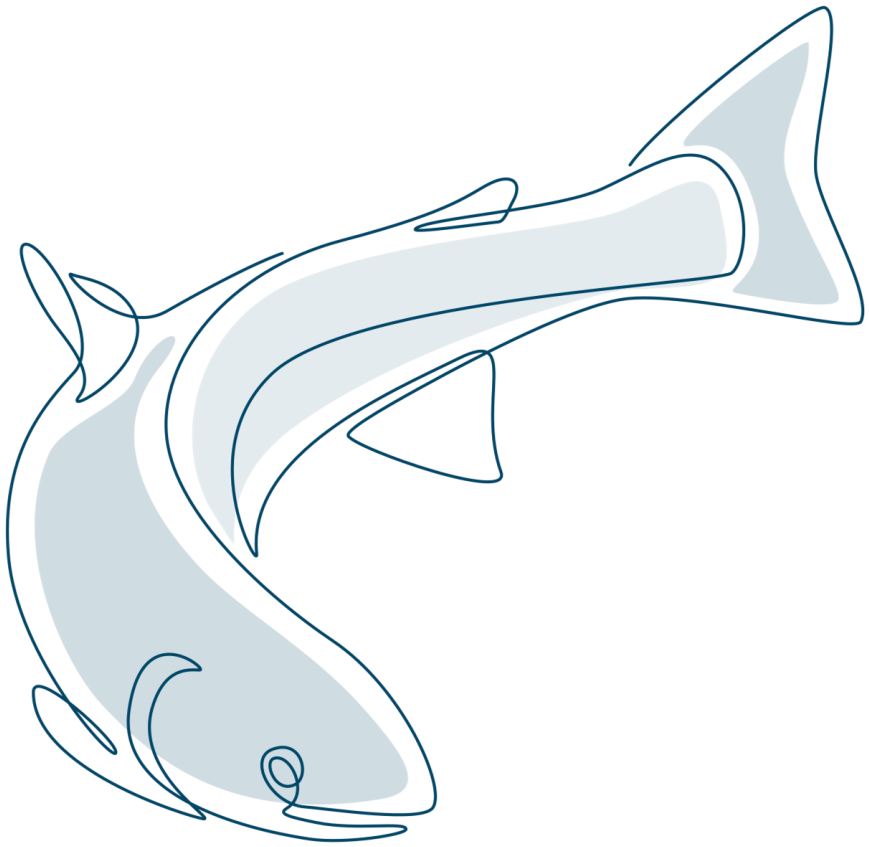

Salmon Stories

Social and Cultural Narratives of Salmon Production, Conservation, and Care

Evolving Narratives of Cultures and Histories

Final Report

DALHOUSIE UNIVERSITY

Oregon State University

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Supplemental data is available. Please contact Hannah Harrison at hannah.harrison@dal.ca.

Co-Investigators and Authors

The project was carried out by an interdisciplinary team of Indigenous and settler researchers and practitioners in Canada and the United States. The team was assembled through the International Year of the Salmon, an initiative by the North Atlantic Salmon Conservation Organization (NASCO) and the North Pacific Anadromous Fish Commission (NPAFC), to conduct a systematic literature review of the state of knowledge on salmon hatcheries from 2012- 2021 (inclusive).

The lead institution for this study, Dalhousie University, is located in Mi'kma'ki, the ancestral and unceded territory of the Mi'kmaq, and our work crosses many Indigenous territories. We acknowledge our obligations to the lands, waters, people, and non-human beings in these places to live and work in good relations. This includes upholding conditions of treaties that govern us and an ongoing commitment to decolonizing our institutions and practices.

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Content

Executive Summary

Global declines in biodiversity have led to a proliferation of human-assisted reproduction programs aimed at conserving and sustaining wildlife populations. In the Canadian context, some of the most well-known examples so these programs focus on the recovery of salmon on both the Pacific and Atlantic coasts. A large body of evidence built up over decades suggests that artificial breeding of salmon in hatcheries may lead to reduced fitness and survival in as little as a single generation, which has purported negative implications for the health of salmon populations. This has resulted in a highly technical and often fraught debate within conservation science and fisheries management about the wisdom of continuing these programs.

As a cultural keystone species, salmon play an irreplaceable role in shaping the cultures, economies, and identities of many Indigenous and non-Indigenous communities. For Indigenous peoples, salmon are a vital relationship and resource deeply tied to governance, self-determination, and Treaty-protected rights. Understanding and incorporating Indigenous perspectives is critical to informing salmon policy and management in the face of increasing conflict related to their use.

We hypothesized that these community perspectives may be better understood by analysing information from sources outside of peer-reviewed literature, namely grey literature and public-facing materials produced by Indigenous communities in Canada and the United States. To our knowledge, there has been no review of this literature, which represents a significant knowledge gap. To explore the cultural and historical narratives of salmon decline, and the past, present and future role of hatcheries in shaping human-salmon relationships, we performed a critical realist review of each dataset. This analysis characterises knowledge about the social and cultural dimensions of the hatchery debate, identifies knowledge gaps, and compares narratives presented across diverse sources and knowledge systems.

Hatchery policy should account for the role of hatcheries in upholding Indigenous fishing rights and governance, alongside ecological and genetic considerations. Strengthening co-management requires addressing disparities in authority and resources, while supporting Indigenous research priorities and long-term monitoring aligned with Indigenous temporal scales. Policies should also recognize hatcheries as one tool within a broader salmon recovery strategy and ensure decision-making processes reconcile diverse risk perceptions and values.

By providing a more holistic view of the diverse social and cultural perspectives on hatcheries, this knowledge synthesis is intended to support more equitable assessments of hatchery programs and identify practices and factors that contribute to greater social outcomes. These findings not only enrich but may also reframe the broader debate on the role of hatcheries in salmon restoration. The ideas presented here are drawn from the documents reviewed in this study and should not be taken as universal truths about either body of literature. The findings will aid the work of fisheries managers, policymakers, and stewards in Canada and the United States. These ideas are also relevant for genetic and genomic scientists and social scientists engaged in research on salmon conservation by situating evolving genetic narratives within a broader social and political discourse.

Key Themes in Indigenous Public-Facing Literature

- Salmon are strong and resilient but not invulnerable to stressors such as habitat loss, degradation and climate change, which many sources cite as the primary factors contributing to their decline.
- Indigenous communities often describe their relationship with salmon through a lens of care, respect and obligation to live responsibly with them. Indigenous communities have frequently demonstrated these values beyond the standards set by settler entities (e.g., regulators).
- Both hatchery- and natural-origin fish provide nutritional, social, cultural, environmental and economic benefits, regardless of origin. These benefits, often considered as important as genetic concerns, could be lost if enhancement programs are eliminated.
- Many Indigenous communities have inherent and often Treaty Rights to fisheries access. Hatcheries help uphold these rights by allowing continued harvests for food, social, ceremonial and commercial purposes.
- Enhancement programs have historically been evaluated through economic, ecological and genetic lenses, which do not fully account for the social benefits of the presence of salmon and the interconnected nature of these sometimes intangible outcomes.
- The success or failure of hatchery and stocking programs is often assessed at temporal scales far shorter than those used by many Indigenous Peoples (e.g., ensuring continued benefits and rights for multiple generations).
- Some Indigenous communities express concern that populations to rebound through 'natural' restorative processes alone would disrupt Indigenous cultures and ways of life due to an inability to access salmon.
- Hatcheries are not a panacea, but given existing legal, political and environmental constraints on salmon recovery, they can play an important role alongside other restoration measures.
- Meaningful co-management of salmon recovery can help align governance rights and responsibilities more equitably between Indigenous and settler governments.

Key Themes in Grey Literature

- Hatcheries are invaluable for research into fundamental aspects of salmonid biology, their interactions with ecosystems and the effective management of both hatchery- and natural-origin populations.
- Adverse genetic and fitness effects arose due to poor understanding of salmon biology, unsatisfactory hatchery practices, and misalignment between fisheries and environmental management objectives.
- Modern hatchery practices, which are based on the best available science, may allow managers to limit genetic impacts to an acceptable degree when weighed against the full range of desirable outcomes.
- The health of salmon populations is described differently in grey literature, which focuses on broad geographic scope, and Indigenous public-facing literature, which emphasizes specific, place-based scales.

Introduction

In the face of accelerating biodiversity loss, human-assisted breeding programs are increasingly being relied on to augment "wild" populations (Kardos et al., 2021). This practice has attracted controversy for the potential to reduce the adaptive fitness and survival of progeny in these programs (Laikre et al., 2010). Salmon (Oncorhynchus spp., Salmo spp.) have been a focal species for the debate about human-assisted reproduction for conservation.

Some genetic and genomic (hereafter referred to simply as genetic) studies of salmon breeding programs in "hatcheries" have shown that compared to naturally spawning salmon, hatchery-produced salmon have lower rates of productivity, and may carry genes and genetic expression that are less well adapted to the marine and freshwater environment (Araki et al., 2008; Christie et al., 2012; 2014). By interbreeding with salmon that spawn in the natural environment, hatchery-reared salmon can pass on characteristics that negatively affect the survival of wild populations.

Mounting studies of hatchery-produced salmon have called into question the utility of hatcheries as conservation tools. Some authors have concluded that hatchery-based stocking programs are exercises in hubris (Young, 2017:20), demonstrations of "techno-arrogance" (Meffe, 1992), or only appropriate where there are no wild salmon (Gibson, 2017; Young, 2017).

Where populations are critically endangered, others have suggested that measures such as live gene banks (Lennox et al., 2021; Siverstsen, 2017) or re-location (Young, 2017) are the best approaches to preserve genetic integrity and effective population size for declining subpopulations.

However, these approaches are technologically intensive and not necessarily appropriate or achievable for community-based conservation efforts. What is more, hatcheries produce more than fish. Salmon hold enormous significance, both for the environments they traverse and for the communities that depend on them.

As they make their journey from spawning rivers to the ocean and back, salmon feed webs of wildlife, provide nutrients for dense and lush "salmon forests," and, by digging rock beds for their nests, reshape mountains and streams (Field and Reynolds, 2011; Hassan et al., 2008; Reimchen et al., 2003). The magnitude of these ecosystem services may depend, in large part, on the abundance of the organisms providing the service, rather than their source (Buckley & Torsney, 2024).

Human societies have similarly been influenced by salmon. Salmon are integral to the cultural practices, knowledge systems, laws, and identities of Indigenous communities who have sustainably harvested, stewarded, and managed salmon for millennia (Carothers et al., 2021; Denny, 2022; Harrison and Berseth, 2024; Reid et al., 2022). They are also important cultural and economic drivers of Canadian and US coastal communities, sustaining economic and recreational activities on the Pacific and Atlantic coasts.

The production of salmon, therefore, is not merely a biological endeavour, but a social one that intertwines humans with salmon and myriad other species that are implicated in this relational web (Harrison et al., 2018). The loss of these ecological and cultural keystone species (Garibaldi and Turner, 2004, Earth Economics, 2021) could have ripple effects on community identity, intergenerational knowledge transmission, and food security and sovereignty. By excluding Indigenous and community narratives about human-assisted breeding programs, the decisions about whether to close down or expand hatcheries becomes dominated by Western scientific discourses and benchmarks for success.

Analysing Hatchery Narratives

Narratives are forms of discourse that ascribe meaning to events by providing a logical connection between cause and consequence. As social artefacts, narratives reflect particular worldviews and knowledge systems. They are also

situated in fields of unequal power relations, drawing conclusions that provide lessons for directing policies and action and thus can serve to legitimise particular paths towards the future (Hagström & Gustafsson, 2019).

The narrative that hatchery-produced fish pose genetic risks to wild salmon is based on decades of research based in the western natural science paradigm that has evolved alongside advances in genetic theory and data, as well as the development of genomic technologies. This body of evidence has re-configured the practice of salmon production through policy reforms in the United States and more recently in Canada (Hatchery Scientific Review Group, 2004; Withler et al., 2018). However, an emergent counter-narrative has gained attention in recent years, highlighting the role hatcheries play in generating broad social outcomes (many of which are viewed as beneficial) , and in the exercise of Indigenous sovereignty and self-determination (Braun, 2022; Harrison et al., 2018).

For example, kʷikʷəƛ̓əm First Nation broke ground in 2022 on a new hatchery to restore Coquitlam Sockeye. In their announcement, the Nation situated the hatchery in a much longer history of interconnections between the Nation and Coquitlam Sockeye:

> *The destiny of kʷikʷəƛ̓əm First Nation is tied to the future of this fish whose name we proudly carry. Just like the fish, we didn't die, and we are proud to be back as stewards and guardians of our territory with the new kʷikʷəƛ̓əm Sockeye Hatchery. (kʷikʷəƛ̓əm First Nation, 2022:1)*

Several non-Indigenous organisations contributed financial, technical, and operational support to this hatchery's development, describing it as a step towards reconciliation and the realisation of the UN Declaration on the Rights of Indigenous Peoples (UNDRIP). Thus, the narratives told about hatcheries reveal important context for salmon restoration as Indigenous communities and settler agencies challenge the intertwined environmental and colonial histories that have contributed to the current salmon crisis.

The present debate about salmon breeding programs lacks engagement with the social and cultural contexts in which hatcheries operate and the challenges communities face in conserving salmon. Genetics-driven metrics of hatchery success or failure are poorly suited to account for or measure these social outcomes, or to capture the evolving (re)conceptualizations of human-salmon relationships in a changing climate that cannot be measured solely by assemblages of DNA. Moreover, definitions of genetically "good" salmon center Western, institutionalised science to the exclusion of other ways of knowing and relating to salmon (Harrison and Berseth, 2024).

Hatchery and stocking narratives are at a critical point. Hatchery systems in Canada and the United States expanded exponentially in the 1970s as settler governments in both countries sought to grow their fisheries industries, despite the impacts to habitat from the rapid growth of hydropower installations on salmon-bearing rivers (Lichatowich, 1999; Taylor, 2009). Over time, hatcheries have expanded their objectives to include conservation and stock rebuilding for salmon populations that have declined or become extinct (Berseth, 2022).

Today, conservation- oriented hatcheries and stocking programs sit at the intersection of complex social-ecological systems in communities and ecosystems. In some places, these systems have become the ragged edge of no-analogue climate futures that threaten the future of salmon populations and accompanying social dynamics. Culturally and collectively rooted narratives of salmon breeding programs told by Indigenous communities are essential for understanding how people in these communities make sense of the challenges facing salmon and 'Salmon People' (Reid et al., 2022), the possibilities for adaptation, and a vision for the future resilience of human-salmon communities (Kirmayer et al., 2011).

Objectives

We pursue two lines of synthesis in this study:

1. How do Indigenous communities publicly articulate the role of hatcheries within their broader relationships with salmon?

In what ways do these narratives reflect Indigenous governance priorities, rights, and long-term

stewardship perspectives? How can greater attention to these narratives inform more just and effective approaches to hatchery policy and management? How can underrepresented narratives of hatcheries contribute to innovative political, economic, and technical solutions to the salmon crisis?

2. How are hatcheries discussed in grey literature, and what key themes emerge in relation to their role in salmon conservation, management, and governance?

How does this literature compare with Indigenous public-facing narratives, particularly in framing hatcheries' benefits, risks, and trade-offs? How do discussions of genetic risk and genomic technologies in grey literature shape broader understandings of hatcheries, and where do these perspectives diverge from or align with Indigenous viewpoints?

Methodology

In this study, we undertook a **critical realist review.** Critical realism is a philosophical perspective that views the social world as consisting of both observable and unobservable aspects, requiring reviewers to move beyond taking evidence at face value to consider the underlying causal mechanisms and structures that produce social outcomes. This approach aligns with our aim of understanding the social and historical context in which hatcheries operate, the social and cultural factors that shape their operations, and the construction of narratives surrounding the role of hatcheries in salmon communities and their efforts to conserve remaining salmon populations.

A critical realist approach aims "to bring conceptual innovation or theoretical development to the issue under analysis" (Edgley et al., 2016: 318). In contrast to positivist approaches to systematic reviews which take evidence and facts at face-value, a critical realist approach examines the underlying assumptions and normative questions about power, inequality, and other issues that may contribute to certain knowledges and narratives as being present or absent in published literature. A critical realist review combines the strengths of a systematic review by producing empirically-based descriptions that synthesise available knowledge about a given subject, while attending to the underlying social context that shapes how that knowledge is produced (Clegg, 2007).

An advantage of realist reviews is their targeted scope. Because this project is aimed at providing advice to inform specific policies and practices, a realist review approach is feasible within the time frame allocated by this grant. Another advantage of a critical realist approach is that this approach has greater flexibility for including non-peer reviewed literature, as realist syntheses take a researcher-driven approach to assessing the value of literature for inclusion, including grey literature which is often excluded from systematic reviews on the basis of potential bias (Fletcher, 2017).

The present project is specifically analysing literature outside of peer review (including reports, documents, and press releases) as identified in database searches and community-based hatchery program materials. These were selected because these represent an important source of narrative storytelling and can provide counter-narratives that challenge potential bias and narratives produced by dominant knowledge systems in solely peer-reviewed academic research on hatcheries.

Within this critical realist framework, our analytic strategy draws on **narrative analysis** to examine how hatchery-related stories are constructed and communicated across various documents.

Narratives can be understood as texts in which speakers connect events into a sequence to convey meaning (Polkinghorne, 1995). These sequences can be temporal (showing how one event follows another) or causal (illustrating how one event leads to another). According to Riessman (2008), narratives serve multiple functions: they help people make sense of events, remember the past, argue or justify ideas, persuade others, mobilize groups into action, and foster a sense of belonging. In other words, narratives do more than recount what happened; they also shape how individuals understand and relate to the world around them.

Narrative analysis goes beyond individual texts and seeks to understand how narratives weave together in ways that may reflect dominant perspectives and

agendas, or articulate alternative worldviews (Bergman, 2017). By employing a critical realist lens, we not only identify which narratives arise but also consider why they may dominate or remain absent, and how broader social structures such as governance, funding, and cultural norms shape these discourses.

Our datasets include both non-narrative or static text (statements that capture a snapshot of current beliefs) and narrative or dynamic text (temporally or causally ordered sequences of events that unfold over time). Rather than isolating these two forms, the goal is to explore how they interact and contribute to broader patterns or meanings (Polkinghorne, 1995; Riessman, 2008). Non-narrative content provides a synchronic view of what people believe or feel at a given moment, while narratives offer a diachronic perspective on how and why those beliefs have developed.

This combined approach acknowledges that each source contains its own self-contained story and that some narratives may recur across multiple sources, while others remain distinct (Bruner, 1991). Ultimately, both forms are essential for understanding the deeper meanings that speakers aim to convey in their discussions of salmon hatcheries and conservation.

Data Collection

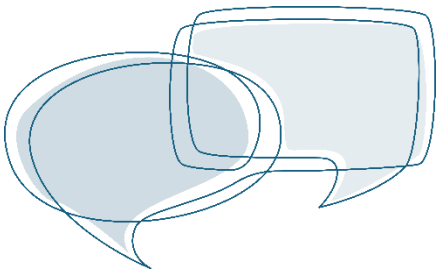
This review comprises two parts: (1) an analysis of grey literature - identified through systematic database search; and (2) an analysis of published materials (e.g., reports, policy documents, press releases, news articles) purposely sampled from Indigenous hatchery programs.

