PSSI Science Project Reporting Template

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| ⚠️ | The PSSI Implementation Team is compiling a technical report to demonstrate the important research and advancements made by the Science Branch through the PSSI funding. The technical report will include a 3-4 page summary (including graphics and figures) for each project to show their key results and findings. Please fill in the following fields and sections for your project to be included in the report. Feel free to include and draw from any reports or presentations previously created through your research.  A plain language science bulletin will also be created to follow up on last year’s “[DFO Pacific Region Science Bulletin, 2024. New research and monitoring for Pacific salmon and their ecosystems](https://publications.gc.ca/collections/collection_2025/mpo-dfo/Fs141-15-2024-eng.pdf).” While the first bulletin introduced project backgrounds, methods, and timelines, this new bulletin will highlight the projects’ results, key findings, and conclusions with links to reports and data available. The bulletin will include a 1-2 page summary for each project gleaned from the content entered below.  **⏱️ Completed forms are due January 26, 2026.**  \*Please include or send separately any graphics or pictures (with photo credits) that will help promote the projects. |

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| **📁 PART 1: PROJECT METADATA** |

## 📋General Project Information

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| **Project ID (number)** | **Project Title** |
| 2449 | A decision-support tool that considers harvest, hatchery, and habitat management levers to support implementation of the *Fisheries Act* for Pacific salmon |
| **Project Leads** | **Collaborations and External Partners** |
| Carrie Holt, Catarina Wor and Brendan Connors | Blue Matter Science  Huu-ay-aht First Nation  LGL |
| **Location (if applicable)** |
| Click or tap here to enter text. |

## 🐟Geographic and Stock Information

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| **Salmon species (if applicable)** | **Waterbodies (if applicable)** |
| Applicable to all species; case study on Chinook salmon | Click or tap here to enter text. |
| **Life history phases (if applicable)** | **Region** |
| Complete life cycle | Applicable across regions; case study on Sarita River Chinook within the South Coast region. |
| **Stock (if applicable)** | **Population (if applicable)** |
| Applicable across populations and stocks; case study on Sarita River Chinook (component of West Coast Vancouver Island Chinook Stock Management Unit) | Applicable across populations; case study on Sarita River Chinook |
| **Conservation Unit (if applicable)** |  |
| Applicable across populations and stocks; case study on Sarita River Chinook within West Vancouver Island-South Chinook CU |  |

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| **🧰 PART 2: PROJECT METRICS** |

## 🎯Project Outputs

Include any anticipated outputs denoted as (in progress). Please include links to any outputs available online so they can be referenced in the report.

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| **List scientific publications and technical reports (with links)** |
| Manuscript and technical report in prep. Details available upon request. |
| **List datasets generated (with links)** |
| NA |
| **Describe dataset locations and data management systems** |
| NA |
| **List code, programs, or other software created (with links)** |
| 1. salmonMSE R package: Huynh Q (2025). salmonMSE: Management Strategy Evaluation for Salmon. R package version 0.1.1. <https://cran.rstudio.com/web/packages/salmonMSE/index.html> 2. salmonMSE code Repository: <https://github.com/Blue-Matter/salmonMSE> 3. Application of salmonMSE to Westcoast Vancouver Island, Sarita River Chinook- Code repository: <https://github.com/Blue-Matter/WCVI_Chinook> 4. Application of salmonMSE to Upper Strait of Georgia Chinook- Code Repository: <https://github.com/Pacific-salmon-assess/UpperSoG_Chinook> |
| **List communication or social media products** |
| salmonMSE: management strategy evaluation for Pacific salmon (website containing technical documentation and examples). <https://salmonmse.com/>  Communication products: Presentations  Holt, C., Huynh, Q., Wor, C. and Connors, B. 2024. salmonMSE: A decision-support tool to evaluate harvest, hatchery and habitat management decisions for Pacific salmon. Presented at All-staff meeting for Salmon Enhancement Program, 12 Sept. 2024.  Huynh, Q., Holt, C., Vos, A., Wor, C., Connors, B, Hordyk, A., Carruthers, T., and Luedke, W.  2025. salmonMSE, a decision-support tool to evaluate harvest, hatchery and habitat management levers for Pacific salmon: Application to Sarita River Chinook salmon. Presented at the American Fisheries Conference- Washington-BC Chapter Annual Meeting. 12 March 2025.  Huynh, Q., Holt, C., Wor, C., Bocking, B., Brown, N., Connors, B., Kwong, L., Luedke, W., McHugh, D., Thom, M., Vos, A., Zoehner, B. 2025. salmonMSE, a decision-support tool to evaluate harvest, hatchery and habitat management levers for Pacific salmon: Application to Sarita River Chinook salmon. Presented at DFO’s EAFM workshop, hosted the Technical Expertise in Stock Assessment, 25 Nov. 2025  Huynh, Q., Holt, C., Wor, C., Bocking, B., Brown, N., Connors, B., Kwong, L., Luedke, W., McHugh, D., Thom, M., Vos, A., Zoehner, B. 2025. salmonMSE, a decision-support tool to evaluate harvest, hatchery and habitat management levers for Pacific salmon: Application to Sarita River Chinook salmon. Presented to DFO’s Pacific Salmon Science Symposium, Session on Data & Modelling to Inform Decision-Making. 9 Dec. 2025  Huynh, Q., Holt, C., Wor, C., Bocking, B., Brown, N., Connors, B., Kwong, L., Luedke, W., McHugh, D., Thom, M., Vos, A., Zoehner, B. 2026. salmonMSE, a decision-support tool to evaluate harvest, hatchery and habitat management levers for Pacific salmon: Application to Sarita River Chinook salmon.. Presented to SEP Planning and Assessment Unit, 13 Jan 2026. |
| **List and describe field work completed** |
| NA |
| **List and describe samples collected/analyzed (number of samples)** |
| NA |
| **List and describe large capital assets or equipment acquired** |
| NA |
| **📝 PART 3: WRITTEN CONTENT** |

