Salmon Habitat Restoration Practice in Vancouver Island:

An active review of the literature developed by restoration practitioners
to restore salmon habitat degraded by forestry practises.

ER 390 - Project Report

Prepared by German Ocampo
Prepared for Nancy Shackelford

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Summary:

Wild Salmon on the Pacific Northwest coast are under threat. Historical silvicultural activities, both timber harvesting and road construction have degraded salmon habitat all over the coast to the point that many watersheds currently require restoration. This project developed an interactive tool to review the project reports developed by restoration practitioners to restore salmon habitat degraded by silviculture practices on Vancouver Island, British Columbia, Canada. The project reviewed restoration reports on this specific area of restoration to serve as a first step to inform future restoration projects or people interested in salmon habitat restoration. The project also serves as a repository where grey literature on this topic can be easily accessed. This project stores restoration reports describing management actions planned, underway, and completed easily accessible. This project surveyed non-scholarly sources (grey literature) to provide an overview highlighting a variety of attributes such as:

- The name of organizations carrying out the project
- Date of publication and timeline of the project
- A description of the location and overview of ecosystems managed
- Project expenditures and funding sources
- A summary of the methods/techniques used
- Evaluation of project outcomes
- Compilation of monitoring data

Background:

Wild salmon are the connective tissue of the Pacific Northwest, connecting oceans, forests and communities. Over the last 150 years, every primary industry – forestry, mining, fishing, energy production, and agriculture – has had adverse effects on the ecosystems wild salmon depend on to survive. The intensification of industrial logging has come at a high cost for salmonids and has played a significant role in the degradation of their ecosystem across British Columbia, Canada. Poor logging practices have left a legacy of watershed disturbances that require ecological restoration (Pike et al., 2010). Most salmon-bearing watersheds on Vancouver Island have been degraded by silviculture activities threatening all five native salmon species found on the region: Chinook (*Oncorhynchus tshawytscha*), Coho (*Oncorhynchus kisutch*), Chum (*Oncorhynchus keta*), Pink (*Oncorhynchus gorbuscha*), and Sockeye (*Oncorhynchus nerka*). The negative impacts generated by the silviculture activity vary from site to site, affecting the various stages of the salmonid's life cycle throughout the watersheds (Pike et al., 2010). According to the Land Management Handbook, developed by the B.C. Ministry of Forests and Range, the most significant disturbances created by past forest practices are:

1. **The logging of floodplains, fans, and riparian forests**: Riparian, fans and floodplains contain some of the most productive forest lands due to being the interface between forest, fish and wildlife. Timber harvesting of the riparian areas compounds the chances of landslides and simplifies the streamside forest, destabilizing stream banks and halting the natural recruitment of large woody debris into the system. Logging floodplains and river fans increase channel bank erosion, channel destabilization, widening, and sediment

aggradation. Furthermore, logging riparian forests in the short-term limits shade, cover, and food sources for salmon.

2. **Stream composition damage:** Cross-stream yarding and the removal of LWD from within stream channels have resulted in long-term loss of channel structure (i.e., pools, habitat features) and increased sediment transport causing the coarsening of channel bed material. Landslides, created both from the weakening of slopes and the deterioration of decommissioned roads, result in scouring caused by debris, extensive bank erosion and channel widening. Cross-stream yarding was a major contributor to debris in the streams.
3. **Log harvesting on features susceptible to instability or erosion:** One of the significant adverse impacts of log harvesting is the weakening of slopes surrounding creeks and rivers, causing persistent landslides. Logging on features susceptible to instability or erosion such as gullies, steep slopes, escarpments, and unstable slopes increase the natural abundance of landslides. Landslides are essential sources of coarse sediment for stream substrates and spawning gravels. However, increased sediment supply can result in higher sediment loading rates, which causes the degradation of salmon ecosystem features habitat conditions.
4. **Poor road construction practices:** Road construction on steep slopes altered drainage and limit fish passage while increasing sediment supply and erosion. Poor road construction practices generated over steepened, unstable fills on steep terrain changed surface flow and groundwater. Landslides and increased erosion levels from old roads have become significant sediment sources to river systems (Pike et al., 2010).

Rationale for project

The decreasing numbers of returning wild salmon to watersheds all across the Pacific Northwest has prompted an increase in public and private restoration initiatives (Bash & Ryan, 2002). Both governmental and non-governmental organizations acknowledge the importance of salmon for B.C.'s forests and communities' wellbeing. They have begun working to restore these habitats to prevent salmon population collapse. Most restoration projects are currently carried out independently, and their approaches and results are kept separate and mostly inaccessible or difficult to find. According to a metanalysis comprised of over 23,000 restoration actions in Washington, Oregon, Idaho, and Montana, salmon restoration projects generally lack stable and reliable evidence of salmon populations' responses to specific restoration techniques (Katz et al., 2007).