Part 1: Grey Literature

There is currently no universally accepted definition of grey literature. Historically, it was defined as documents not available through commonly used indexing or electronic search repositories (Schöpfel & Prost, 2021). However, with the advent of newer technologies which allow for automated indexing of information from across the internet and the proliferation of media beyond written text, the definition of what constitutes grey literature continues to evolve.

In contemporary discourse, a commonly accepted definition of grey literature is information produced by experts such as governments, academics, and business or industry practitioners, but which is not controlled by commercial publishers (Paez, 2017)**.** This covers a wide range of documents including academic papers such as theses or dissertations, conference papers, reports by governments or other organisations, book chapters, magazines articles, preprints, updates of ongoing research, etc. (Mahood et al., 2014; Paez, 2017).

Data identification. Grey literature sources were identified through Google Scholar (GS) due to its prominence as an index of non-peer-reviewed, publicly available research and reports and its popularity among fisheries managers and decision-makers. A set of search strings were devised using a four-column method wherein column 1 contained the common names of the species under study, column 2 contained keywords related to hatcheries or enhancement programs, column 3 contained keywords associated with disciplines within the natural and social sciences which are involved in the study of these programs, and column 4 contained terms to be excluded which are related to fish production but are areas outside the scope of this study (Appendix 1). The date range of the



search was a ten-year period between January 1, 2012 to December 31, 2021.

To strike a balance between the relevance of results and the effort required to retrieve results, we assessed the results of searches. We found that the relevance of results rapidly declined after the first 200 results. Therefore, we limited the scope of the review to the first 200 results for each search string. In order to minimize discrepancies caused by periodic updates to the GS algorithm, we performed a fresh search for all search strings for the final data collection on 05-May-24. Results were saved to a GS library, and the associated bibliographic information was extracted as .RIS files.

Screening. The .RIS files were uploaded to Covidence (Veritas Health Innovation, 2025), a cloud-based software platform that facilitates literature reviews. The full text of each document was read and screened based on the following inclusion criteria:

- The subject matter dealt with in-scope species and geography (Pacific and Atlantic basins)
- The document dealt only or mainly with situations related to the purposeful and/or intentional releases of fish (i.e., accidental releases were out of scope)
- The document addressed at least one of the following topics:
  Policy, governance, regulation, research, and management of hatchery/enhancement programs
  Relationships between humans, fish and hatchery/enhancement facilities
  Economic, social, political, environmental or other values associated with hatchery/enhancement programs

This produced a final sample of 107 documents which was then extracted from Covidence for further analysis (Appendix 2). More details on screening procedures can be found in Appendix 4. The PRISMA diagram is provided in Figure 1.

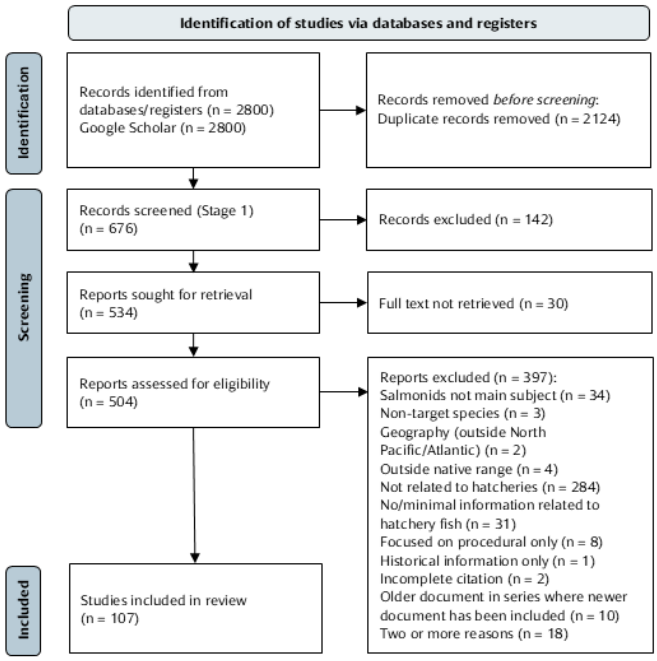


Figure 1. PRISMA Diagram of Grey Literature search and screening results.

Part 2: Indigenous Public-Facing Literature

This analysis was conducted through a purposive sampling search of online or otherwise publicly available materials from Indigenous salmon conservation hatchery and stocking programs in Canada and the USA. From that search, we compiled a selection of relevant published materials. Following the same screening procedure as in Part 1, all selected literature were analysed for their relevance to the research questions, resulting in a total sample of 172 documents.

Data identification. Unlike grey literature, there are no specific databases which could be searched to identify Indigenous groups associated with hatcheries/enhancement programs. Thus, we developed a two-stage process.

In the first stage, we identified federal and state government agencies such as NOAA Fisheries and Washington Department of Fish & Wildlife in the United States and Fisheries and Oceans Canada in Canada, which maintain lists of hatchery facilities that they regulate and/or operate. We searched each hatchery's web page for references to Indigenous involvement in these programs, either as co-managers or in other capacities.

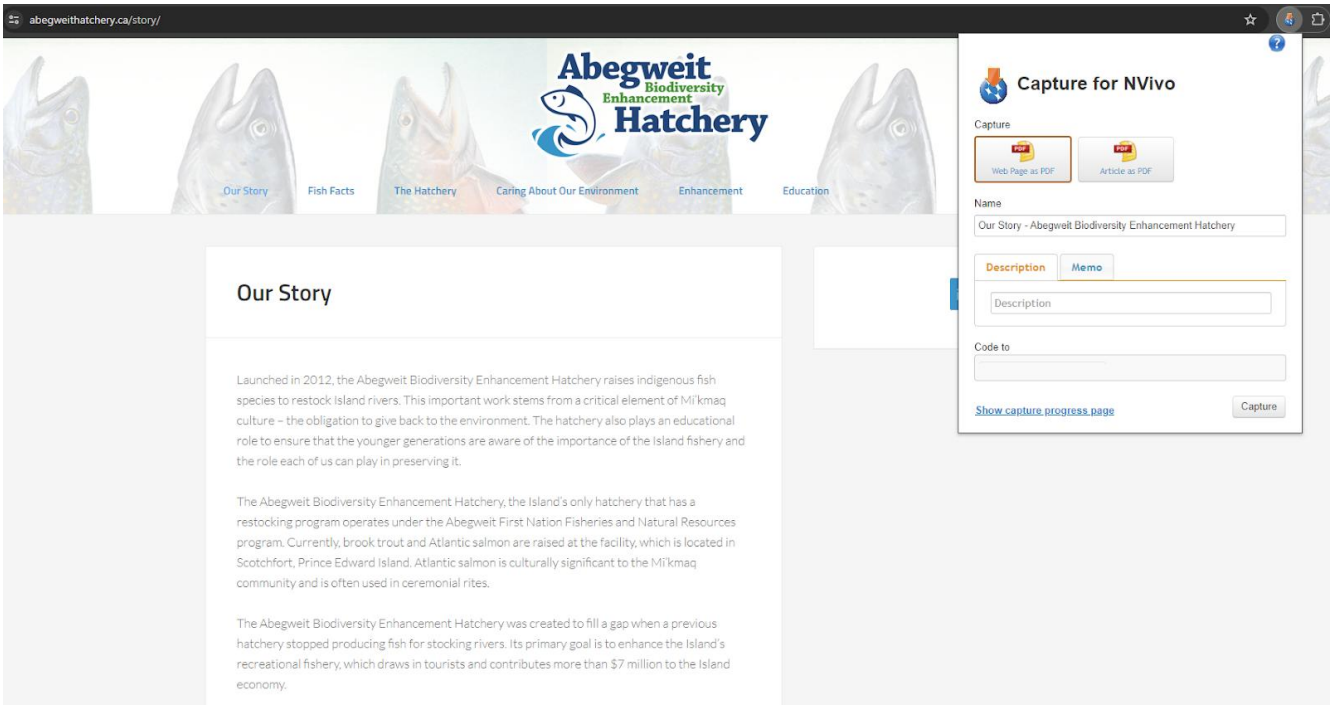


Figure 2. An example of a document which fulfilled all three inclusion criteria.

In the second stage, we supplemented the list generated above by trying to ascertain whether specific Indigenous groups were connected to salmon hatchery/enhancement programs. Using an atlas of (native-land.ca)[1] as a starting point, we compiled a list of First Nations and Tribes across Canada and the United States whose traditional territories overlie the known ranges of the target salmonids. Web searches were performed using the names of the Indigenous communities and relevant terms (e.g., hatchery, salmon, steelhead) and the results were assessed to determine whether they were involved in hatchery/enhancement programs.

This list was further augmented with Indigenous collective organisations known to the research group as being involved with salmon fisheries management and adjacent activities.

Screening. The website of each Indigenous government or organization was then examined for the following inclusion criteria:

- Mentioned the group's role in the operation of a hatchery/enhancement program.
- Explicitly or implicitly provided information about the aims of the program and/or operational details.
- Presented qualitative or quantitative information about the (positive and/or negative) impacts of the program on the Indigenous group.

For each website, all webpages that provided text information relevant to hatcheries (news, opinions, blogs, etc.) were accessed and captured (see example in Figure 2) using the Google Chrome browser extension (v. 1.1.315.0) for Nvivo

[1] The information provided from native-land.ca is a publicly informed resource. The disclaimer provided by native-land.ca is: "The map is a living document, informed by the contributions of Indigenous communities, Indigenous knowledge holders and their stories. It does not claim to represent official or legal boundaries." Our research approach also included consulting the websites of Indigenous communities and our professional networks to address possible omissions from the map resource.

(Lumivero, 2023), a qualitative data analysis software. To allow for comparability across sources, all other media types, such as images, audio, and video, were excluded from this study while recognizing that they may capture ideas not presented in the text. We also excluded documents which had a date associated with them (e.g., news articles or blogs) which fell outside the study's range (2012-2021). The complete set of webpages included for analysis is available in Appendix 2.

Data Analysis

To generate an initial set of codes, a random sample of 10% of in-scope grey literature documents (11 out of 107) was created. This was done by assigning random numbers between 0 and 1 using the RAND() function in MS Excel to each of these documents and selecting the 11 documents with the smallest numbers associated with them. These documents were imported into Nvivo (v. 14.23.4).

The full text of each document was qualitatively analysed and any ideas that were deemed as being potentially relevant to the research questions were coded using an inductive process. Codes expressing similar ideas were then grouped together into categories to create a codebook which was reviewed for coherence and comprehensiveness by the broader research team. The feedback from this review was used to further refine the codebook. To ensure that all relevant ideas were encapsulated for analysis, an additional code called 'Other' was also added to capture ideas outside these codes which may be present in the other documents. This codebook is available in Appendix 3. Using this codebook, the text from the entire dataset of 107 documents was coded in a deductive process.

The codebook created for the grey literature coding was expanded and revised for the Indigenous public facing literature. Based on feedback from members of the research team who are associated with Indigenous groups, the food/nutrition values, and social and cultural values were separated into two codes. The webpages captured using the Nvivo plugin were imported into a new project file and the deductive coding process was applied using this updated codebook. This process captured several references under the code 'Other', all of which were related to hatchery/enhancement programs as a cause of public controversy.

In addition, each document was assigned case classifications to identify the type of author (federal or state government, Indigenous groups, private sector, academic, environmental group, and intergovernmental organisation), basin of interest (Atlantic, Pacific), and document type (technical report, management plan, knowledge synthesis/review, dataset, and opinion).

We began by grouping the material into overarching themes, sub-themes, and categories to capture the breadth of topics discussed across all sources. We then examined the patterns and relationships among these codes, paying close attention to recurring sequences and connections between ideas. For instance, we noted whether certain codes (e.g., funder roles, cultural values) frequently appeared together and whether these co-occurrences suggested a particular narrative emphasis or a shared perspective.

We also looked for temporal sequences (i.e., how events or beliefs change over time) and causal links (i.e., how one event or condition leads to another). These sequences helped to identify common storylines that reappeared across multiple sources, as well as distinct narratives that reflect particular contexts or histories.

By identifying similarities among the narratives told by individual sources, our aim is not to erase the nuances but to understand what these narratives reveal about the future role of hatcheries in maintaining salmon populations and how these stories connect to broader cultural values, governance structures, and funding mechanisms that collectively shape public and policy discourses on hatchery-based conservation.

After determining key patterns, we linked the emergent themes to the broader social context surrounding hatcheries and salmon conservation to identify patterns and interconnected themes related to how narratives of hatcheries and salmon production are constructed and sustained. Following Adams et al. (2017), we report the findings for each body of literature separately to preserve the unique qualities of each type of

evidence and to enable readers to more accurately interpret the strength of the findings presented. We then discuss where narratives converge and exist in tension between the two, and what these points of intersection suggest for engaging in wider dialogue about the role of hatcheries in salmon restoration. Source materials are referenced in-text using document IDs (e.g., #G1) provided in the Supplemental Information.

A note on terminology...

We encountered several terms that carry specific meanings in different knowledge systems, including salmon management, natural sciences, and Indigenous perspectives. However, we observed that these terms were not always used in strictly technical ways or were not explicitly defined.

Rather than assessing the technical validity of these materials or seeking to reconcile differences in how these terms were used, our study focuses on identifying and disentangling narrative elements within them. As a result, some terms may be used interchangeably and should be interpreted in their broader, commonly understood sense.

Examples include:

- ‘Indigenous’ is often used to refer to the original Peoples in a particular place. ‘Tribe’ is a term that is commonly found in the United States, and ‘First Nation’ is a term that appears in Canadian sources.
- ‘Salmon' is used to refer to one or more of the Pacific (*Oncorhynchus spp*.) and Atlantic (*Salmo salar*) species, which were the focus of this study.
- 'Wild' or 'natural' to describe the origin of salmon or their habitats.
- 'Recovery' or 'restoration' to describe efforts aimed at reversing salmon population declines.
- 'Hatchery', 'enhancement', and 'supplementation' to describe programs where breeding and release of juvenile salmon involves deliberate human interventions.

Findings

Indigenous Public-Facing Literature

The narratives shared in the Indigenous Public-Facing (IPF) materials provided context for understanding hatcheries and their changing roles through time. These narratives contained varying levels of detail but largely spoke to four major periods (Figure 3) and comprised largely websites from the Pacific basin (Figure 4).

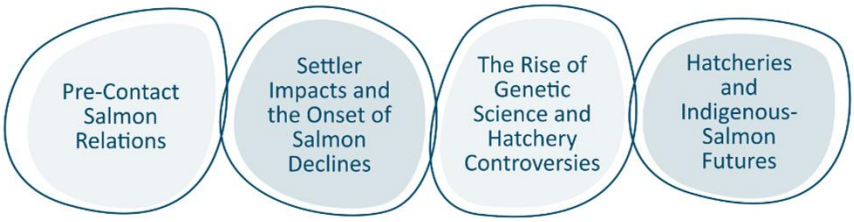


Figure 3. Periods described in Indigenous Public Facing Literature.

While we identify four broad eras to highlight shifts in salmon management and discourse, these periods have heuristic boundaries that often overlap and certain ideas may be present in multiple periods of time. For example, the significance of salmon as a food source can be traced back to pre-colonial salmon relationships and is also attributed as a benefit of hatchery production.

Similarly, concerns about genetic risks, often associated with more recent controversies, appear in ongoing contemporary discourses. In grouping these narratives into distinct epochs, our goal is to illuminate patterns in how Indigenous voices recount and interpret changes over time, rather than to claim a single authoritative timeline.

1. Pre-Contact Salmon Relations

A recurring theme across the sources was the rich habitat that sustained thriving salmon runs prior to colonization, which supported Indigenous peoples since time immemorial. The Columbia River Intertribal Fish Commission (CRITFC) wrote that "tribal people of the Columbia Basin annually consumed over 40 million pounds of salmon prior to the arrival of non-Indians" (#I19). The Spokane Tribe of Indians described "bountiful runs of salmon and steelhead that thrived in the Spokane and Columbia Rivers" as being the "primary form of sustenance" since time immemorial (#I3).

Notably, the fragmentation of once continuous salmon habitat was criticized for its harmful impacts on salmon genetic integrity. According to CRITFC:

> *In the past, salmon habitat, which was continuous, provided links between local populations, creating a metapopulation. But human activity partitioned the habitat and fragmented the populations, increasing the possibility of inbreeding depression by reducing natural gene flow and effective population size (#I47).*

Over time, environmental degradation has threatened salmon abundance. For example, the Yakama Nation described summer- and fall-run chinook as "once abundant in the Yakima River Basin" before runs were decimated by land and water development, and poor fisheries management (#I170). The Tulalip state, "current habitat conditions are incapable of supporting the healthy salmon populations the Tulalip Tribes relied on since time immemorial" (#I160).

The pre-colonial period was also discussed in the context of the long-standing and profound connection between Indigenous peoples and salmon. According to these sources, salmon have long shaped Indigenous cultural identity, informing social structures, trade practices, and communal bonds. Indigenous connections to salmon are deeply rooted, characterized by a sense of belonging and shared heritage, uniting generations through collective histories and practices. Salmon were described as "ntytyix (Chief Salmon)" by the Syilx Okanagan People (#I93), as foundational to "the continuation of human life" in the Columbia Basin (#I169), as "seagoing cousins" by the Coquille

Indian Tribe (#I127), and as integral to the identity of communities such as the Spokane who described themselves as "salmon people" (#I3). There is a symbolic and material importance to the cyclical return of the salmon that signaled the return of a critical food source and hope for the future, even when returns were small (#I45; #I169). While ceremonies are particular to individual communities' stories and traditions, 'First Salmon' ceremonies are shared by many as a way to mark the return of salmon to their territories.

> *We believe the salmon people to be our relatives and that their homes must be respected and protected. The first salmon to return each fall is welcomed and honored in a sacred ceremony. The salmon are linked with immortality, eternity, and rebirth. Salmon run not only in the ocean and streams; their spirit runs through our blood and in our souls. (Squaxin Island Tribe, #116)*

> *A myriad of Syilx Okanagan cultural practices demonstrate snxa? l'iwlem (honouring the sacredness of the river) while reinforcing strong cultural-spiritual ties between Syilx Okanagan communities and the salmon. (Okanagan Nation Alliance, #I93)*

Many sources described salmon as relatives or sacred beings and this spiritual connection is inseparable from a collective responsibility to protect salmon and their habitats for the sake of salmon and future generations. Restoration therefore is a high priority and hatcheries were described as linked to this endeavour through their perceived role in restoring salmon populations to historic levels of abundance.