## 📌 Highlights

Please summarize in 2-3 bullets:

* The main idea of the project
* Key findings
* Implications of these findings for salmon and decision-makers
* For a more technical audience, but still as plain language as possible

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| * Understanding the performance of management actions prior to implementation is increasingly critical for Pacific salmon given accountabilities under the modernized *Fisheries Act* and growing risks associated with environmental and biological variability and change, yet tools to evaluate harvest, hatchery and habitat levers have not been available. * We developed an open-source, decision-support tool, **salmonMSE**, to prioritize management actions related to harvest regulation, hatchery enhancement and habitat restoration to achieve objectives across sectors. * This tool expands on those previously used by explicitly accounting for dynamics of hatchery-origin and natural-origin fish, modelling mark-selective fisheries, considering risk and uncertainty, and including biological realism with the ability to model a diversity of life-history strategies. |

## 🌐Background

Please provide 1-2 paragraphs to summarize

* The relevant biological, environmental, and/or management context
* What knowledge gap or demand were you trying to fill?
* Collaboration and partner relationships

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| Pacific salmon are exposed to numerous interacting stressors, including climate change, fishing, and land-use changes related to e.g., urban development, forestry, mining, and agriculture (Tulloch et al. 2022). Management of salmon is multifaceted to address these stressors: including harvest regulation, hatchery enhancement and habitat restoration.  Management decisions increasingly require transparency and risk-based approaches to respond to uncertainties. For example, the ***Fisheries Act*** requires the development of rebuilding plans for stocks that fall below limit reference points (considered in a ‘critical’ status zone). There is an emerging need to evaluate performance of candidate management actions for rebuilding plans prior to implementation, and the DFO’s precautionary approach framework requires uncertainty and risk to be taken into account when developing and implementing decision rules.  Similarly, under the ***Species at Risk Act***,there is a need to evaluate recovery potential of populations at risk of extinction under various management scenarios. However, we lack accessible, broadly applicable quantitative tools to evaluate management options across management levers.  Through this project we developed an open-source, decision-support tool for Pacific salmon, **salmonMSE**, to inform science advice for Integrated Management Plans, Rebuilding Plans under *the Fisheries Act*, Salmon Enhancement Plans, and the SARA listing process.  This tool can address questions like:   * What level of hatchery enhancement and harvest regulation are required to achieve rebuilding targets? * What is the maximum hatchery production possible while maintaining ‘wild’ population status, as defined by proportionate natural influence, PNI goals by Wither et al. (2018)? * How should mass-marking strategies and mark-selective fisheries be designed in order to achieve harvest and PNI goals while allowing for conservation of wild populations? * Within hatcheries, which harvest release strategies and broodtake rules best meet conservation and PNI objectives? * Where relationships between environmental drivers or limiting factors and survival rates have been identified, what are the benefits of habitat restoration to mitigate impacts of those factors on conservation and harvest objectives, relative to other management levers?   In partnership with Huu-ay-aht First Nation, DFO Salmon Enhancement Program and DFO Science, we applied salmonMSE to Sarita River Chinook, on the west coast of Vancouver Island as a case study, to evaluate the impacts of mark-selective fisheries and hatchery scenarios on the ability to achieve a range of conservation, harvest and hatchery objectives, and to inform rebuilding plans. |

