example shown below, where icons can be used with or without built-in labels.

Pressure	Data Type	Knowledge Type	Data Description	Data Sources
Disease	Biological	Western Scientific Knowledge	Sampling to determine sea lice infection rate of adult and juvenile sockeye in the Broughton Archipelago.	1,2,4
		Local Knowledge	Local knowledge of infection hotspots based on observation in local fisheries activities.	5,8,9
	Abundance & Productivity	Western Scientific Knowledge	Annual redd counts for coho in index spawning streams.	1-2
		Indigenous Knowledge	Indigenous knowledge of changing trends in abundance, size over time in FSC fisheries carried out in specific areas.	9-10
	Physical	Western Scientific Knowledge	Academic research program sampling changing temperature profiles to investigate links to disease susceptibility.	12
			Academic research program sampling changing nutrient profiles to investigate links to disease susceptibility.	14-16