> *This important work stems from a critical element of Mi'kmaq culture – the obligation to give back to the environment. (Abegweit First Nation, #I93)*

> *Salmon are at the heart of Puget Sound Tribal culture and spirituality. Without salmon Tribes run the risk of losing their traditional teachings and stories that have been passed down from time immemorial. (Stillaguamish Tribe, #I43)*

These references to pre-colonial conditions provide context for understanding narratives related to salmon hatcheries and visions for what can and should be restored. They also underscore the irreplaceable and multi-faceted connection between people and fish marked by interdependence and reciprocity, and the role that spirituality plays in Indigenous decision-making where salmon are concerned.

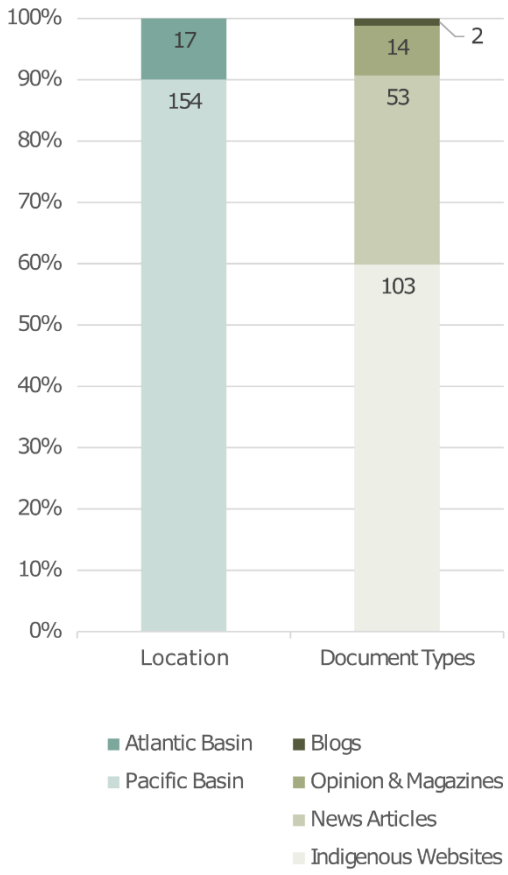


Figure 4. Composition of Indigenous Public-Facing Literature.

2. Settler Impacts and the Onset Of Salmon Declines

A common refrain in the Indigenous public-facing sources was that salmon are adaptable, strong, and resilient. However, as noted above, the arrival of settlers brought many changes to the environment that negatively impacted salmon, their habitats, and their relationship to Indigenous Peoples. The most common message was that the recent population declines and loss of fisheries are largely due to habitat loss or degradation and climate change. The Northwest Indian Fisheries Commission (NWIFC) articulated this directly: "Throughout the region,

salmon runs are imperiled by the cumulative effects of habitat degradation and a changing climate" (#I10). They argued that the problem of salmon decline "is simply mirroring the collapse of the eco-systems that support them" (#I8). These broader factors threaten "all salmon, whether born in a hatchery or not," (#I78), as well as the ecosystems and humans that depend on them.

> *Rebuilding, sustaining, and protecting functioning ecosystems is central to salmon recovery. Habitat degradation and fragmentation are leading factors resulting in declining salmon populations. (Salmon Defense, #I12)*

> *Salmon populations in the Columbia Basin continue to face problems of loss and degradation of freshwater habitat, and significant juvenile out-migration mortality associated with the hydrosystem. (CRITFC, #I87)*

Historical accounts in the literature noted that hatchery programs were originally introduced to counteract the impacts of hydropower and other development. Over time, the focus of hatchery programs evolved from merely replacing lost natural production to actively supporting conservation objectives. For instance, Lorraine Loomis of the NWIFC stated:

> *Washington's hatcheries originally were built to replace the natural salmon production that was lost to dams, development and other factors. Hatcheries have evolved since then to become an important part of protecting and restoring salmon stocks. (#I78)*

In this context, hatcheries were described as necessary tools to help recover salmon and have been adopted in response to declines in salmon habitat and salmon returns.

However, there were many caveats to this support. A predominant narrative thread was that Indigenous and non-Indigenous communities have become dependent on hatcheries, not through choice, but because of failings in addressing the loss of productive salmon habitat. Some of these changes include "increasing water temperatures, decreasing water flows, and the ongoing destruction and degradation of habitat" (#I60) and "reduced habitat productivity and hydrosystem mortality" (#I138). NWIFC chairman Billy Frank Jr. stated, "We would prefer not to rely so heavily on hatcheries, but today more than half of the chinook and coho harvested by Indian and non-Indian fishermen come from hatcheries" (#I86). Several documents underscored that as long as habitat degradation persists, communities will remain reliant on hatcheries. There was an emotional expression of loss in several sources, particularly related to the battle that Indigenous Peoples have continuously fought for salmon.

> *The collapse of our fisheries is simply mirroring the collapse of the eco-systems that support them. For more than 100 years, hatcheries have tried to make up for that loss, but hatchery salmon depend on the same declining habitat as naturally spawning salmon. (NWIFC, #I8)*

These descriptions illustrate how habitat degradation and fragmentation are central to ongoing salmon declines, with hatcheries emerging as both a consequence of, and a response to, these losses. The persistence of salmon populations depends on the broader conditions that support their life cycle. However, hatchery reliance has grown as habitat loss has continued. This tension between the need for intervention and the limitations of hatcheries as a long-term solution remains a central theme in Indigenous discussions of hatchery risks and controversies.

3. Rise of genetic science and hatchery controversies

Sources in the materials studied directly addressed the controversies surrounding hatcheries which center on critiques of their efficacy and their potential to negatively affect salmon through ecological and genetic risks. One critique of hatchery management raised by Indigenous sources is the misalignment between hatchery goals and their operations. Instead of restoring salmon to their traditional, natural habitats, conventional hatchery programs were criticized for simply boosting overall fish numbers without ensuring that the fish are distributed in the areas where wild salmon historically thrived (#I97). Illustrative of this is the location where many hatchery facilities are located. One of the motives

for creating hatcheries was to make up for the loss of salmon production caused by dams and other development. However, most hatcheries were built in the lower parts of the rivers rather than in the upper reaches where the habitat was actually lost and where Indigenous communities traditionally and customarily fished (#I112; #I143). As a result, these mitigation efforts only partially address the problem. The CRITFC encapsulated this misalignment, writing:

> *Nevertheless all these efforts have proven inadequate to maintain anadromous fish numbers and productivity. The lesson is inescapable: technical solutions alone cannot maintain salmon populations in the face of massive disregard for, and destruction of, the ecosystems within which salmon evolved. (#I100)*

Genetic risks of hatcheries were also referenced as concerns for Indigenous communities.

> *Do hatcheries threaten wild salmon stocks? Of course there are risks associated with hatchery programs. There is risk that the program might fail; risk that hatchery salmon will compete with wild salmon for food and space in our rivers; and risk that hatchery fish might affect wild salmon if they interbreed. These are all risks we must measure and balance. (NWIFC, #I51)*

There were also explicit and implicit suggestions that many of these concerns can be addressed through an improved state of understanding of salmon biology and ecology, alongside reform measures such as program design, better management, and infrastructure upgrades.

Indigenous communities have also advanced new techniques and procedures for broodstock selection which can help address some of the genetics and fitness concerns of conventional hatchery programs (Table 1). The CRITFC described their approach as involving “radically different hatchery practices” (#I122) and stated:

> *Rather than perpetuating the dominant hatchery rearing and release paradigm, which focuses on hatchery returns for harvest, supplementation uses hatchery technology to rebuild naturally spawning fish stocks while also providing harvest. (#I169)*

Thus, it is accurate to characterize views towards hatcheries in the Indigenous public-facing literature as diverse and critical, but accepting of hatcheries as part of overall efforts to restore salmon.

Some documents suggested that genetics is a less critical problem than critically low population sizes compared to historical abundance, as “the risk of losing a whole population outweighs the risk of losing genetic variation” (#I47). The Nez Perce Tribe stated:

> *... restoring the lower Snake River to a natural river and eliminating these barriers that stand between the largely-pristine habitat in the Salmon, Snake, and Clearwater basins is the cornerstone to rebuilding returns along with ongoing hatchery and habitat actions; and 4) as dire as the situation already is, these fish may have even less time given the looming impact of a warming climate. (#I90)*

Moreover, small population size may be a more significant risk factor than genetics due to “factors related to demographics, survival rates, and spatial structure” and in these cases, focusing on abundance may be a higher priority and hatcheries are often the best hope for stemming the losses of salmon runs (#I47).

Several sources also pushed back against what they described as an overemphasis on genetics in salmon enhancement discourse, arguing that hatcheries are unfairly blamed for salmon declines. Lisa Wilson, a member of the Lummi Indian Business Council, highlighted that “hatcheries keep getting blamed for declining salmon runs and lost fishing opportunities. Much of this blame comes from false accusations that hatchery salmon are contaminating the genetic purity of wild salmon" (#I9). She noted that “Tribal treaty rights are being attacked by so-called conservation groups that threaten legal action against our hatcheries” (#I9). Others described these lawsuits in similar terms while arguing that they are based on a misguided view that removing hatcheries would lead to a ‘miraculous’ return of wild fish.

Table 1. Hatchery reforms and interventions implemented or proposed by Indigenous communities in the Indigenous Public-Facing Literature.

Practice/Intervention	Description	Sources
Naturalization & Natural-Origin Broodstock	Selecting wild or naturally adapted fish as broodstock to build locally adapted, "localized" stocks and emphasize natural production	#I18, #I155, #I164
Integrated & Adaptive Broodstock Management	Integrating hatchery production and natural populations, adjusting production based on status of natural population, and designing protocols to balance risks	#I76, #I107, #I161, #I32
Breeding Practices	Includes approaches (e.g. controlled rearing, selective breeding, and genetic testing) to maximize diversity and minimize risks of hatchery impacts to the fitness of wild populations	#I48, #I60, #I91, #I107, #I131, #I119
Supplementation Hatchery Approaches	Uses less intrusive methods than conventional captive breeding to produce fish that supplement naturally spawning populations while mitigating genetic or behavioral impacts	#I138, #I138, #I87, #I47, #I122
Program-Level Stocking Decisions	Addresses management decisions related to the continuation or cessation of stocking	#I71, #I72, #I17,
Disease Prevention & Fish Health Management	Developing protocols and measures that prevent disease outbreaks and support fish health, including quarantine, tissue sampling, and preventative health services	#I172, #I14, #I34

These documents further noted that hatchery and wild fish behave similarly in the natural environment (e.g., maintaining the same diets, and spawning) (#I54). Given this, the emphasis on genetic risks may overlook more immediate threats to salmon survival, such as habitat fragmentation and warming waters, which have already severely constrained genetic exchange (#I47; #I145).

Several factors were cited as contributing to this amplification of the risks of hatchery production including a lack of information leading to speculation and disagreement, false accusations that hatchery salmon are contaminating the genetic purity of wild salmon, and evidence accrued through monitoring and studies of their own hatchery programs that has not been centered in hatchery discourse.

Some sources directly cited peer-reviewed literature criticizing hatcheries, countering that although some studies have claimed that there are substantial negative genetic effects from as little as one generation in a hatchery system, observations in hatchery programs showed "rapid readaptation of the reintroduced fish to the natural environment...in the face of natural selective processes and judicious management of broodstock and hatchery rearing" suggesting that fitness changes may not be as long-term as critics suggest (#I111).

For example, reviews of the Nez Perce Tribe's Johnson Creek Artificial Propagation Enhancement project showed that "hatchery-reared salmon that spawned with wild salmon had the same reproductive success as salmon left to spawn in the wild" (#I68, #I87, #I138). The authors wrote,

> *The results of the Johnson Creek artificial propagation study refute a commonly held misconception and some previous research suggesting that interbreeding of hatchery-reared fish with wild fish will always decrease*

productivity and fitness of the wild populations. In fact, the Johnson Creek research demonstrates how supplementation programs are able to increase populations and minimize impacts to wild fish populations. (CRITFC, #I68)

As discussed in section 2, sources pointed to habitat destruction, hydroelectric projects, and climate change rather than hatcheries as the true underlying causes of salmon decline. From this view, eliminating hatcheries would lead to catastrophic consequences for the ecosystem and would not stop the losses of fish due to these stressors. Instead, sources advocated for smarter, more integrated hatchery practices that work alongside habitat restoration efforts to achieve sustainable salmon returns. The ongoing controversies surrounding hatcheries were summarized by Lisa Wilson, commissioner of the NWIFC:

We know the real reason we are failing to recover salmon is that their habitat is being destroyed faster than we can restore it and climate change wreaks havoc on marine productivity and survival. But for some reason, hatcheries keep getting blamed for declining salmon runs and lost fishing opportunities. (#I9)

Or, as Jeremy Wolf, chairman of the CRITFC, succinctly stated:

Columbia Basin salmon were not decimated because of hatcheries. The Columbia Basin has hatcheries because natural fish were decimated. (#I167)

4. Hatcheries and Indigenous-Salmon Futures

While genetic science and hatchery controversies have shaped much of the debate over salmon conservation, Indigenous perspectives reflect a broader view of hatcheries as tools that, when used appropriately, contribute to the long-term stewardship and future resilience of salmon populations. Rather than seeing hatcheries solely through the lenses of genetic risk or production efficiency, many Indigenous communities emphasized their role in building sustainable relationships between salmon, people, and ecosystems that will be crucial for salmon survival in the face of ongoing environmental change (e.g. #I27, #I45, #I69).

The costs of restoration must be at least equated with the value of restoration. That value includes the spirit of the salmon (Wy-Kan-Ush-Mi Wa-Kish-Wit). Tribal peoples can feel the yearning of salmon to serve its life purpose. There is no model that can factor in spirituality nor the ultimate value of living creatures. (CRITFC, #I27)

The kɬ cp̓ɔlk̓stim̓ Hatchery is a testament to the perseverance of the Syilx people to realize their dream of restoring the ntytyix (Salmon) – one of our Four Food Chiefs – to their original habitat and rightful place in our territory. (Okanagan Nation Alliance, #I69)

Indigenous perspectives on salmon management and hatchery use continue to evolve. Sources described multifaceted approaches that go well beyond genetic or production metrics. In these accounts, salmon are not merely biological entities to be managed for harvest or restoration; they are part of a complex web of social, cultural, and ecological values.

Care for salmon is exercised through multiple means, including hatchery programs that support biodiversity, sustain fisheries, and provide opportunities for intergenerational knowledge transfer. This ethic of care extends beyond hatchery operations, shaping a range of Indigenous-led conservation practices. Several communities described instances where they had voluntarily reduced or stopped their own fishing activities to protect salmon populations, often at great cultural and dietary cost (#I5; #I7; #I65).

Others had invested in hatchery programs that prioritize biodiversity, genetic management, and naturalized rearing conditions, even when these approaches required sacrificing production volume (#I15; #I111; #I138; #I172). In some cases, Indigenous groups including the Nisqually, Quileute, and Puyallup Tribes had taken direct control of hatcheries when federal, provincial, or state budgets were cut, assuming management roles, supplementing feed, or volunteering to ensure that these facilities can continue to operate in

accordance with stewardship responsibilities (#I52; #I61; #I94).

Hatcheries were described as serving multiple evolving objectives, including sustaining harvest opportunities, alleviating fishing pressure on wild stocks, conserving threatened salmon populations, restoring extirpated runs, and supporting broader ecosystem functions. In some cases, hatcheries provided fish for harvest while simultaneously protecting weak natural-origin stocks by shifting fishing pressure to hatchery fish (#I28; #I110; #I129). In other cases, they acted as conservation tools, helping to maintain endangered populations listed under the Endangered Species Act (ESA) or supporting ecosystem restoration by bolstering prey availability for species such as southern resident orcas (#I9; #I78).

Reintroduction efforts also featured prominently in the data, with communities identifying hatcheries as a means of reconnecting fish to their historical spawning basins such as the Upper Yakima Subbasin (#I76) and the Rapid River in Idaho (#I71) and, by extension, restoring the relationships between salmon, people, and the landscapes they shape. Additionally, hatchery programs contribute to research by facilitating monitoring efforts and informing adaptive management strategies.

Throughout the data, sources highlighted concrete evidence of positive outcomes from hatchery programs. In several cases, hatcheries played a direct role in reversing population declines, with previously extirpated or near-extinct runs successfully reintroduced. For example, the Nez Perce Tribe's efforts restored lost salmon runs, while fall Chinook returns in the Columbia River system increased dramatically, with annual counts rising from fewer than 1,000 to over 55,000 in some years (#I129; #I155). Similarly, hatchery-supported coho reintroductions in the interior Columbia Basin led to substantial population growth, despite initial resistance to these programs (#I18; #I155).

Food Security

There were numerous descriptions of salmon (including hatchery origin) as a foundational food central to health, and survival, as well as cultural identity and ceremonial use. Hatchery programs played a crucial role in ensuring continued access to salmon, particularly as natural stocks have declined.

> *This project demonstrates the Nez Perce Tribe's commitment to the recovery of steelhead and other culturally important life sources for the benefit of the ecosystem, our traditional use of these First Foods, and for all residents who enjoy healthy and sustainable fish runs," said Chairman Wheeler. (Nez Perce Tribe, #I92)*

Hatcheries were described as essential for maintaining traditional fishing practices, upholding treaty rights (see also "Treaty Rights and Governance" below) and continuing long-standing relationships with salmon (#I3; #I161; #I169). Reliable hatchery returns helped communities avoid overharvesting wild stocks while sustaining customary fishing practices.

Salmon have historically been an essential source of subsistence. In many regions, hatchery salmon helped fill the gap created by declining wild runs, ensuring that freezers and smokehouses remain stocked for the winter months (#I19; #I59; #I179). This is particularly important for communities facing food insecurity, where salmon is not just a dietary staple but a deeply rooted part of Indigenous food systems.

> *Steelhead are a culturally important species that the Upper Skagit Tribe harvests for commercial, ceremonial and subsistence purposes. Historically, steelhead were available during the long winter months when other species were not available to feed tribal families. (Upper Skagit Tribe, #I161)*

> *"We're talking about a group of people who have a lot of food insecurity issues anyway and chinook (salmon) was really a cornerstone of our subsistence larder," she said. "Most of our freezers had a huge portion of it devoted to our king salmon dried fish." (Kuskokwim River Inter-Tribal Fish Commission, #I104)*

In addition to sustenance and traditional fishing practices, there are social benefits to the harvest and distribution of salmon within communities. Implicit in these descriptions is the idea that it

strengthens community bonds, strengthens networks, and fosters community well-being and reciprocity. For example, the Cowichan Tribe implemented an annual food fish distribution program, requiring citizens to apply for food fish cards to receive their share (#I39). Similarly, the Confederated Tribes of the Colville Reservation established a comprehensive harvest and distribution system to ensure that salmon were accessible to all member nations of the Upper Columbia United Tribes (#I153).

Hatchery salmon were also distributed beyond tribal communities as an act of generosity and solidarity. The Nisqually Tribe, for instance, provided free salmon to thousands of people in the fall rather than selling surplus fish (#I85). During times of crisis, this reciprocity can extend further - wildfire victims and firefighters in eastern Washington received donated salmon from the Quileute Tribe and the Sol Duc Hatchery in an expression of support (#I108).