## 🛠️ Methods and Findings

Please insert a few paragraphs to summarize:

* Main methods used
* Products and tools produced
* Advancements in methodology, technology, and application
* Advancements in communication and knowledge transfer
* Key results and information generated

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| SalmonMSE is a decision-support tool developed for Pacific salmon founded on ‘management strategy evaluation’, MSE, which is an approach for evaluating the relative effectiveness of management actions using computer simulations that represent various possible realities of the fishery and the biological systems (Punt et al. 2016; openMSE 2023). To account for uncertainties, these simulations are repeated over numerous possible realities to produce a distribution of outcomes for each management action.  We developed a stage-based life-cycle model, capturing population processes relevant to Pacific salmon acting in freshwater and marine environments, and the impacts of harvest and environmental conditions on juvenile and adult stages. The underlying model structure is modular and flexible allowing for reduced complexity to simpler model forms when data are limited and increased complexity to address emerging threats when data are available. We included the ability to model an integrated hatchery population, whereby the hatchery and natural spawning components of a population are modelled separately but interact on the spawning grounds.  SalmonMSE provides advances relative to previously available tools that either did not consider risk and uncertainty or did not consider hatchery dynamics explicitly and therefore could not evaluate performance on hatchery objectives related to maintaining wildness of integrated hatchery populations, i.e., high PNI values (Withler et al. 2018). By explicitly modelling hatchery impacts on populations, salmonMSE can evaluate performance on conservation, production and ‘wildness’ objectives. Our application to a case study on Sarita River Chinook salmon highlights the potential for trade-offs among objectives, suggesting that in some cases it may not be possible to achieve both wildness and high abundances simultaneously. Our case study further highlights that habitat restoration may be needed to support production objectives when survival in freshwater is limiting. An illustrative example is provided in Box 1. This tool fills a critical cap in DFO’s ability to strategically evaluate decisions on all three management levers.  The salmonMSE tool is generic and can be applied across Pacific salmon species and populations. salmonMSE can be adapted to data availability, relying on coarse resolution survival rates (e.g., freshwater vs. marine) and meta-analyses, neighbouring populations, and expert opinion for parameterization when data are limited, and providing population-specific finer life-stage resolution and evaluating management actions targeting specific life stages where data are available.  An open-source R package ([salmonMSE](https://cran.rstudio.com/web/packages/salmonMSE/index.html)) was developed to facilitate access of the tool, with three underlying repositories providing [code for the R package](https://github.com/Blue-Matter/salmonMSE) and an application to one case study on the west coast Vancouver Island, [Sarita River Chinook](https://github.com/Blue-Matter/WCVI_Chinook), and second on-going application to [Upper Strait of Georgia Chinook](https://github.com/Pacific-salmon-assess/UpperSoG_Chinook) to support the development of a Fisheries Science Advisory Report. |

## 💡Insights

Please insert a few paragraphs to summarize:

* What this project has added to knowledge about salmon populations, health, or ecosystems.
* How this project informs salmon management:
  + decisions
  + policy guidance
  + trade-offs
  + planning
* Addition of knowledge to understanding:
  + limiting factors/stressors/threats/ pathways of effects/risks
  + biologically significant thresholds
  + cumulative impacts
* Sources of uncertainty

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| This tool can inform management decisions and address trade-offs between conservation, harvest, and ‘wildness’ objectives within rebuilding plans under *Fisheries Act*, Fisheries Science Advisory Reports, SEP production plans, and SARA listing decisions. Furthermore, the modernized *Fisheries Act* requires that management consider the biology of the fish and environmental conditions affecting the stock, and this tool is designed to account for biological characteristics like life-history diversity (e.g., accounting for differences in survival rates among life-history groups within a population) and environmental drivers of survival at various life stages, where data are available.  In answering these questions, this tool can inform both strategic decisions about choices among management lever(s), and operational decisions about harvest control rules, hatchery release strategies and habitat restoration.  Uncertainties are explicitly considered in salmonMSE in two ways. First, distributions are included in parameterization and projections are run over a large number of random Monte Carlo trials to account for parameter uncertainties and to provide probabilistic outcomes (e.g., the probability of achieving management objectives). In this way, the outcomes of management evaluations are less certain and probabilities of achieving objectives more diffuse when underlying parameters are more uncertain. In addition, uncertainties in model structure and parameters can be explicitly considered by running sensitivity analyses over a range of plausible hypotheses. These analyses can help to identify those parameters with the highest impact on the relative performance of management strategies, requiring further monitoring or research to reduce uncertainties. |

## ⏩ Next Steps

Please insert 1-2 paragraphs to summarize:

* Remaining knowledge gaps and recommendations for future studies
* How can/should the project findings be operationalized for salmon conservation and management?

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| A training session for technical analysts within DFO, First Nations and partner organizations will be hosted April 2026 to support implementation of salmonMSE. The intended outcomes for the workshop are for participants to understand the scope and capabilities of salmonMSE, have working knowledge of how to apply salmonMSE to simple examples that include integrated hatcheries, and understand how these can be expanded to include complexities in life-history diversity, environmental drivers, and harvest and hatchery management strategies.  SalmonMSE is currently being applied to Upper Strait of Georgia Chinook salmon to inform the evaluation of harvest and hatchery management options for an upcoming FSAR process (planned for Nov 2026). We recommend the application of salmonMSE to inform fisheries stock advice for Pacific salmon more broadly, especially when harvest and hatchery levers are considered and conservation, harvest, and PNI objectives are identified. We further recommend exploring salmonMSE for SEP production planning, e.g., for evaluating alternative release strategies and broodtake rules.  Gaps remain in our ability to include environmental drivers and impacts of habitat restoration into salmonMSE. There are opportunities to combine salmonMSE with inferences from other habitat models or limiting factors frameworks, such as [CEMPRA](https://essatech.github.io/CEMPRA/index.html) (Cumulative Effects Model for Prioritizing Research Activities) and [RAMS](https://marinedata.psf.ca/knowledge-hubs/risk-assessment-method-for-salmon/) (Risk Assessment Methods for Salmon), and causal modelling (e.g., using [DSEM](https://james-thorson-noaa.github.io/dsem/articles/model-description.html), Dynamic Structural Equation Models). Doing so would allow us to more clearly and transparently identify and document risks created by environmental or ecosystem conditions for achieving management objectives, and the relative benefits of more specific restoration efforts to mitigate those impacts. |

## 📈 Tables and Figures

Please provide captions and numbering for any tables and figures. Graphics can be copied below or e-mailed separately.

* Include a brief caption with each figure and table in the box below
* Number each table and figure, and include references in the above sections where appropriate.
* 1-3 figures are recommended per project

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| Box 1. Illustrative example of decision tables from salmonMSE providing performance on (a) ability to achieve abundance-based rebuilding target and (b) ‘wildness’ objective with proportionate natural influence, PNI>0.5 (top right) under combinations of harvest strategies (exploitation rates: 0.25, 0.5, 0.75 ) and hatchery broodtake targets (the proportion of natural-origin fish in the broodtake, pNOBtarget: 0.5, 0.75, 1). When pNOBtarget is high, fish tend to be more adapted to the natural environment than the hatchery environment and PNI values are high, though hatchery sizes are often smaller due to challenges in collecting large numbers of natural-origin brood, especially when mark rates are low. Green cells depict relatively high probability of achieving objectives and pink, low. Trade-offs between achieving high abundances and high PNI are shown in panel (c) (x-axis and y-axis, respectively). In this example, none of the proposed management strategies (coloured circles and x’s) clearly maximize both abundances and PNI. The vertical dotted line is a candidate rebuilding target, and the horizontal dotted line is the PNI objective. |

## 📈 References

Include full references for any publications referenced in other sections. Please format references in Harvard style according to Instructions to Authors for the *Canadian Journal of Fisheries and Aquatic Sciences*, at [Canadian Science Publishing](https://cdnsciencepub.com/journal/cjfas/authors#guidelines).

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| openMSE 2023. Open source software for management strategy evaluation. Accessed 14 Jan. 2026. <https://openmse.com>  Punt, A.E., Butterworth, D.S., de Moor, C.L., De Oliveira, J.A.A., and Haddon, M. 2016. Management strategy evaluation: best practices. Fish & Fisheries **17**(2): 303–334. doi:10.1111/faf.12104.  Tulloch, V.J.D., Adams, M.S., Martin, T.G., Tulloch, A.I.T., Martone, R., Avery-Gomm, S., and Murray, C.C. 2022. Accounting for direct and indirect cumulative effects of anthropogenic pressures on salmon- and herring-linked land and ocean ecosystems. Phil. Trans. R. Soc. B **377**(1854): 20210130. doi:10.1098/rstb.2021.0130.  Withler, R.E., Bradford, M.J., Willis, D.M., and Holt, C.A. 2018. Genetically Based Targets for Enhanced Contributions to Canadian Pacific Chinook Salmon Populations. DFO Can. Sci. Advis. Sec. Res. Doc. **2018/019**: xii + 88 p. |