Social and Cultural

While earlier sections have discussed the deep cultural and spiritual significance of salmon to Indigenous nations, this section focuses on the role of hatcheries in ensuring these relationships persist into the future. As salmon runs continued to decline, hatchery programs became critical tools in maintaining cultural practices (#I17; #I19; #I107; #I159). For example, Indigenous Peoples from the Columbia River to the Hillsborough River continue to fish for salmon primarily for ceremonial and subsistence purposes, even in the face of declining runs and restricted harvest opportunities. Tribes in the Columbia Basin strategically targeted only spring and summer Chinook to meet sustenance and ceremonial needs (#I19).

As the Okanagan Nation Alliance noted, there is a mutually reinforcing relationship between Indigenous cultural beliefs and traditional salmon stewardship practices (#I50). The Umatilla Tribe similarly attributed the origins of their spring chinook reintroduction program as a need to meet cultural and spiritual needs, as well as ecosystem functions in the Walla Walla River (#I164).

In the data, hatcheries were often described as playing a role in sustaining the kinship relationship between Indigenous peoples and salmon. Hatcheries were framed as tangible expressions of care that are rooted in the understanding that salmon restoration is inseparable from the obligation to care for and restore the broader interconnected systems of life that have been disrupted. As Chairman Shannon F. Wheeler of the Nez Perce Tribe explained,

> *We view restoring the lower Snake River as urgent and overdue. To us, the lower Snake River is a living being, and, as stewards, we are compelled to speak the truth on behalf of this life force and the impacts these concrete barriers on the lower Snake have on salmon, steelhead, and lamprey, on a diverse ecosystem, on our Treaty-reserved way of life, and on our people. (#I90)*

Care was exemplified by the sacrifices that communities have made to ensure salmon recovery for future generations. Some nations have chosen to forego ceremonial and subsistence harvests out of precaution for vulnerable stocks, despite their central importance to cultural and spiritual ways of life. The Abegweit First Nation, for example, refrained from using the salmon they are legally entitled to harvest for ceremonial rites, recognizing the need to prioritize conservation over immediate cultural practices (#I5) .

Other communities implemented self-imposed fishing closures or habitat restoration projects, such as those undertaken by the Shuswap Nation Tribal Council on the Deadman River (#I7; #I65). The Upper Skagit Tribe described contemporary efforts in the context of past sacrifices, saying, “Our ancestors gave up everything so that we could continue to fish in our traditional areas... without hatchery production, we can’t have a meaningful fishery” (#I161).

Stories of collective action highlighted the role that Indigenous and non-Indigenous volunteers play in hatchery operations. In some cases, communities came together to physically collect and transport salmon to hatcheries, as seen in the collaboration between the Coquille Tribe, the Oregon Department of Fish and Wildlife, and local volunteers (#I1; #I85).

The cultural and social importance of hatcheries was highlighted through the naming of facilities and fisheries in honour of respected elders. For example, the spring chinook fishery enabled by Lummi Nation's hatchery program was named "Paq wet sut" to honor Randy Kinley Sr., a Lummi Nation policy representative who passed away in 2017 (#I9). In 2018, the Yakama Nation began construction on a new hatchery named in honor of Mel Sampson, a respected elder and former Tribal Council Chairman (#I76). The Tulalip Tribes named their hatchery in honour of Bernie Gobin, who was instrumental in their efforts to reclaim fishery rights (#I159). Hatcheries can also serve as gathering sites, as is the case for The Levi George Supplementation and Research Facility at Cle Elum which has hosted an annual open house since 1997 with self guided tours, performances, and lunch for visitors (#I67).

Treaty Rights and Governance

Hatcheries play an important role in the exercise of Indigenous treaty-protected rights to fish for subsistence, ceremonial, and commercial purposes. Multiple sources emphasized that federal governments have a legal obligation to honour these rights and ensure fishing opportunities, as affirmed by federal courts in the United States in legal cases such as U.S. v. Washington and U.S. v. Oregon (#I10; #I12; #I19; #I44) as well as in Canada through the Sparrow decision (#I5). At the same time, these rights exist even in the absence of treaties. The Syilx Okanagan Nation, for example, stated that they "never signed treaties, nor relinquished our right to harvest and manage the fishery" (#I14).

Hatcheries, including those run by Indigenous communities and those run by federal and state agencies, were widely recognized in the data as a mechanism for protecting treaty rights and inherent governance rights (#I18; #I87; #I126). In many cases, courts of law have ruled that treaty rights apply to both hatchery and non-hatchery origin fish. In these situations, hatchery programs play a direct role in sustaining access to salmon fisheries (#I58).

Many Indigenous nations described hatcheries as not only a tool for fish production, but as an expression of their inherent governance rights, rooted in their legal traditions and obligations to the land, water, and salmon. For example, the Nez Perce wrote:

> *The Clearwater Coho Restoration Project provides benefits to the tribe and the region. Returning adult coho support a tribal and non-tribal fishery along the Columbia River and provide the tribal hatchery program with a local broodstock. Because of this program, tribal members are exercising their treaty reserved fishing right, and coho are once again spawning in the wild. (#I18)*

Hatcheries are frequently embedded within co-management arrangements, where Indigenous nations share decision-making power over fisheries management with federal and state agencies (#I11; #I138; #I155). These agreements recognize Indigenous nations as sovereign entities with inherent governance rights over their traditional territories, providing a mechanism for Indigenous leadership in hatchery operations.

However, many documents emphasized that co-management must go beyond formal agreements. For co-management to be meaningful, Indigenous Nations must be treated as full and equal partners in fishery management, with authority over decisions related to harvest levels to hatchery production and habitat management (Wilkinson, 2024, chapter 13).

Despite the existence of these agreements, there was frequent recognition of the limitations of co-management as it is practiced. While Indigenous nations are working to assert their governance rights, fisheries management still operates within Western legal and scientific frameworks, limiting Indigenous decision-making structures and autonomy in hatcheries and salmon management more broadly (#I79; #I150).

Ongoing jurisdictional conflicts, funding disparities, and inconsistent recognition of Indigenous knowledge and authority in hatchery and fishery management further complicate co-management arrangements (#I127; #I145; #I150; #I167). Billy Frank Jr. of the NWIFC underscored the persistent challenges facing Indigenous communities in sustaining treaty-protected fisheries:

> *Our hatcheries uphold those treaties, because ongoing habitat degradation prevents natural-origin salmon from returning in harvestable numbers. There is no legal ground to challenge our hatchery programs, and yet we face the constant threat of litigation [...] To make matters worse, we find ourselves having to compete for funding with these groups as tribes fight to solve a problem we didn't create – to recover the fisheries that were promised to us in treaties. (#I7)*

Ultimately, the degree to which co-management arrangements reflect Indigenous governance and decision-making authority continues to be a point of contention, reinforcing the broader struggle to uphold treaty rights and inherent sovereignty in fisheries management.

Economic

Salmon fisheries are important to Indigenous communities through direct and indirect economic benefits. Sources emphasized the role that hatcheries and salmon management play in sustaining tribal and commercial fisheries. In some cases, such as in Washington state, and the Gulf of Alaska region, hatchery salmon were a sizeable contribution to overall catch (#I9; #I17; #I79).

Many sources also described the ways that fisheries and hatcheries support individual and community economic well-being, subsistence, and economic security. For communities where incomes are low, supporting fishing opportunities made a tangible impact on livelihoods (#I114). Economic benefits are also created through associated industries such as fish processing, hospitality, fleet maintenance, training, and the operation of hatchery facilities (#I19).

Several sources emphasized that everyone - including Indigenous and non-Indigenous groups - benefited from fisheries which rely on hatcheries and the benefits can be geographically dispersed (e.g., fish caught in AK which originate elsewhere) (#I8; #I45; #I51; #I61). In many cases, when funding had declined for federal or provincial/state hatcheries, Indigenous communities stepped in to take over or support continued hatchery production (#I8; #I12; #I15; #I30; #I98).

However, the economic importance of hatchery production was often connected to broader histories of salmon decline and the inequitable burden this has had on Indigenous prosperity and economic security (#I19; #I129). The CRITFC, for example stated that compensation for the cumulative losses of millions of salmon borne by Indigenous communities was not addressed through treaties and is often overlooked in discussions of salmon fisheries (#I19).

Others noted that waiting for salmon to rebound without any intervention would take a long time, leaving Indigenous people with nothing to catch in the meantime (#I126). Ultimately, despite the substantial costs of salmon restoration (#I19), the value of salmon is beyond measure and cannot be understood through purely reductive economic measures (#I7; #I10; #I27).

Education and Learning

Hatcheries contribute to education and learning at several levels, from hands-on learning experiences to workforce training. Many hatchery programs introduce children and youth to salmon through programs such as Salmon in the Classroom or Fish Friends that provide juvenile salmon to be raised in school classrooms before releasing them into local waters (#I24; #I29; #I37; #I88).

These programs were described by sources as contributing to developing early connections to the environment and a sense of stewardship. They also support learning by deepening students' understanding of the salmon life cycle and the essential role they play in freshwater and marine ecosystems. The Gitga'at First Nation wrote, "School kids are shown how everything works including harvesting fish and eggs, plus the release of juvenile salmon into waterways" (#I96).

The educational benefits of these programs extend beyond biology lessons. Through public outreach, hatcheries help reinforce the deep cultural significance of salmon for Indigenous communities, and the need to contribute to environmental protections into the future. As Farron McCloud, chairman of the Nisqually Tribe, stated, "This food is vital to us and sharing it is part of our culture. It's also a way to educate people about how important

it is to us and what salmon need to thrive. It takes all of us for that to happen" (#I85). Echoing this, the Stillaguamish wrote, "If we are to have measurable growth in salmon populations, entire communities must shift to new patterns of behavior focused on environmental protection" (#I99).

Hatcheries provide opportunities for Indigenous youth to experience closer contact with salmon, which communities hope can inspire them to pursue careers in fisheries, conservation, and related job fields. Multiple communities described their involvement in internship programs where students can develop skills in data analysis, monitoring and evaluation, scenario planning, water management, and salmon biology and habitat (#I117; #I137).

Beyond school systems, hatcheries also play a role in continuing education programs for folks who are further along in their careers such as fishers, technicians, and managers (#I34; #I37). One community specifically referenced the inclusion of Traditional Ecological Knowledge (TEK) into educational programs (#I24).

Role of Hatcheries Going Forward

Hatcheries were frequently described as an interim solution, necessary to revitalize depressed salmon populations while long-term threats such as habitat degradation and climate change are addressed. Merle Jefferson, director of Lummi Natural Resources, articulated their vision of restoring Lummi fisheries as getting "back to the days our elder fishers reminisce about" (#I75). Many Indigenous nations emphasized that hatcheries alone cannot reverse population declines, but will continue to be a central component of salmon recovery efforts (#I52; #I58; #I87; #I171).

At the same time, there was recognition that hatchery reliance should evolve over time and many examples of instances where Indigenous hatchery programs are innovating and adapting practices (#I111). For example, Billy Frank Jr. stated, "Because every watershed and its salmon are unique, we believe that the use of hatcheries should evolve over time depending on the health of our watersheds" (#I52).

Some nations have already begun shifting hatchery strategies, reducing reliance on non-local stocks and moving toward more localized broodstock to promote natural spawning populations (Table 1, above). Other innovations include sea pen and saltwater rearing methods to better acclimate salmon before release, increasing survival rates (#I15; #I32). The Lummi Nation used a similarly novel technique whereby both freshwater from the Nooksack River and saltwater from Lummi Bay are used at the Lummi Bay Hatchery, which allows culturists to slowly acclimate young salmon to saltwater before release (#I83).

Other programs adjusted release timing to align with key ecological conditions, including the presence of prey species and migration windows; and used more naturalized rearing environments to improve fitness and reduce domestication effects (FFHR; #I139; #I165). The Sun'aq Tribe of Kodiak, for example, used artificial redds and other experimental techniques to replicate natural spawning conditions and enhance genetic resilience in hatchery-reared salmon (#I117).

These efforts are part of a broader effort to rehabilitate salmon populations and their habitats, particularly in the context of climate change (#I166). The impacts of climate change are accelerating, making it clear that habitat restoration alone may not be enough to protect salmon in the coming decades.

Some Indigenous nations argued that hatcheries will be needed as a buffer against extreme environmental conditions that increasingly threaten both wild and hatchery-raised salmon (#I92; #I165). The Nez Perce, for example, wrote, "Rising temperatures have added to these challenges, making this project crucial for the survival of these remarkable fish" (#I92). As natural and hatchery origin salmon both need the same high quality habitat to thrive, this adaptive approach is integral to supporting salmon resilience (#I7). An additional benefit of these programs is that they yield insights that can inform fundamental understanding of salmon biology and hatchery best practices (#I87; #I158; #I171).

Looking ahead to future challenging climate conditions, hatcheries may offer the opportunity to

conserve salmon genetics as 'live gene banks' (#I58). Some hatchery programs, such as the Stillaguamish Tribe's, also provided rescue operations and refuges for salmon facing extreme conditions, moving fish to cooler waters or controlled environments when temperatures became lethal.

However, climate change is also disrupting hatchery operations themselves (#I55; #I165). Rising temperatures and extreme weather events have damaged hatchery infrastructure, reduced water availability, and made broodstock collection more difficult. Russ Ladley, fisheries director for the Puyallup Tribe, described their challenges, saying, "we have now had four of these '50-year flood events' in 5 years" (#I30).

As climate change increasingly threatens both wild and hatchery salmon, Indigenous nations are expanding their role in fisheries management, emphasizing the need for co-management approaches that integrate both Western science and Indigenous knowledge. Existing co-management efforts demonstrate the potential for collaborative strategies, but greater investment is needed to ensure that hatchery programs, habitat restoration, and conservation initiatives are adaptive to changing environmental conditions.

Grey Literature

The narrative passages contained in this literature can be understood through four major periods (Figure 5). As with the Indigenous Public Facing literature, these periods sometimes overlap and represent broad patterns rather than absolute delineations in time. The grey literature focused largely on technical aspects of salmon production and conservation from the Pacific basin (Figure 6).

1. Hatchery Origins and Early Rationale

This period reflects the historical context documented in grey literature sources, where salmon production was initially framed as compensation for habitat loss due to dams and infrastructure projects, rather than as a tool for conservation or ecosystem recovery. Hatchery programs were widely seen as essential for sustaining commercial, recreational, and tribal fisheries, particularly in regions where natural salmon production had been severely constrained by hydropower development (#G24; #G32; #G35).

Many sources from the Pacific Northwest emphasized the role of large-scale dam construction, such as the Landsburg Dam and the lower Snake River dams, as key contributors to habitat loss and fragmentation, which significantly impacted salmon populations (#G24; #G43; #G51; #G58). In response, hatchery programs were implemented both to support fisheries and to facilitate reintroduction efforts by compensating for the loss of access to historical spawning habitat.

In addition to mitigating fishery losses, nutrient transport by hatchery-origin (HOR) fish was cited by some sources as a means of partially countering habitat degradation, either through natural spawning or human-assisted carcass placement to enrich inland ecosystems (#G24, #G45, #G72).

However, a document from the United States' National Marine Fisheries Service (NMFS) challenged this rationale, arguing that hatchery fish cannot truly replace lost habitat or the natural populations that rely on it, and that mitigation strategies centered on hatcheries do not align with contemporary conservation principles (#G34). The same source also noted that while fishways have improved passage for certain species, the decline of economically important salmonid populations has thus far largely been addressed through stocking programs rather than habitat restoration (#G34).

Figure 5. Periods described in Grey Literature.

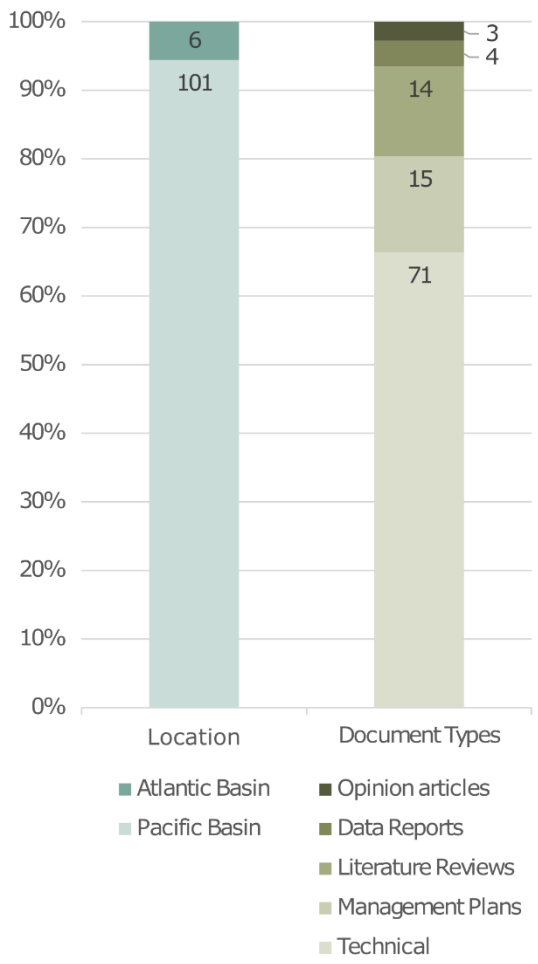


Figure 6. Composition of Grey Literature.

2. Emerging Concerns and Scientific Advances

Over time, concern about unintended consequences led to increased scientific efforts (metrics, studies, data) to address or understand those consequences (e.g., ecological interactions, genetics, fish health) (#G18; #G24; #G34; #G42).

Discussions of problems associated with enhancement programs often occurred alongside considerations of best management practices, with an implicit assertion that past hatchery issues resulted from poor practices and a lack of knowledge; in other words, that problems with stocking can now be mitigated through improved understanding of salmonid biology and ecology (#G13; #G24; #G34). Effective marking programs became widely recognized as essential for collecting management and evaluation data as a way to facilitate mark-selective fisheries and enabling controlled broodstock selection (#G3; #G45; #G79).

However, there was not a uniform approach to responding to these concerns. For example, the choice of approach to broodstock collection varied by program objective, with some prioritizing wild stock to minimize genetic divergence in response to emerging concerns about hatchery production, while others focused on larger fish or higher egg numbers to maximize fishery production (#G5; #G23; #G26 #G39).

Hatchery rearing and release strategies were commonly examined for ways that they could be optimized to identify the most suitable practices. In some cases, enhancement programs acknowledged the need to limit interactions between HOR and natural-origin (NOR) fish, addressing concerns like straying and competition for food resources (#G24).

Additionally, authors noted the importance of coordinating hatchery operations with hydropower dam management, given that juvenile out-migration depends on downstream flow, a factor increasingly impacted by climate change (e.g., shifting precipitation patterns and lower freshet levels) (#G22; #G31; #G55). Finally, multiple sources stressed the need to integrate disease management into broader salmon management plans to maintain population health and sustainability (#G26).

Ecological Concerns

As hatchery programs became more sophisticated and data-driven in their management, attention expanded beyond their immediate role in fisheries management to their broader ecological effects and interactions with their surrounding ecosystems. The most common focus in the literature was the abundance of HOR fish, both absolute and relative compared to NOR fish (#G1; #G5). The main takeaway from these sources was that the relative abundance of HOR fish varies from very low to very high based on the river basin being discussed. There were also suggested methods for balancing HOR and NOR abundances. For example, #G45 described appropriate actions for managing salmon

populations in different situations based on a range of criteria. It also discussed most of the issues highlighted in other documents (competition, displacement, disease, spawning).

Interactions of hatchery-origin (HOR) fish with other species in the ecosystem largely fell into three categories. The first and most common category was interactions between HOR fish and natural-origin (NOR) fish of the same species, in both freshwater and marine environments. These interactions were often described as being negative for NOR fish, with impacts including competition for habitat and food resources (#G7; #G35; G69; G96), increased prevalence of disease and parasites (#G7; #G26; #G75), and predation by HOR fish on NOR fish, in part due to the larger size of HOR fish at release (#G24; #G27; #G69; #G75).

It should be noted that many of these references were generalized comments in management plans or literature reviews which cited previous work. The role of predators in this dynamic was also debated - one document proposed that in some cases, HOR fish buffer NOR fish from predation by providing an alternative food source, while in others the presence of HOR fish may attract more predators to the system (#G37).

The second category of interactions involved HOR fish and other salmonid species (either different species from the HOR fish in question or salmonids in general). Similar to within-species interactions, competition for food and inter-species predation (both as predator and prey, depending on species and year class) were frequently discussed (#G1; #G24; #G27; #G37; #G62). Notably, some documents pointed out higher abundances of HOR fish in even-numbered years, which coincided with lower numbers of pink salmon in the ocean, potentially influencing competitive dynamics (#G1). Disease and parasite transmission were again mentioned, as was the idea that HOR fish may either buffer other species against predation or attract more predators, depending on the context.

The third category of interactions, which was discussed less frequently, involved HOR fish and non-salmonid species. These studies mainly focused on predation on juvenile HOR fish by other fish species and birds, as their smaller size at early life stages made them particularly vulnerable (#G34). Some documents also noted predation by HOR fish on non-salmonid species, though this was mentioned less often (#G34; #G54).

Genetic Concerns and Fish Health

HOR fish have also raised concerns about genetic integrity and fish health in wild populations. The scientific concerns related to genetics included long-term effects on genetic diversity, disease transmission, and overall population fitness (#G34; #G43).

Several documents provided quantitative data related to hatchery fish including absolute or relative (to NOR fish) abundance, freshwater survival and smolt-to-adult return (SAR) metrics (#G18; #G24; #G42). The abundance data is discussed in the ecosystem interactions section, but it affects freshwater survival and SAR metrics which are dealt with in this section. While these were mainly from state or federal government agencies which are mandated to collect and disseminate this information, a few were from Indigenous groups which have a role as co-managers (e.g., #G1).

A summary of different genetic effects of hatchery production is outlined in the ESA Recovery plan for Columbia River salmon (#G32) and includes loss of within-population diversity and genetic drift, outbreeding effects such as homogenisation and loss of fitness (lower disease resistance, lower ability to avoid predators, etc.), and domestication effects (e.g., changes in selection of fish size, timing of spawning, growth rate, and feeding behaviors, relaxation of selection (ability to choose mates).

Some authors emphasized that genetic effects can persist for long periods, underscoring the importance of considering long-term consequences in hatchery management decisions (#G34).

Along with deliberate introduction of non-native fish, straying of hatchery fish into basins where they are not native and subsequent spawning with native fish was also noted as a contributory factor affecting population genetics (#G24). The use of broodstock maintained in hatchery environments for long periods was also suggested to contribute to domestication effects, reducing genetic diversity and fitness and greater use of integrated programs

was suggested as a remedy to this problem (#G24; G#32).

Several documents also discussed the use of quantitative metrics, such as proportion of hatchery-origin spawners (pHOS) and proportionate natural influence (PNI), to maintain genetic impacts at acceptable levels (#G18; #G24; #G42). Thresholds for these metrics can be used as targets for sustaining wild populations as well as for harvest related decisions.

Discussions about fish health concerns focused on the prevalence and management of diseases such as bacterial kidney disease (BKD), infectious hematopoietic necrosis (IHN), and myxosporean parasites (#G26; #G45; #G68; #G77). Studies compared disease occurrence in hatchery and wild populations, raising concerns about potential disease transmission from hatchery fish to wild populations (#G37).

It should be noted that these diseases originated in the natural environment and eventually spread into the hatchery environment. Therefore, care must also be taken to manage the transmission of disease from natural environments to hatcheries (#G26). Some documents also raised climate change considerations, noting that rising water temperatures could increase disease severity in salmon (#G24).

Another commonly studied topic was differences in migration timing and spatial distribution between HOR and NOR fish (#G7; #G31). HOR fish, typically released in large batches, out-migrate in a short, synchronized pulse, whereas NOR fish out-migrate gradually based on individual growth and maturation rates (#G37; #G96). In contrast, the National Marine Fisheries Service suggested that differences in spatial and temporal distribution in the ocean environment are likely to be smaller than those observed in freshwater and estuarine environments, where hatchery and wild fish exhibit more pronounced differences in migration timing and habitat use (#G33).

The literature presented conflicting results regarding the relative survival rates of HOR and NOR fish (#G37). Some studies found lower reproductive success for HOR fish (#G26), while others found similar or even higher success rates (#G28; #G43). Faster growth and smoltification in hatchery fish due to controlled environments (e.g., regular feeding, absence of predators, and disease management) may confer a temporary survival advantage at out-migration, but HOR fish also experience higher post-release mortality as they adjust to the natural environment (#G8; #G9; #G99). A report by the Nez Perce Tribe suggested that the survival advantage of HOR fish weakens over time as they struggle to develop natural feeding and predator-avoidance behaviors (#G31).

Some studies linked hatchery practices to fish health and fitness concerns, noting that certain disease management strategies could unintentionally weaken natural resistance. For example, the culling of bacterial kidney disease (BKD)-positive females and the destruction of their eggs in hatcheries could reduce the prevalence of naturally disease-resistant populations (#G26; #G32). Broader concerns were raised about the loss of locally adapted populations, which may have been best suited to specific environmental conditions and therefore more productive in the long run (#G32).

Overall, the grey literature suggests that because hatchery genetic and fitness effects co-occur alongside other factors which impact salmon populations, it may be difficult to ascribe outcomes solely to hatchery impacts.

3. Refinement and Current Practices

The response to concerns about the negative effects of hatcheries has resulted in the growth of ideas and studies of hatchery reform, which refers to contemporary hatchery methods (e.g., integrated vs. segregated broodstock, advanced disease management, coordinated research) that seek to alter hatchery operations to mitigate these impacts. They also demonstrate efforts to balance production with conservation, while acknowledging ecosystem complexities and genetic health.

Current Management, Infrastructure, and Operations

A predominant focus in the grey literature was the interrelation between the management of hatchery programs and fisheries (as is evident when

evaluating the economic aspects). Most discussions of this relationship focused on managing enhancement programs in a manner that maximised fishery production (#G32; #G44; #G63, #G78). Several documents discussed the process of broodstock selection, and the method chosen depends on the aim of the program. For example, preference may be given to wild stock to minimise genetic divergence from the source population or larger fish or greater number of eggs if the aim is to maximise fishery production (#G5). Several documents also discussed the management of integrated vs segregated stocks, a topic which is closely related to broodstock selection (#G24; #G42; #G64).

Shifting Goals to Conservation and Sustainability

Contribution to conservation efforts was an oft-cited benefit of hatchery programs. These are aimed at restoring natural populations and production levels where natural stocks have declined to such an extent that their continued survival is at risk. They incorporate practices such as integrated stock management and selective choice of broodstock that reflect preferred, naturally occurring traits such as run timing. A number of documents also noted that hatcheries are essential for reintroduction programs aimed at restoring extirpated populations, often in basins cut off by dams (#G20; #G24; #G58). In many cases, these are used when efforts to allow salmon to naturally recolonize through straying fail. In some basins, natural populations are so low that hatchery fish are included in the ESU descriptions (#G32).

However, many documents also critiqued the use of hatcheries in conservation efforts. Some provided examples of programs which failed to achieve their goals or where the outcome was unclear (#G11; #G12; #G42; #G49). These documents noted that while hatchery releases may lead to spawning, they may not result in the establishment of naturally adapted populations which are viable in the long-term. They also highlighted that the success of such programs may be context-specific. Other critiques included the narrow focus on one or a few species and the potential for conflict between conservation aims and hatchery production for harvest (#G13; #G45; #G69; #G75).

Benefits of Current Hatchery Operations

Economic. Most discussions of hatcheries' economic importance centred around commercial, sport/recreational, and Tribal/Indigenous fisheries (see also Governance, Rights, and Co-Management below) (#G10; #G13; #G15; #G24). Selective fisheries were often described as an acceptable method of conserving and restoring wild populations while also providing the economic benefits of salmon fisheries (#G32; #G68). These also allow NOR fish to reach their spawning grounds while preventing HOR fish (reduce straying).

A more commonly used method is mark-selective fisheries, which typically rely on the presence or absence of adipose fins to distinguish between hatchery-origin and natural-origin salmon (#G34; #G66). In their fishery and conservation plan for Trinity River coho salmon, the Hoopa Valley Tribe discussed the economic importance of fishery-adjacent industries such as processing and logistics (#G46).

Similarly, one document mentioned that spending associated with running the hatchery itself has a positive (albeit small) economic impact (#G24). A few documents weighed the cost of running stocking programs against their economic benefits and noted that the costs may outweigh the benefits (#G29, #G49).

Research, Management, Evaluation. An important aspect is the information/data collected indirectly through hatchery management practices such as fin clipping and tagging (CWT, genetic, etc.) (#G37; #G60; #G63). While there are limitations with these approaches (assumption that HOR and NOR are analogues, need to collect heads for CWT analysis, limitations of genetic tagging), they are often the most accurate or even the only method available. The information collected is often related to abundance and survival, which in turn can be used to make conservation and fisheries management (e.g., catch limits) decisions.

Moreover, information gained through hatchery research may aid in understanding fundamental aspects of salmonid biology and ecology (#G66;

#G68; #G91). It was argued that HOR fish can be used to assess the feasibility of reintroduction or re-naturalisation programs (#G49; #G55). This contrasts with the alternative, which is to allow this process to occur naturally through straying. The data collected informs management decisions related to both HOR and NOR fish (#G10; #G14; #G21; #G51). The inference (implicit or explicit) is that in the absence of this data may have negative consequences for management of the fishery resource.

The other commonly discussed role in research relates to the use of hatchery fish in field or controlled experiments where they were used as analogues or substitutes for NOR fish and to study aspects of fish biology and ecology, where it is not possible to use NOR fish (#G2; #G17; #G24; #G68). This can be especially important where the NOR fish are listed under endangered species legislation, and it is not possible to conduct experiments on NOR fish. It was also noted that hatchery staff have substantial technical expertise, which can be utilised in the conservation and management of NOR populations (#G52).

Education and Learning. This category of benefits was the least frequently discussed among the documents that were studied and was driven by state and federal government agencies. There were brief references to hatcheries providing an opportunity for community outreach and educational opportunities across a wide spectrum of age groups ranging from students in school to those in tertiary education (#G24; #G75).

Food, social, and cultural value. While the catch from both types of fisheries is consumed as food, the documents made a clear distinction between sport and recreational versus personal use and subsistence fisheries (#G6; #G88). A technical report by Alaska Department of Fish and Games characterized the scale of subsistence fisheries as much smaller than commercial and recreational fisheries (#G21). Salmon, including those from hatcheries, have enormous cultural value and are an integral component of many Indigenous groups' identity (#G24; #G34; #G41; #G49). This cultural importance is not limited to Indigenous groups alone, and it was noted that many non-Indigenous communities also have cultural affinity for salmon, even though the dataset lacked references to concrete examples (#G29).

4. Future Outlook and Debates

In their framing of the future, sources in the grey literature dataset contained several open-ended questions pertaining to unresolved controversies, how hatcheries might adapt to climate change, the potential for co-management to shape the future, and the long-term viability of hatcheries. These discussions addressed both ecological and governance considerations, underscoring the need for interdisciplinary approaches and collaboration in hatchery management moving forward.

Climate Adaptation

Some suggested that salmonids have an inherent adaptability, particularly steelhead, that may enable them to adjust to climate change by seeking out suitable habitat (#G20; #G33). In some cases, this may potentially lead to range expansion of some populations into the Arctic. However, climate change may also affect broodstock availability and create selection pressure for later-run fish, influencing population dynamics over time (#G57).

As environmental conditions shift, hatchery practices may need to evolve to mitigate climate-related impacts. One proposed approach is the concept of 'live gene banks', where hatcheries preserve genetic diversity by maintaining captive populations of locally adapted fish (#G97). These programs serve as a climate adaptation tool, allowing for reintroductions in the event of extirpation and ensuring that populations retain genetic traits suited to changing environmental conditions. T

here were also documented cases where hatcheries have been used to expand salmon habitat or provide access to previously inaccessible areas (#G84). In the future, monitoring tools like thermal marking may become increasingly important for tracking fish survival, migration, and reproduction. This data will help adjust hatchery practices and support informed management decisions (#G30).

Additionally, hatcheries may be used to shield fish from certain climate-related stressors (e.g., increased peak flows and sedimentation) that

would otherwise impact salmon populations (#G24). Lastly, hatchery production has already been scaled up in some cases in response to climate-driven mortality events, such as drought-induced high water temperatures, to compensate for declines in natural reproduction (#G33).

Assessing Long-term Sustainability

Many authors emphasized that hatchery programs should be used alongside other conservation measures to achieve the best long-term outcomes (#G11; #G55; #G84; #G103). While enhancement programs can help sustain populations in the short to medium term, the NMFS argued that these programs should complement broader efforts to address habitat degradation and ensure the long-term stability of wild populations (#G34). Some documents also examined the sustainability of hatchery operations themselves, focusing on excessive water use (both surface and groundwater) and the effects of effluent discharge on aquatic ecosystems (#G24; #G45).

Two documents highlighted a unique conservation role for hatcheries - releasing Chinook juveniles to increase prey availability for Southern Resident Killer Whales, demonstrating how hatchery practices may have ecological benefits beyond salmon populations (#G24; #G37). Other sustainability concerns included the need to balance fishery harvest levels to ensure sufficient escapement and the long-term recovery of wild populations (#G34).

Some documents suggested that achieving sustainability goals may require adjustments in hatchery management practices and harvest regulations to prevent overreliance on artificial production (#G13; #G45; #G69; #G75).

Governance, Rights, and Co-Management

Over the last century, governance and management of natural resources in North America has relied heavily on Western scientific knowledge, primarily produced by federal and state/provincial governments and academic institutions.

Unsurprisingly, such knowledge constitutes a substantial proportion of the documents analysed. However, sources including Several documents noted the federal government's treaty obligations to ensure that Indigenous groups have access to fishery resources and that these resources be sufficiently abundant (#G24; #G35; #G41; #G42).

While references to traditional Indigenous knowledge were not frequent in the grey literature, the monitoring plan for hatchery-produced spring Chinook in the Grande Ronde Basin highlighted the use of TEK in understanding salmonid ecology and its incorporation into management (#G64). Notably, multiple documents acknowledged the contributions of Indigenous groups beyond just data collection roles (e.g., fish enumeration, carcass surveys) (#G23; #G67; #G82; #G88).

Several documents highlighted federal treaty obligations to ensure that Indigenous groups have access to fishery resources and that these resources remain abundant (#G24; #G35; #G42). Indigenous groups emphasized their inherent governance rights over their traditional territories, with one document - an environmental assessment of Lake Washington Basin Hatcheries - by the NMFS clearly outlining the unique legal status of Tribal rights in the U.S. compared to other entities (#G24).

The role of Indigenous groups as co-managers of fishery resources was frequently asserted by Indigenous groups and acknowledged by federal government agencies (#G28; #G31; #G35; #G41). However, some documents noted inconsistencies between federal legislation and administrative actions, and Indigenous rights, emphasizing the need for greater cooperation and knowledge co-production (#G49; #G72).

Summary

Our investigation of grey and IPF literature highlighted that the population-level genetic impact of hatchery programs is just one among several factors that need to be considered in the assessment of the role of hatchery programs in sustaining salmon populations. These factors go beyond biological and ecological aspects and include the diverse relationships between salmon and humans. These relationships consist of various facets including nutritional and cultural value, contributions to social and community identities, economic importance, intergenerational knowledge transfer, education and professional development, and as a pillar of Indigenous sovereignty.

Along with the significant ecological and social impacts, the decline in salmon populations is intertwined with the complex history of relationships between Indigenous and settler societies. Within these aspects, we also noted ideas of agreement and dissonance between grey literature and IPF, as well as novel ideas in the IPF which were not observed in the grey literature.

Areas of Agreement or Alignment

Hatcheries have a role in restoring salmon populations

Both acknowledge that the use of hatcheries has impacted the health of salmon populations through a range of mechanisms (genetic, competition for resources, disease proliferation, etc.). Both sets of literature also recognized that in some (according to grey literature) or many (according to IPF) cases, the present state of salmon populations and habitat preclude the natural recovery of abundant salmon populations. Besides these environmental constraints, the existing socio-economic, political, and legal conditions may not allow for recovery to occur through purely natural means. Therefore, achieving both short- and long-term goals may require the use of hatcheries to sustain and rebuild populations. In other words, while hatcheries are not a panacea, they have an important role to play in salmon recovery. Both datasets also noted that the use of hatcheries should be one component among a suite of tools used. This is also a clear departure from the genetics focused narrative commonly seen in the peer-reviewed literature.

Programs need to be tailored to local contexts

The grey literature dataset contained several subsets of documents which each examined a similar parameter (e.g., reproductive success) across different regions or timeframes. We also noted that for many of these parameters the results from these studies diverged meaningfully from each other.

While the analysis of the validity of these findings is beyond the scope of the present study (and the expertise of the authors), the wide variations indicate that each ecosystem contains unique and complex sets of drivers such as climate, topography, human impacts, etc. which preclude the derivation of generalized conclusions about the impacts of hatchery programs. Therefore, it may be advisable to incorporate the specific characteristics of each system into conservation or fisheries management plans. This idea was also explicitly mentioned in an NMFS guidance document (#G35).

Similar views were also evident in the IPF as various Indigenous groups described the bespoke management strategies being employed in their respective territories. Many groups also highlighted their research priorities, which also varied widely.

Treaty and Inherent Rights.

Both sets of literature highlighted the complex history of Indigenous-settler relationships and their effects on natural resource management in the present day. While the language and tone used in the two datasets was notably different, each acknowledged that Indigenous peoples have inherent rights to access fisheries resources, some of which are protected also by (historical or modern) treaties, where they exist.

Both sets of documents also described the complex histories of how Indigenous groups in both Canada and the US reclaimed these rights through arduous, and often fraught, legal proceedings. In addition, IPF also highlighted that Indigenous groups'

inherent governance rights to these resources go beyond those set out in the legal jurisprudence of settler systems of governance.

The settlement of the lands now known as Canada and the US by European settlers ultimately resulted in large declines in salmon populations in many river basins, which placed limits on the amount of fish that can be harvested. The use of hatcheries to support overall populations, and to provide fish specifically for harvest has allowed many Indigenous groups to harvest salmon in sufficient quantities to sustain food, social and ceremonial (FSC) and commercial uses. Therefore, hatcheries play a crucial role in upholding Indigenous rights and act as symbols of Indigenous sovereignty.

Differences and Areas of Tension

Spatial and temporal boundaries

The two sets of documents assessed or described the health of salmon populations at different geographic scales. The grey literature documents covered a wide range of geographical contexts from individual rivers to entire river basins and large swathes of marine ecosystems.

In contrast, the IPF was more narrowly focused on the traditional territories of the Indigenous group(s) who authored these documents. This is not entirely unexpected, given that the mandates of settler governments typically extend over much larger geographical areas than the traditional territories of each Indigenous group.

However, the reverse was typically true with respect to temporal boundaries. The technical studies in grey literature often lasted a single year or a few years while management plans and reviews typically had time horizons of at most a few decades. In comparison, the IPF described salmon-human relationships, and abundance of salmon populations over hundreds or thousands of years. Similarly, they also highlighted the need to sustain these intricate connections for generations in the long-term future.

It was also interesting to note that the grey literature authors were predominantly fisheries resource managers. Although not strictly necessary, it is likely that the spatial and temporal boundaries described in these documents align with the priorities and positions of the authors. This highlights a potential aspect of divergence from the geographic and temporal scales used by Indigenous peoples to evaluate the success or failure of enhancement programs.

Causes of salmon decline

While the IPF documents in the dataset acknowledged the adverse impacts of hatcheries on salmon genetics over the preceding decades, they viewed it as a minor or contributory factor. They instead highlighted that the main causes of declining salmon populations in the past were the loss, degradation, and fragmentation of salmon spawning and rearing habitat caused by European settlement such as infrastructure development (notably hydropower) and land use changes.

These documents also noted that the major threats confronting salmon populations were unavailability of suitable, continuous habitat and climate change while also strongly emphasising that salmon recovery cannot be achieved without addressing these root causes of their decline. Until this becomes a reasonable prospect, hatcheries must be strategically managed, continuously improved, and adapted to the realities of climate change.

On the other hand, the grey literature viewed habitat loss as just one among a range of stressors afflicting salmon populations. While not explicitly stated, the widespread discussion of genetic impacts, technical studies to evaluate these effects, and the use of management plans to address this problem indicates that genetic impacts were considered by the grey literature authors to represent a major threat to salmon recovery.

Topical focus

While some of the grey literature documents provided socio-economic, legal, and cultural context relevant to the ecosystem(s) being studied, the focus tended to be on the biological and ecological conditions of the system, which was largely presented as technical information. When evidence related to hatchery and natural origin fish were presented in the same document, the emphasis was often on the differences.

On the other hand, the IPF focused more on the cultural, nutritional, legal, and socio-economic

considerations related to the use of hatcheries. When comparisons were made between hatchery and natural origin fish, the emphasis was typically on the similarities between them and evidenced by the nutritional, social, cultural, economic, and ecological benefits provided by salmon, regardless of their origin. While not always stated explicitly, these documents implied that if enhancement programs were to be eliminated, this entire suite of benefits would be lost.

Definitions of success

In keeping with the topical focus of the documents, the grey literature dataset defined the success of enhancement programs mainly through genetics or ecological lenses and in a few cases through economic ones related to the availability of fish for harvest. The IPF instead more often described the success of salmon recovery in terms of the maintenance of salmon-human relationships, the preservation of salmon-related Indigenous cultures and spiritual connections, and the continued existence of these relationships, cultures, and spirituality among future generations.

Within these discussions, we also detected an implicit argument that enhancement programs have historically been evaluated through narrowly focused lenses which do not fully account for the intangible benefits associated with salmon and the interconnected nature of non-economic values.

While both datasets articulated the long-term goals as creating conditions where salmon populations can sustain themselves without human intervention, many IPF documents indicated that this would entail achieving population sizes which mirror pre-colonisation abundance. This differs from the grey literature, which largely aimed to restore population levels to those seen in the more recent past.

Human-salmon relationship becoming fragile. While both sets of data described salmon as being strong and adaptable to changing environmental conditions, the IPF introduced another facet related to the human-salmon relationship. As populations decline and salmon respond to habitat degradation and global climate change by shifting their natural ranges, the physical space for human-salmon interactions is changing. As the traditional territories (and reservations based on colonial systems of government) are static, many Indigenous groups expressed concern that they may not be able to interact with and harvest salmon in the future resulting in the previously strong human-salmon bonds becoming fragile and tenuous.

Salmon as being worthy of care. As noted earlier, the IPF highlighted the deep connections between human communities and salmon, which resulted in relationships of care and respect. By frequently placing the needs of salmon at an equal or higher level than themselves, Indigenous communities have demonstrated this care beyond the mandates set out by settler governments. Correspondingly, Indigenous groups also referred to hatcheries using language which indicated that these facilities were viewed as sites where this care is expressed, biodiversity is prioritized, innovative rearing practices are cultivated, and traditional stewardship is centered.

In contrast, the grey literature often described them as production facilities using language that may be appropriate when referring to industrial or clinical contexts.

Co-management as a way forward

The Indigenous literature provided extensive background on the evolution of co-management in fisheries management and salmon recovery. They also highlighted several issues such as imbalances in jurisdictional authority, vast disparity between the financial and administrative resources of Indigenous and settler governments, and negative perceptions of hatcheries among the public which undermines their legitimacy. At the same time, these examples highlighted that co-management can more equitably align governance rights compared to the administrative structures of the past, especially given the constraints of the current social and political milieu.

The documents studied also highlighted that co-management approaches may allow for the reclamation of Indigenous sovereignty in an environment where settler management approaches are still dominant. Therefore, while co-management is an important step forward, it is still in its formative stages.

Policy Implications

The grey literature often lacked the historical, cultural, and socio-political context that frame how programs operate. Indigenous public-facing and community-centric literature contains important narrative strands that can fill these gaps.

The bodies of evidence reviewed provided rich historical, socio-political, and legal context of the evolution of human-salmon relationships and Indigenous-settler relationships as seen through the prism of salmon fisheries and conservation.

While this dataset barely scratched the surface of these complex issues, it helped to contextualize the contentious topic of salmon enhancement through the words of the Indigenous communities whose lives are intertwined with the health of salmon populations. As much of this contextual information is largely absent in the peer-reviewed literature, Indigenous public-facing (and other community-centric) literature and grey literature can offer important narrative strands that can fill the gaps.

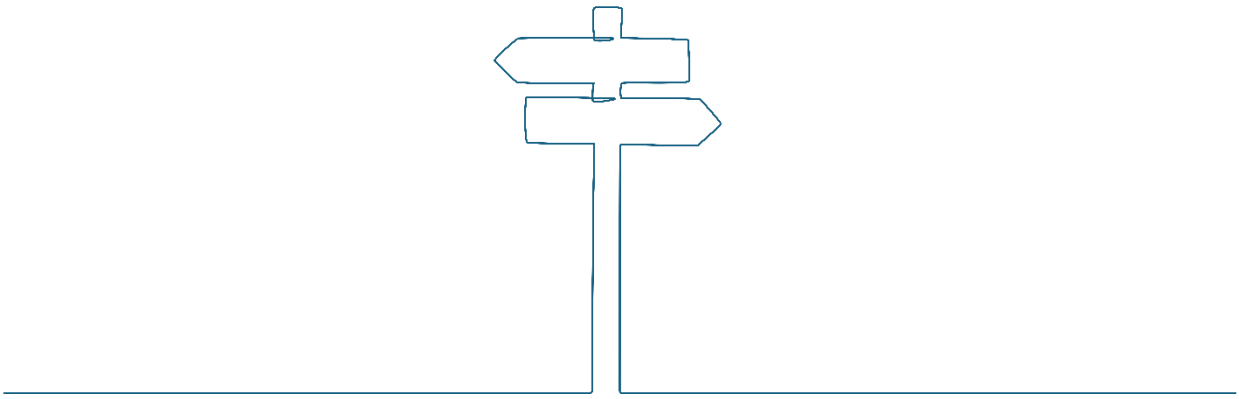
The design and assessment of hatchery programs should consider social and cultural evidence with the same attention given to ecological, genetic, and economic considerations.

Hatchery programs need to navigate competing priorities, including biological, genetic, and ecological factors, as well as those related to salmon-human relationships, such as social, cultural, legal and economic aspects.

The design of salmon enhancement programs and assessments of their efficacy need to incorporate each of these factors.

Meaningful co-management as a pathway for salmon stewardship has support from many Indigenous communities. However, imbalances in jurisdictional authority and administrative and financial resources need to be addressed to fully realise the value of this approach.

The Indigenous public facing literature noted that co-management as a governance structure for salmon stewardship has the support of many Indigenous communities.



However, the evidence also highlighted that these communities face a variety of encumbrances, such as imbalances in jurisdictional authority and scarcity of the administrative and financial resources needed to perform as equals alongside settler governments. These disparities need to be addressed to fully realise the value of this approach.

Allocate additional resources to support Indigenous research priorities on anadromous salmonid conservation to improve understanding of their biology and their role in social and ecological systems.

Indigenous groups have made substantial contributions to advancing anadromous salmonid conservation research and management. The deployment of additional resources to further support Indigenous research priorities will help improve understanding of salmonid biology and role in social and ecological systems, and inform better decision-making about methods for fish culture, while also supporting Indigenous sovereignty.

Hatchery discussions reflect diverse perspectives shaped by differing values and interpretations of risk. Hatchery decision-making should focus on reconciling competing values and risk perceptions through inclusive, deliberative, and interdisciplinary processes.

Debates about hatchery use are shaped not only by biological and ecological considerations but also by underlying values and risk perceptions. Some emphasize the need to balance benefits and impacts, viewing hatcheries as essential tools, while others highlight concerns about adverse effects, such as genetic risks, which may be estimated to have greater or lesser magnitude or long-term importance.

These perspectives reflect broader differences in how risks are framed and balanced, making it unlikely that disputes will be resolved through technical assessments alone. Alongside technical aspects of hatcheries and stocking, decision-makers should focus on reconciling these sometimes conflicting sets of values and risk perceptions through inclusive, deliberative, and interdisciplinary processes.

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Appendix 1. Grey Literature Search Strings

Table 1. Grey literature search strings – natural science themes

#	Search String	Theme
NS1	pacific salmon|atlantic salmon|masu salmon|salmon|brown trout|steelhead|cutthroat|sea trout|seatrout|stock|hatch|cultivate|sea ranch|enhance|selection|fitness|heritability|"relative reproductive success" -Aquaculture AND -Farming filetype:pdf	Genetic
NS2	pacific salmon|atlantic salmon|masu salmon|salmon|brown trout|steelhead|cutthroat|sea trout|seatrout|stock|hatch|cultivate|sea ranch|enhance|compensatory|genetic|epigenetic|introgression|domestication|plasticity -Aquaculture AND -Farming filetype:pdf	Genetic
NS3	pacific salmon|atlantic salmon|masu salmon|salmon|brown trout|steelhead|cutthroat|sea trout|seatrout|stock|hatch|cultivate|sea ranch|enhance|"proportionate natural influence"|tradeoff|"norm of reaction"|trait -Aquaculture AND -Farming filetype:pdf	Genetic
NS4	pacific salmon|atlantic salmon|masu salmon|salmon|brown trout|steelhead|cutthroat|sea trout|seatrout|stock|hatch|cultivate|sea ranch|enhance|ecology|trophic|food web|habitat|migrate|spawn|stray|homing -Aquaculture AND -Farming filetype:pdf	Bio-Ecological
NS5	pacific salmon|atlantic salmon|masu salmon|salmon|brown trout|steelhead|cutthroat|sea trout|seatrout|stock|hatch|cultivate|sea ranch|enhance|imprint|distribution|abundance|compete|diversity|survival|interaction -Aquaculture AND -Farming filetype:pdf	Bio-Ecological
NS6	pacific salmon|atlantic salmon|masu salmon|salmon|brown trout|steelhead|cutthroat|sea trout|seatrout|stock|hatch|cultivate|sea ranch|enhance|conservation|extirpation|extinction|risk|benefit|reintroduce|success -Aquaculture AND -Farming filetype:pdf	Management
NS7	pacific salmon|atlantic salmon|masu salmon|salmon|brown trout|steelhead|cutthroat|sea trout|seatrout|stock|hatch|cultivate|sea ranch|enhance|temperature|warming|climate|"thermal limit"|stress|tolerance|interaction -Aquaculture AND -Farming filetype:pdf	Climate
NS8	pacific salmon|atlantic salmon|masu salmon|salmon|brown trout|steelhead|cutthroat|sea trout|seatrout|stock|hatch|cultivate|sea ranch|enhance|pathology|disease -Aquaculture AND -Farming filetype:pdf	Fish Health

Table 2. Grey literature search strings – social science themes

Name	Search String	Theme
SS1	pacific salmon|atlantic salmon|masu salmon|salmon|brown trout|steelhead|cutthroat|sea trout|seatrout|stock|hatch|cultivate|sea ranch|enhance|"human dimensions"|perception|human|community|anthropology -Aquaculture AND -Farming filetype:pdf	Social, Human dimension
SS2	pacific salmon|atlantic salmon|masu salmon|salmon|brown trout|steelhead|cutthroat|sea trout|seatrout|stock|hatch|cultivate|sea ranch|enhance|anthropocene|social|subsistence|food|beliefs|identity -Aquaculture AND -Farming filetype:pdf	Social, Human dimension
SS3	pacific salmon|atlantic salmon|masu salmon|salmon|brown trout|steelhead|cutthroat|sea trout|seatrout|stock|hatch|cultivate|sea ranch|enhance|policy|politics|governance|management|economy|conservation -Aquaculture AND -Farming filetype:pdf	Political, Economic
SS4	pacific salmon|atlantic salmon|masu salmon|salmon|brown trout|steelhead|cutthroat|sea trout|seatrout|stock|hatch|cultivate|sea ranch|enhance|conflict|wild|recreational|fisher|commercial -Aquaculture AND -Farming filetype:pdf	Political, Economic
SS5	pacific salmon|atlantic salmon|masu salmon|salmon|brown trout|steelhead|cutthroat|sea trout|seatrout|stock|hatch|cultivate|sea ranch|enhance| Indigenous|"traditional ecological"|"local ecological" -Aquaculture AND -Farming filetype:pdf	Indigenous perspective
SS6	pacific salmon|atlantic salmon|masu salmon|salmon|brown trout|steelhead|cutthroat|sea trout|seatrout|stock|hatch|cultivate|sea ranch|enhance|"LEK"|"IEK"|knowledge|cultural|traditional|worldview -Aquaculture AND -Farming filetype:pdf	Indigenous perspective

Appendix 2. Source Document IDs

Table 1. Bibliographic Information – Indigenous Public Facing Literature

ID	Document Title	Author Name
I1	Coquille Indian Tribe - 2022 fall Chinook salmon run	Coquille Indian Tribe
I2	Colville Tribes - Annual Activities Work Plan	Confederated Tribes of the Colville Reservation
I3	Spokane Tribal Fisheries - Anadramous	Spokane Tribe of Indians
I4	Colville Tribes - Annual Program Review	Confederated Tribes of the Colville Reservation
I5	Abegweit Hatchery - Fish Facts - Atlantic Salmon	Abegweit First Nation
I6	Being Frank: Federal funding supports tribal hatcheries that...	Northwest Treaty Tribes
I7	Being Frank: Habitat, Hatcheries Equal Fishing	Northwest Treaty Tribes
I8	Being Frank: Hatcheries Bridge Gap Between Habitat, Harvest	Northwest Treaty Tribes
I9	Being Frank: Hatchery Fish Are Treaty Fish	Northwest Treaty Tribes
I10	Being Frank: Hatchery salmon hold the ecosystem together	Northwest Treaty Tribes
I11	Being Frank: Washington fisheries are managed using a conservation...	Northwest Treaty Tribes
I12	Salmon Defense - Billy Frank Jr. Salmon Coalition	Salmon Defense
I13	Abegweit Hatchery - Biodiversity	Abegweit First Nation
I14	Okanagan Nation Alliance - kɬ cp̓alk̓stim̓ Hatchery Broodstock	Okanagan Nation Alliance
I15	Can Tribal Hatcheries Help Feed Southern Resident Orcas?	Northwest Treaty Tribes
I16	Abegweit Hatchery - Caring About Our Environment	Abegweit First Nation
I17	Colville Tribes - Chief Joseph Hatchery	Confederated Tribes of the Colville Reservation
I18	CRITFC - Clearwater River Coho	Columbia River Inter-Tribal Fish Commission
I19	Tribal Restoration Plan - Costs of Implementation	Columbia River Inter-Tribal Fish Commission
I20	Tribal Restoration Plan - CRFMP (Institutional Recommend 2)	Columbia River Inter-Tribal Fish Commission
I21	Umatilla Indian Reservation - Fisheries	Confederated Tribes of the Umatilla Indian Reservation
I22	Quileute Tribe - Cultural Resources	Quileute Tribe
I23	Abegweit Hatchery - Derby Fish	Abegweit First Nation
I24	Abegweit Hatchery - Education	Abegweit First Nation
I25	Abegweit Hatchery - Enhancement	Abegweit First Nation
I26	Tribal Restoration Plan - Evolutionarily Significant Unit	Columbia River Inter-Tribal Fish Commission
I27	Tribal Restoration Plan - Executive Summary	Columbia River Inter-Tribal Fish Commission
I28	Fall chinook continue to set records on the Snake River	Columbia River Inter-Tribal Fish Commission
I29	Abegweit Hatchery – FAQs	Abegweit First Nation
I30	February Floods Cause Loss of Young Coho in Tribal Hatcheries	Northwest Treaty Tribes
I31	Live Gene Bank Salmon Releases – October 27th to 31st	Fort Folly First Nation
I32	First Marine-Based Wild Atlantic Salmon Conservation Farm Site	Fort Folly First Nation
I33	Abegweit Hatchery - Fish Facts	Abegweit First Nation
I34	NWIFC - Fish Health Program	Northwest Indian Fisheries Commission
I35	Muckleshoot Indian Tribe - Fish Production Program	Muckleshoot Indian Tribe
I36	Abegweit Hatchery - Fish Stocking	Abegweit First Nation
I37	Warm Springs - About Fisheries	Confederated Tribes of the Warm Springs
I38	Simpcw Fisheries - Dunn Creek Hatchery	Simpcw First Nation
I39	Cowichan Tribes - 2022 Food Fish Harvest & Distribution Notice	Cowichan Tribes
I40	Cowichan Tribes - Cowichan Fish Hatchery	Cowichan Tribes
I41	Quinault Indian Nation - Fisheries Department	Quinault Indian Nation
I42	Quileute Tribe - Fisheries management	Quileute Tribe
I43	Stillaguamish Tribe - Fisheries Program	Stillaguamish Tribe
I44	CRITFC - Fisheries Timeline - Chronology of tribal fishing and fishing...	Columbia River Inter-Tribal Fish Commission
I45	UCUT - Frequently Asked Questions – Salmon Reintroduction Upstream...	Upper Columbia United Tribes
I46	From Fishing Wars to Alcatraz, Ramona Bennett Shares Stories for...	Puyallup Tribe
I47	Tribal Restoration Plan - Genetic Considerations	Columbia River Inter-Tribal Fish Commission
I48	NWIFC – Genetics	Northwest Indian Fisheries Commission
I49	CRITFC - Hagerman Genetics Laboratory	Columbia River Inter-Tribal Fish Commission
I50	Okanagan Nation Alliance – Harvest	Okanagan Nation Alliance
I51	Hatcheries Are Necessary Tools	Northwest Treaty Tribes
I52	Hatcheries Critical to Salmon Management	Northwest Treaty Tribes
I53	Puyallup Tribe - Hatchery Programs	Puyallup Tribe
I54	Hatchery and wild coho in the same boat this year	Northwest Treaty Tribes
I55	Hatchery chinook benefit tribal culture, guide salmon recovery	Northwest Treaty Tribes

I56	Hatchery coho programs looking ahead to a bad year	Northwest Treaty Tribes
I57	Spirit of the Salmon Plan - Hatchery Management	Columbia River Inter-Tribal Fish Commission
I58	Hatchery Movie Misguided, Inaccurate	Northwest Treaty Tribes
I59	Quileute Tribe - Hatchery Operations	Quileute Tribe
I60	Hatchery program no longer has to raise broodstock in captivity	Northwest Treaty Tribes
I61	Hatchery salmon coming back to McAllister Creek	Northwest Treaty Tribes
I62	Quinault Indian Nation - Hatchery Seasonal Projects	Quinault Indian Nation
I63	Coquille Indian Tribe - Healing the Coquille River	Coquille Indian Tribe
I64	Hells Canyon Complex Fisheries Resource Management Plan	Upper Snake River Tribes
I65	Skeetchestn Indian Band - History	Skeetchestn Indian Band
I66	Lower Elwha Klallam Tribe - House of Salmon Fish Hatchery	Lower Elwha Klallam Tribe
I67	In Case You Missed It: Levi George Hatchery 25th Anniversary Event	Yakama Nation
I68	CRITFC - Johnson Creek Summer Chinook	Columbia River Inter-Tribal Fish Commission
I69	Okanagan Nation Alliance - kɬ cp̓ɔlk̓ stim̓ Hatchery	Okanagan Nation Alliance
I70	Okanagan Nation Alliance - kɬ cp̓ɔlk̓ stim̓ Hatchery Lab	Okanagan Nation Alliance
I71	CRITFC - Lookingglass Cr. Spring Chinook	Columbia River Inter-Tribal Fish Commission
I72	Lower Elwha Klallam Tribe hatchery case dismissed	Northwest Treaty Tribes
I73	Lower Elwha Klallam Tribe to decommission old hatchery	Northwest Treaty Tribes
I74	Lower Elwha Klallam Tribe transfers first group of fish to new hatchery	Northwest Treaty Tribes
I75	Lummi Nation harvests hatchery fish, releases natural origin chinook	Northwest Treaty Tribes
I76	Yakama Nation - Mel Sampson Coho Facility	Yakama Nation
I77	CRITFC - Methow Wenatchee R Coho	Columbia River Inter-Tribal Fish Commission
I78	More Hatchery Fish Needed	Northwest Treaty Tribes
I79	CRRC - Nanwalek Salmon Enhancement Project	Chugach Regional Resources Commission
I80	Lummi Nation - Whatcom Waterway Chinook Fishery	Lummi Nation
I81	Lummi Nation - Salmon Enhancement	Lummi Nation
I82	Lummi Nation - Chinook Captive Brood Program	Lummi Nation
I83	Lummi Nation - Lummi Bay Hatchery	Lummi Nation
I84	Lummi Nation - Water Reclamation	Lummi Nation
I85	Neighbors carry home bounty from Nisqually tribal hatchery	Northwest Treaty Tribes
I86	New Hatchery a Blessing	Northwest Treaty Tribes
I87	New science shows that hatcheries rebuild abundant salmon populations	Columbia River Inter-Tribal Fish Commission
I88	“She Who Retraces Her Steps”	Spokane Tribe of Indians
I89	Nez Perce Tribal Program Resurrects Snake River Basin Coho Salmon	Columbia River Inter-Tribal Fish Commission
I90	Nez Perce Tribe Calls for Leadership on Lower Snake River Restoration	Nez Perce Tribe
I91	Hatcheries Saving Salmon and Feeding Orcas	Northwest Treaty Tribes
I92	NPT Begins Construction of Kelt Reconditioning Facility in Idaho	Nez Perce Tribe
I93	Okanagan Nation Alliance - ntytyix Chief Salmon	Okanagan Nation Alliance
I94	Quileute and Puyallup Tribes Keep Hatchery Programs Running	Northwest Treaty Tribes
I95	Steelhead hatchery broodstock and new leadership	Northwest Treaty Tribes
I96	Gitga'at First Nation - Protecting Oceans & Lands While Preserving...	Gitga'at First Nation
I97	Tribal Restoration Plan - Operation and Location of Hatcheries	Columbia River Inter-Tribal Fish Commission
I98	Abegweit Hatchery - Our Story	Abegweit First Nation
I99	Stillaguamish Tribe - Outreach & Education Program	Stillaguamish Tribe
I100	Tribal Restoration Plan - Past Attempts at Restoration	Columbia River Inter-Tribal Fish Commission
I101	Petitcodiac Watershed Fry Releases 2016	Fort Folly First Nation
I102	UCUT - Phase 2 Implementation Plan (P2IP): Testing Feasibility of...	Upper Columbia United Tribes
I103	Fishery managers call for deeper look at salmon bycatch, but decline...	Kuskokwim River Inter-Tribal Fish Commission
I104	Roundtable discussion focuses on salmon sustainability, culture	Kuskokwim River Inter-Tribal Fish Commission
I105	For Western Alaska’s salmon and its people, survival is on the line	Kuskokwim River Inter-Tribal Fish Commission
I106	Discussion Begins On Guidelines For Producing More Kuskokwim...	Kuskokwim River Inter-Tribal Fish Commission
I107	Colville Tribes - Chief Joseph Hatchery Program	Confederated Tribes of the Colville Reservation
I108	Quileute Tribe and state Sol Duc hatchery send salmon to fire victims...	Northwest Treaty Tribes
I109	Abegweit Hatchery - Recirculating Aquaculture System	Abegweit First Nation
I110	Record Number of Fall Chinook Salmon Spawn in Snake River Basin	Columbia River Inter-Tribal Fish Commission
I111	Spirit of the Salmon Plan - Reintroduction	Columbia River Inter-Tribal Fish Commission
I112	Tribal Restoration Plan - Reintroductions (Tech Recommend 5)	Columbia River Inter-Tribal Fish Commission
I113	Quinault Indian Nation - Resource Enhancement - QIN Fish Hatcheries	Quinault Indian Nation
I114	Return of the Fish Wars: Hatchery pits environmentalists against tribe	Northwest Indian Fisheries Commission
I115	Returning Hatchery Fish Released to Spawn Naturally	Northwest Treaty Tribes
I116	Squaxin Island Tribe - Salmon	Squaxin Island Tribe
I117	Sun'aq Tribe - Salmon Enhancement	Sun'aq Tribe of Kodiak
I118	Heiltsuk Nation - Salmon Enhancement	Heiltsuk Nation
I119	Suquamish Tribe - Salmon Enhancement	Suquamish Tribe

I120	Kitasoo Xai'xais Nation - Salmon Enhancement program	Kitasoo Xai'xais Nation
I121	Old Massett Village Council - Salmon Enhancement Program	Old Massett Village Council
I122	Tribal Restoration Plan - Salmon Population Structure	Columbia River Inter-Tribal Fish Commission
I123	Salmon Defense - Can you imagine a future without salmon?	Salmon Defense
I124	Sauk-Suiattle Tribe Rears Chum Fry at New Hatchery Site	Northwest Treaty Tribes
I125	Okanagan Nation Alliance - kł cp̓ałḵ̓stiṁ̓ Hatchery Scientific Information	Okanagan Nation Alliance
I126	Elwha River hatchery steelhead and “Treaty rights are not a bumper sticker”	Northwest Treaty Tribes
I127	Coquille Indian Tribe - Seining	Coquille Indian Tribe
I128	Skokomish Tribe Triples Size of Hatchery Facility	Northwest Treaty Tribes
I129	CRITFC - Snake River Fall Chinook Recovery	Columbia River Inter-Tribal Fish Commission
I130	Sockeye and summer chinook arrive in time for barbeque season	Columbia River Inter-Tribal Fish Commission
I131	Coquille Indian Tribe - Spawning	Coquille Indian Tribe
I132	Spokane Tribal Fisheries - Spokane Tribal Hatchery	Spokane Tribe of Indians
I133	Spokane Tribe - Spokane Tribal Hatchery	Spokane Tribe of Indians
I134	Squaxin Island Tribe makes sure state hatchery can release chinook	Northwest Treaty Tribes
I135	CRITFC - Steelhead Kelt Reconditioning	Columbia River Inter-Tribal Fish Commission
I136	Stillaguamish Hatchery to Double Releases of Fall Chinook	Northwest Treaty Tribes
I137	Spokane Tribe - Student Internships	Spokane Tribe of Indians
I138	Spirit of the Salmon Plan - Supplementation	Columbia River Inter-Tribal Fish Commission
I139	Tribal Restoration Plan - Supplementation (Tech Recommend 4)	Columbia River Inter-Tribal Fish Commission
I140	State plans for hatchery do not pass sniff test	Northwest Treaty Tribes
I141	NWIFC - Tagging and Marking Services	Northwest Treaty Tribes
I142	Tribal Restoration Plan - The Columbia Basin Treaty Tribes	Columbia River Inter-Tribal Fish Commission
I143	Tribal Restoration Plan - The Columbia River Basin Fish and Wildlife...	Columbia River Inter-Tribal Fish Commission
I144	Tribal Restoration Plan - The Columbia River Fish Management Plan	Columbia River Inter-Tribal Fish Commission
I145	Tribal Restoration Plan - The Federal Energy Regulatory Commission	Columbia River Inter-Tribal Fish Commission
I146	Abegweit Hatchery - The Hatchery	Abegweit First Nation
I147	Tribal Restoration Plan - The U.S.-Canada Pacific Salmon Treaty	Columbia River Inter-Tribal Fish Commission
I148	Treaty tribes release 43 million hatchery salmon last year	Northwest Treaty Tribes
I149	Treaty tribes speak up to defend hatcheries	Northwest Treaty Tribes
I150	Spirit of the Salmon Plan - Tribal Hatchery Management	Columbia River Inter-Tribal Fish Commission
I151	Tribal Restoration Plan - Tribal Hatchery Management	Columbia River Inter-Tribal Fish Commission
I152	Tribal Program Increases Adult Wild Steelhead in Snake River by 20 Percent	Columbia River Inter-Tribal Fish Commission
I153	UCUT - Tribal Salmon Management, Harvesting and Sharing	Upper Columbia United Tribes
I154	Tribes Celebrate New Adult Fall Chinook Record Passing Bonneville Dam	Columbia River Inter-Tribal Fish Commission
I155	Tribes did the 'heavy lifting' on bringing once extinct Coho back to Upper...	Yakama Nation
I156	Tribes Open Long-Anticipated Commercial Fishery for Summer Chinook...	Columbia River Inter-Tribal Fish Commission
I157	Tribes released more than 34 million hatchery salmon	Northwest Treaty Tribes
I158	Tulalip Tribes Keep Track of Hatchery Salmon	Northwest Treaty Tribes
I159	Tulalip Tribes - Salmon Hatchery	Tulalip Tribes
I160	Tulalip Tribes - Salmon Recovery	Tulalip Tribes
I161	Upper Skagit Tribe harvests last full return of hatchery steelhead	Northwest Treaty Tribes
I162	Video: First fish transfer to new Lower Elwha Klallam Tribe hatchery	Northwest Treaty Tribes
I163	Abegweit Hatchery - Vision/Mission	Abegweit First Nation
I164	CRITFC - Walla Walla R. Spring Chinook	Columbia River Inter-Tribal Fish Commission
I165	What Tribal Hatcheries Are Doing to Save Salmon from the Drought	Northwest Treaty Tribes
I166	White Salmon River celebration: 11 years after dam removal the river...	Yakama Nation
I167	Wild Fish Conservancy Litigation Places Regional Salmon Fisheries at Risk	Columbia River Inter-Tribal Fish Commission
I168	With too few adult fish to broodstock, hatcheries raise chinook in captivity	Northwest Treaty Tribes
I169	Spirit of the Salmon Plan - Wy-Kan-Ush-Mi Wa-Kish-Wit Plan Basic...	Columbia River Inter-Tribal Fish Commission
I170	Yakama Nation - Yakima Basin Summer/Fall Chinook Project	Yakama Nation
I171	Yakama Nation - Yakima Klickitat Fisheries Project (YKFP)	Yakama Nation
I172	Fort Folly First Nation - Atlantic Salmon Projects	Fort Folly First Nation

Table 2. Bibliographic Information – Grey Literature

ID	Document Title	Author Type
G1	2010-2015 Juvenile Fish Ecology in the Nisqually River Delta and Nisqually Reach Aquatic Reserve	Indigenous Group
G2	2013 South Delta Chinook Salmon Survival Study	Federal Government
G3	A Coordinated Mass Marking Program for Salmonines Stocked into the Laurentian Great Lakes	Two or More
G4	Age and Length Composition of Columbia Basin Chinook and Sockeye Salmon and Steelhead...	Indigenous Group
G5	Age Structure and Hatchery Fraction of Elwha River Chinook Salmon: 2016 Carcass Survey Report	State Government
G6	Alaska Subsistence and Personal Use Salmon Fisheries 2018 Annual Report	State Government
G7	An Assessment of Juvenile Chinook Salmon Population Structure and Dynamics in the Nooksack...	Two or More
G8	Are smolts healthier in years of good ocean productivity	Intergovernmental
G9	Assessment and management of environmental and health factors affecting early marine survival...	Intergovernmental
G10	Assessment of the Interior Fraser Coho Salmon (Oncorhynchus kisutch) Management Unit Relative...	Two or More
G11	Bellevue Salmon Spawner Surveys (1999-2020)	State Government
G12	Biological Characteristics and Population Dynamics of Atlantic Salmon (Salmo salar) from the...	Federal Government
G13	Bypass channels can serve as compensative reproduction habitat for salmonids	Academia
G14	California Department of Fish and Wildlife plan for assessment and management of California...	State Government
G15	Central Valley Chinook salmon in-river escapement monitoring plan	Two or More
G16	Characterizing migration and survival between the Upper Salmon River Basin and Lower Granite...	Two or More
G17	Chinook salmon smolt mortality zones and the influence of environmental factors on...	Federal Government
G18	Chinook Salmon Spawning Ground Surveys on the Entiat River, 2017	Federal Government
G19	Citizen science bird survey in the Cowichan Valley in support of the Pacific Salmon...	Federal Government
G20	Climate change and ocean ecology of northwest steelhead	Environmental Group
G21	Coded Wire Tag Augmented Genetic Mixed Stock Analysis of Chinook Salmon Harvested in...	State Government
G22	Comparative Survival Study of PIT-tagged Spring Summer Fall Chinook, Summer Steelhead, and...	Two or More
G23	Comparison of genetic versus delta model length-at-date race assignments for juvenile Chinook...	State Government
G24	Environmental Assessment Lake Washington Basin Hatcheries	Federal Government
G25	Determining the Effects of Asian Pink and Chum Salmon on Growth and Maturation of Alaskan...	Academia
G26	DNA analysis of Puntledge River Summer Chinook - assessment of run timing inheritance and...	Federal Government
G27	Does predation by returning adult pink salmon regulate pink salmon or herring abundance	Intergovernmental
G28	Duckabush Summer and Fall Chum Salmon 5 Year Review Brood Year 2010-2014	State Government
G29	Ecosystem services provided by Baltic salmon–a regional perspective to the socio-economic...	Academia
G30	Effective Hatchery Releases to Increase Adult Returns of Chum Salmon in the Ishikari River,...	Intergovernmental
G31	Emigration of Juvenile Chinook Salmon and Steelhead from the Imnaha River	Indigenous Group
G32	Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery...(a)	Federal Government
G33	Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery...(b)	Federal Government
G34	ESA Recovery Plan for Lower Columbia River Coho Salmon, Lower Columbia River Chinook...	Federal Government
G35	ESA Recovery Plan for the White Salmon River Watershed	Federal Government
G36	Evaluation of juvenile salmon production in 2016 from the Cedar River and Bear Creek	State Government
G37	Factors limiting survival of juvenile Chinook Salmon, Coho Salmon and Steelhead in the Salish Sea	Two or More
G38	Feasibility of Estimating the 2011 Terminal Run Sizes for Chinook Salmon Driver Stocks Harvested...	State Government
G39	Feasibility of live spawning wild male spring Chinook salmon at Warm Springs National Fish...	Two or More
G40	Final ESA recovery plan for Oregon Coast coho salmon (Oncorhynchus kisutch)	Federal Government
G41	Fish passage and reintroduction into the U.S. and Canadian upper Columbia River	Indigenous Group
G42	Hatchery Scientific Review Group, Comments on the Proposed ESA Recovery Plan for Snake River...	Two or More
G43	Genetic parentage analysis of spring Chinook salmon on the South Santiam River insights into...	Two or More
G44	Genetic Stock Composition of the Commercial and Sport Harvest of Chinook Salmon in Westward...	State Government
G45	Hatchery and Genetic Management Plan (HGMP): Middle Fork Willamette Spring Chinook Salmon	State Government
G46	Hoopa Valley Tribe's Fishery Harvest and Conservation Plan for Trinity River Coho Salmon Summer...	Indigenous Group
G47	Idaho adult Chinook Salmon monitoring 2020 annual report	State Government
G48	Idaho Steelhead monitoring and evaluation studies Annual Progress Report	State Government
G49	Independent review of the science and management of Thompson River steelhead	Private
G50	Interactions of Wild and Hatchery Pink Salmon and Chum Salmon in Prince William Sound and...	Two or More
G51	IPC and LSRCP Monitoring and Evaluation Programs in the State of Idaho: Calendar Year 2017 and...	Two or More
G52	JHTMON-8: Quinsam River Smolt and Spawner Abundance Assessments - Year 5 Interim Summary...	Private
G53	Juvenile Salmonid Emigration Monitoring in the Lower American River, California January – June...	State Government
G54	Klawock Lake Sockeye Salmon Retrospective Analysis	Two or More
G55	Knowledge Synthesis and Re-Establishment Plan for Coquitlam Reservoir Sockeye Salmon	Private
G56	Long-term Trends of Distribution and Regional Composition of Hatchery-released Juvenile Pink...	Intergovernmental
G57	Lower American River Fall-Run Chinook Salmon Escapement Survey October 2017–January 2018	State Government
G58	Lower Cowlitz River monitoring and evaluation, 2013	State Government
G59	Marine survival of Puget Sound Chinook size-selective mortality growth limitation and...	Two or More
G60	Measuring estuary avian predation on juvenile salmon by electronic recovery of passive integrated...	Two or More
G61	Mechanisms, impacts, and mitigation for thiamine deficiency and early life stage mortality in...	Intergovernmental

G62	Migration and survival mechanisms of juvenile salmon and steelhead in ocean ecosystems: The...	Intergovernmental
G63	Mixed stock analysis of Chinook salmon harvested in Southeast Alaska commercial troll and sport...	State Government
G64	Monitoring and Evaluation of Supplemented Spring Chinook Salmon and Life Histories of Wild...	Indigenous Group
G65	Monitoring and Evaluation Updates for John Day The Dalles Dam Mitigation Programs at Spring...	Federal Government
G66	Multidisciplinary evaluation of the feasibility of parentage-based genetic tagging (PBT) for...	Two or More
G67	Myxosporean parasite (Ceratonova shasta and Parvicapsula minibicornis) prevalence of infection...	Federal Government
G68	Ocean ecology of chum salmon	Two or More
G69	Coastal Multi-Species Conservation and Management Plan	State Government
G70	Pacific salmon status and abundance trends-2012 update	Intergovernmental
G71	Parentage based tagging of Snake River hatchery steelhead and Chinook salmon	State Government
G72	Participation in Ecosystem-Scale Research	Academia
G73	Population Genetic Analysis of Chehalis River Basin Chinook Salmon (Oncorhynchus tshawytscha)	State Government
G74	Population genetic analysis of Chehalis River watershed coho salmon (Oncorhynchus kisutch)	State Government
G75	Pre-COSEWIC review of southern British Columbia Chinook Salmon (Oncorhynchus tshawytscha)...	Federal Government
G76	Pre-season run size forecasts for Fraser River Sockeye salmon (Oncorhynchus nerka) in 2012	Federal Government
G77	Prognosis of Ceratomyxa shasta and Parvicapsula minibicornis infections in Klamath River Coho...	Federal Government
G78	Provisional abundance estimates of adult hatchery and wild pink, chum, and sockeye salmon by...	Intergovernmental
G79	Provisional estimates of numbers and biomass for natural-origin and hatchery-origin pink, chum,...	Intergovernmental
G80	Re: NOAANMFS20190097, five-year status review for 17 evolutionarily significant units (ESUs) of...	Environmental Group
G81	Reach conversion rates of radio-tagged Chinook and Sockeye salmon and Steelhead in the Lower...	Federal Government
G82	Reconstruction of the 2012/2013 Steelhead spawning run into the Snake River basin	Two or More
G83	Recovery of Coded-Wire Tags from Chinook Salmon in California's Central Valley Escapement,...	State Government
G84	Recovery Potential Assessment for Southern Upland Atlantic Salmon: Status, Past and Present...	Federal Government
G85	Review of Salmon Escapement Goals in Southeast Alaska, 2014	State Government
G86	Salmon Creek Coho Monitoring 2008-2013 Final Report	Private
G87	Salmon exposure to chromium in the Hanford Reach of the Columbia River: Potential effects on...	Academia
G88	Snake River Basin 2015-2016 Steelhead run reconstruction	Two or More
G89	Snake River Basin Adult Chinook Salmon and Steelhead Monitoring	Indigenous Group
G90	Snake River Juvenile Salmon and Steelhead Transportation Synthesis Report	Academia
G91	Steelhead Kelt Reconditioning and Reproductive Success: 2012 Annual Report	Indigenous Group
G92	Supplementation of Atlantic Salmon in the Southern Extent of their Range: Evaluation of Age-1...	Intergovernmental
G93	Survival and Early Marine Migration of Enhanced Age-0 Sockeye Salmon Smolts Raised in...	Intergovernmental
G94	Survival of Japanese chum salmon during early ocean life in 2011–2017	Intergovernmental
G95	Survival of Wild Hanford Reach and Priest Rapids Hatchery Fall Chinook Salmon Juveniles in the...	Federal Government
G96	Synthesis of scientific knowledge and uncertainty about population dynamics and diet preferences...	Academia
G97	Teaming up Internationally to Optimize Wild and Hatchery Pacific Salmon Production in a Future...	Intergovernmental
G98	Technical feasibility and recommendations for Alouette Lake sockeye salmon re-establishment...	Private
G99	The dispersal pattern of juvenile chum salmon in the Pacific Ocean off the coast of Hokkaido, Japan	Intergovernmental
G100	The Marine Ecology of Juvenile Columbia River Basin Salmonids: A Synthesis of Research 1998...	Two or More
G101	The Way Forward for Wild Salmon Protection and Recovery	Environmental Group
G102	The status of Atlantic salmon (Salmo salar) on Prince Edward Island (SFA 17) in 2013	Federal Government
G103	Coquitlam Reservoir Kokanne/Sockeye (Oncorhynchus nerka) egg take collection, 2015	Private
G104	To save wild steelhead, get rid of hatcheries	Environmental Group
G105	Toxic contaminants in juvenile Chinook salmon (Oncorhynchus tshawytscha) migrating through...	State Government
G106	Trophic Relationships of Resident Chinook and Coho Salmon and the Influence of Artificial Light...	Federal Government
G107	What can genomics tell us about the success of enhancement programs in anadromous Chinook...	Intergovernmental

Appendix 3 - Narrative Analysis Codebook

Table 1. Codes and descriptions for themes related to salmon hatcheries presented in IPF literature

Thematic Code	Description of topics which fall within the theme
Treaty Rights, Inherent Rights, Indigenous Law and Sovereignty (Some nuance may be implicit rather than explicit)	Rights as enshrined in formal treaties as well as inherent governance rights where formal treaties are absent
	Rights enshrined through other legislation (UNDRIP, etc.)
	Matters relating to governance including the interpretation and implementation of laws by various levels or branches of government
	Values related to governance such as trust and cooperation
	How a Nation's sense of identity factors into discussions of these rights
	How discussions around enhancement relate to a First Nation's sovereignty. E.g., willingness (or lack thereof) to follow US/Canadian laws
	Conflict between Indigenous Law and US/Canadian law
	ADDITIONAL - Nation to Nation relations
Food and nutrition	Use as a subsistence food resource
	Sharing of salmon with community members
	Alternative sources of nutrition if salmon are not available (or lack thereof)
Social and cultural value (May often be implicit rather than explicit)	Use of salmon in ceremony and storytelling
	Role of salmon in cultural identity
	Pride related to the management of salmon, including through enhancement
	Creating a sense of community
Economic aspects	Harvest in commerical fisheries
	Sport/recreational fisheries (license sales, outfitting services, etc.)
	Secondary industries such as fish processing
	Direct or indirect job creation
	ADDITIONAL - Role of federal/state government funding for enhancement programs
	ADDITIONAL - Costs of other restoration activities needed alongside hatcheries
Knowledge systems and knowledge holders	The use of various knowledge systems in the context of hatcheries
	The knowledge and skills held by Indigenous peoples including fishers, fisheries managers and technicians
	ADDITIONAL - Participation and management of research programs
Education and learning	Related to fisheries and their management
	Related to a Nation's culture, history, etc.
Habitat integrity and climate change	Impacts of climate change on salmon populations
	Impacts of habitat alteration (building of dams and other infrastructure, reduced water levels due to diversion for human use, etc.)
	Role of hatcheries in mitigating these problems (over short/medium/long time horizons)
Conservation and sustainability	Direct positive contribution to conservation
	Complementarity with other conservation measures
	Sustainability of hatchery operations
Genetic effects and fish health	Genetic introgression
	Positive genetic impacts (e.g., as a living gene bank, reintroduction programs, etc.)
	Lower fitness of hatchery fish compared to wild/natural fish
	Fish health and transmission of disease
Ecological effects	Competition between hatchery and wild/natural fish
	Relative abundance of hatchery fish
	Impact of hatchery fish on freshwater and ocean survival
ADDITIONAL - Enhancement Operations	
ADDITIONAL - Public controversy	
ADDITIONAL - Research, Monitoring, Management and Evaluation	
Others	This code encompasses information that may be be valuable to the study but does not fall within any of the other thematic categories

Table 2. Codes and descriptions for themes related to salmon hatcheries presented in grey literature

Thematic Code	Description of topics which fall within the theme
Treaty Rights, Inherent Governance Rights, Indigenous Law and Sovereignty	Discussions of Treaty or inherent governance rights, relationships between Indigenous people and US/Canadian governments relating to various aspect of salmon management, co-management, and Indigenous sovereignty
Research, management and evaluation	Studies carried out using hatchery fish as the experimental subject or data source
	Information from enhancement programs used to support decision-making for resource management
	Discussions of how RME limitations can be the main issue that led to poor enhancement outcomes and how better RME can improve enhancement outcomes
Food, social and cultural value	Subsistence salmon use by Indigenous and non-Indigenous communities. If the text does not explicitly state subsistence/personal use, the text was interpreted to refer to commercial fishery instead (see thematic code 'Economic importance').
	Social and ceremonial use of salmon by Indigenous communities
	Importance of salmon in Indigenous culture and storytelling
	Socio-cultural values associated with sport/recreational fisheries
	Socio-cultural values relating to commercial fisheries
Economic importance	Mark selective fisheries that only capture hatchery fish
	Commercial fisheries (not mark-selective or undefined) which rely on hatchery releases
	Sport/recreational fisheries
	Harvest specifically by First Nations
Knowledge systems/production and knowledge holders	Notable discussion of knowledge systems used to evaluate the role and impact of hatcheries as well whose (individual or group) knowledge is used in the evaluation. Western science and dominant institutions (governments, academia, industry, etc.) are well typically well represented so the aim is to look for knowledge holders outside this group (Indigenous Peoples, community members, fishers, etc.). Excludes routine operations and data collection (e.g., citizen/community science projects which are not designed or managed by community members).
Education and learning	Importance of hatcheries as a medium for providing education and learning opportunities to children, youth, and adults from both Indigenous and non-Indigenous backgrounds
Habitat integrity and climate change	Impacts of climate change
	Impacts from infrastructure development (dams, irrigation canals, armouring of shorelines, etc.) and pollution
Conservation and sustainability	Direct role in conservation (maintaining stocks if natural stocks decline, reintroduction programs where salmonids are extirpated, etc.)
	Excessive harvest in fisheries
	Complementarity with other conservation/restoration measures
	Sustainability of operations
Genetics, fish health and behaviour	Genetic introgression
	Genetic diversity, effective population size, other genetic effects
	Hatchery fish as a “live gene bank”
	Straying of hatchery fish and potential impacts on native populations
	Similarities and differences between hatchery and wild fish biology and behaviour
	Freshwater and ocean survival rates for hatchery and wild fish
	Comparisons of the relative fitness of hatchery and wild fish
	Diseases afflicting hatchery fish, their transmission to wild fish and relative rates of prevalence
Enhancement operations	Discussions of how hatchery operations can be improved to enhance positive effects or minimize negative ones
Ecosystem interactions and ecological effects	Impacts of escapes from hatcheries or straying of hatchery fish
	Interaction between hatchery and wild fish (except spawning)
	Abundance of hatchery fish
	Transmission of disease from hatchery fish to other species
	Ecosystem carrying capacity and intra/inter species competition for resources
	Interaction between hatchery fish and predators/prey
Other	This code encompasses information that may be valuable to the study but does not fall within any of the other thematic categories

Appendix 4. Grey Literature Methodology

Grey Literature in Literature Reviews

Peer-reviewed publications are often considered to be an indicator of quality. However, they also suffer from several drawbacks. The most notable is the cumbersome publishing process which may lead to long delays between research and the dissemination of findings, and potentially discourage some groups of researchers from pursuing publication in peer-reviewed journals (Pappas & Williams, 2011).

Grey literature can also bridge the time lag between research and publication as studies initially published as grey literature such as conference proceedings, and theses and dissertations may eventually be published in peer-reviewed journals (Godin et al., 2015; Pappas & Williams, 2011). In contrast, grey literature can be timelier as it avoids these time lags (Pappas & Williams, 2011). As access is not controlled by commercial publishers which charge publication or access fees, grey literature is typically much more easily accessible to both authors and readers than peer-reviewed journal articles (Godin et al., 2015).

Peer-reviewed literature also suffers from publication bias, wherein studies with positive results are more frequently accepted for publication than those with negative or null results (McAuley et al., 2000). By providing a forum for disseminating the latter, grey literature reduces publication bias (Benzies et al., 2006; Paez, 2017). Grey literature often captures policy considerations and other research-relevant information from decision-makers and practitioners that are not available from other sources of information (Godin et al., 2015). It also provides useful contextual information which is often missing in peer-reviewed publications due to strictly defined formats and inclusion criteria (Benzies et al., 2006).

Grey literature is often produced by subject matter experts (Pappas & Williams, 2011). While some types of grey literature such as theses and dissertations are thoroughly reviewed by experts, the variability of review processes across various types of grey literature may lower the overall quality and objectivity of this class of documents (Paez, 2017). Therefore, it is essential that rigorous scientific methods be used to assess the quality of information sourced from grey literature (Pappas & Williams, 2011).

As the target audiences for different types of grey literature vary widely, it is often produced in a wide range of formats (Paez, 2017). Due to the absence of consistent procedures for archiving documents and the dynamic nature of websites, the locations of the documents may change over time or in some cases, the documents may cease to be publicly accessible at some time after the research is published (Paez, 2017). These documents often do not have abstracts, the technical vocabulary used may be variable, and lack consistent titles and standardized bibliographic indexing (Godin et al., 2015; Pappas & Williams, 2011). Together, this makes sourcing and screening documents for a systematic review challenging. The increasing rates of grey literature inclusion in scientific studies indicates that the advantages outweigh the limitations (Schöpfel & Prost, 2021).

Due to the diversity of sources and formats, there is no 'gold standard' method for conducting rigorous and scientifically defensible grey literature searches (Godin et al., 2015; Paez, 2017). As with reviews of peer-reviewed literature, studies involving grey literature should explicitly state the methodology and inclusion criteria, attempt to identify most or all documents which satisfy the eligibility criteria, and where possible, be reproducible within the limitations of the data sources used (Godin et al., 2015).

While systematic grey literature reviews cannot match the standards of transparency and reproducibility of academic databases which index peer-reviewed literature, the application of rigorous systematic methods to grey literature searches can provide a reasonably comprehensive and relatively unbiased dataset for examination (Godin et al., 2015). Due to the vast quantities of grey literature, search methods should be designed to maximize sensitivity (proportion of high-quality articles that are retrieved) and specificity (proportion of low-quality articles that are not retrieved), and ensure high precision (proportion of retrieved articles that are of high quality), while managing labour intensity to a manageable level (Wilczynski & Haynes, 2007).

Searching for Grey Literature

There are dozens of databases which either exclusively index grey literature or include both peer-reviewed and grey literature. Many of these focus on either a particular topic (say, clinical trials) or type of document (conference proceedings, theses and dissertations, etc.) while a few such as GreyNet, OpenGrey and SIGLE (System for Information on Grey Literature in Europe) have broader coverage (Pappas & Williams, 2011). A major limitation of these databases is that they rarely include documents from industry and government sources (Godin et al., 2015).

Other commonly used search strategies include hand-searching through relevant databases and websites, application of snowballing techniques, and correspondence with subject matter experts (Paez, 2017). These methods suffer from high labour intensity and are increasingly being replaced by the use of search engines such as Google Scholar (Paez, 2017).

The main advantages of using Google Scholar are that it indexes documents from a wider range of sources than scholarly databases (especially government and industry sources), and its ease of accessibility and familiarity (Mahood et al., 2014). However, it suffers from low sensitivity and specificity (Mahood et al., 2014). As it uses free-text searches, it is difficult to control the vocabulary used for searches and establish relationships between related words (e.g., by using Boolean operators) (Jamali & Asadi, 2010).

The algorithm for ranking results is proprietary and there is limited documentation and product support for the product. However, it has been seen that search results are affected by geographic location and search history, and that results are ranked by popularity rather than relevance (Jamali & Asadi, 2010; Kousha & Thelwall, 2007). This affects the consistency and reproducibility of search results, which is a major limitation of this product (Paez, 2017). Searches commonly yield very large sets of results which may overwhelm the researchers ability to sort and analyse the results within reasonable time frames (Paez, 2017). The application of constraints such as date ranges and language filters, and examining only a pre-specified number of results from each search are common methods to limit search results to manageable levels (Godin et al., 2015; Paez, 2017).

To enable the use of Google Scholar for a grey literature systematic search, we followed guidance from prior studies and online sources such as university libraries for guidance on how to carry out these searches. These sources highlighted several considerations which need to be taken into account, including:

- The search string length should be <= 256 characters (Sanchez-Acedo et al., 2024). However, some posts on ResearchGate and StackExchange discussion boards noted that there is ambiguity regarding how the search string length is calculated (e.g., whether spaces or Boolean operators count as characters).
- Unlike many scholarly databases, the use of parentheses or nested search strings is not allowed (Boeker et al., 2013; Haddaway et al., 2015). Search string columns were combined using the Boolean operators OR, AND, and NOT or their symbolic equivalents which are accepted by GS.
- The use of the 'filetype:pdf' operator results in a higher proportion of grey literature results as it screens out many peer-reviewed documents that GS does not have access to.
- Because the ranking criteria are not known and the search algorithm is continuously updated, the results of searches are not replicable (Paez, 2017).
- GS does not provide the ability to search only within titles and/or abstracts (Tay, 2014).
- The fair use policy does not allow automated searches and results retrieval (Google Inc., n.d.).
- The relevance of search results rapidly deteriorates after the first few pages and many peer-reviewed studies restricted the inclusion scope to the first 50-100 results (e.g., Collaboration for Environmental Evidence, 2022; Franzen et al., 2017; Godin et al., 2015).

Screening Procedures

Screening was performed in two stages. In Stage 1, we excluded documents which fit the following criteria:

- Peer-reviewed publications
- Documents whose publication date was outside the study period
- Documents for which the full text was not available
- Where the GS search result did not link to a document, or the document linked did not match the citation, efforts were made to identify the correct documents using Google search.

In Stage 2, the full text of each document was read to verify that the correct document was linked by GS and conduct a more in-depth review. Documents needed to satisfy the criteria below to be included:

- The subject matter dealt with in-scope species and geography (salmonids, Pacific and Atlantic basins)
- The document dealt only or mainly with situations related to the purposeful and/or intentional releases of fish (i.e., accidental releases were out of scope)
- The document addressed at least one of the following topics:
    - Policy, governance, regulation, research, and management of hatchery/enhancement programs
    - Relationships between humans, fish and hatchery/enhancement facilities
    - Economic, social, political, environmental or other values associated with hatchery/enhancement programs

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