It is crucial to develop restoration intervention based on observed and measured results to carry out successful restoration projects. This project compiles restoration project reports to serve as a resource for current and future restoration practitioners on this topic and make this information both accessible and transparent. This report describes generating a database of restoration projects intended to improve salmon habitat throughout Vancouver Island. The database explicitly highlights the various restoration approaches taken to help practitioners evaluate past restoration actions' effectiveness. The data comprised within the StoryMap is practitioner-generated research, considered grey literature, published by non-governmental organizations, governments, private companies, and consultants. Although grey literature has not been subject to a rigorous academic-peer-review process, it holds valuable information for restoration practitioners. It constitutes a significant proportion of accessible information on the topic. It is important to note that grey literature is generated in greater volume than peer-reviewed scientific literature in the fields of ecology and conservation (Corlett, 2011). The higher volume of grey literature in these fields increases the practitioner's ability to identify trends and patterns that can reliably inform restoration practice. Furthermore, grey literature is an excellent resource for conservation and environmental management as it is a body of knowledge that explores the effectiveness of commonly used ecological interventions (Haddaway & Bayliss, 2015). Furthermore, the project reports are generated from restoration activities in the field, demonstrating more practical, applied data than those produced through academic research.

Goals and Objectives:

The overall goal of this project is to help watershed restoration partitioners find information about the most successful restoration practices in ecosystems degraded by silviculture practices on Vancouver Island. This project's specific objective is to create a StoryMap to serve as a resource for restoration practitioners and ecosystem managers in Vancouver Island. ArcGIS StoryMaps is a didactical tool, both informative and practical, allowing for an immersive experience. A StoryMap is a web map embedded in a story to provide context and information via text, photos, and video to capture the audience's attention and help them explore its contents. By making all the project reports accessible through the maps embedded on the StoryMap, the readers gain access to information from its source promoting further research and learning. The intent is to compile a list of "who, where and how" of restoration projects on Vancouver Island. Access to restoration outcomes in diverse ecological conditions on Vancouver Island can provide the scientific rationale for improving future planning and implementation of restoration projects. The task of restoring salmon habitat degraded by silviculture practices is complex, therefore compiling and sharing the most relevant data into accessible resources becomes critical to timely problem-solving.

Methods:

Data Gathering:

This project reviewed restoration reports using a systematic, transparent and reproducible data gathering methodology. The methodology chosen is context-specific and focused on the subject area and geographic scope. The project systematically gathered data, beginning with direct conversations with relevant organizations, groups and networks. These conversations naturally led to further conversations with more practitioners working in organizations that are likely to collect relevant data. Then, the project searched the websites of other relevant organizations that may produce non-academic reports and researched online catalogues focusing on the specific geographical and subject area. Lastly, online resources such as Google Scholar - which catalogues both academic and grey literature - were searched specifically for project reports. The use of gray literature - consultant reports, non-for-profit project reports, governmental publications, and institutional reports - provided a complete overview of all available information of the restoration projects taking place in Vancouver Island. The research was carried out in three stages:

Stage 1: Reviewed projects from 'local experts, content experts and stakeholders' and consulted with them about other organizations or further publications, grey literature documents, as well as sources of grey literature they felt would be essential to include in the review. In conversations with local experts, the following information was requested:

- Who is carrying out restoration in this specific field, and how to get in contact with them? (e.g., Organization affiliation, name, email, phone number, etc.)
- What is the focus on those restoration projects? (e.g., what kind of restoration projects is it, and is the restoration project explicitly on restoring salmon habitat degraded by silviculture practices?
- Where did the work take place, or where is the work going to happen? (e.g., the name of the watershed being restored, Lat./Long.)
- When did the restoration happen, or when will the work start?
- Do you know of any databases that may have a repository for this kind of project?

Stage 2: Searched online databases to reflect various subject areas, including Ecological restoration, fisheries management, forest management. As the search results available for each database are different, the search of customized variations was carried using the "OR" and "AND" features whenever possible. The databases searched were:

- Cross-Linked Information Resources
- Fisheries Information Summary System (FISS),
- Fisheries and Oceans Canada Library,
- Web of Science
- SCOPUS
- EcoCAT: Ecological Report Catalogue,
- J.T. Fyles Ministry of Forests online library

Stage 3: Conducted a methodological search for grey literature in library catalogues, online organizational repositories, web repositories and popular Web search engines such as Google.ca and Google Scholar (http://scholar.google. com/). As controlled vocabulary searching was performed in the main and advanced search screens of these search engines. Performed searches in the advanced search mode to control for specific vocabulary ("logging restoration salmon British Columbia"; "forest restoration salmon British Columbia"; "forest management salmon British Columbia"; etc.)

Database Design:

The first step in developing the database was standardizing the data collected. It was important to dedicate time to craft the various attributes collected from each project to get the most valuable information for further synthesis and analysis. A unique project I.D. code was assigned to each restoration report in order to ensure trackability. Each project was then reviewed, and its data organized into different attributes (Table 1). It required a significant investment of time to understand and filter the useful information. While the data was being organized, a few questions were asked to find commonalities and uncover the various restoration approaches taken around the island:

- What are the standard methods/techniques of restoration?
- Are there similarities or differences?
- Is there a standard theory on these restoration practices?

Table 1	
Attribute name	**Definition**
Project_ID_#	Unique number code is given to each project to differentiate it from
Name_of_Project	Name given to the specific project taken from project reports.
Latitude	Latitude coordinates provided in decimal degrees.
Longitude	Longitude coordinates provided in Decimal degrees
Data_Source	Description of where information from which information about the restoration project was gathered
Watershed/Stream	Name of the Watershed and stream where the restoration took or is taking place/
Start_Date	The year the restoration project was implemented
End_Date	The year the project implementation was finished. It does not include monitoring time - monitoring is addressed in a different column
Lead_Organizations	Name of organization/group that initiated the project
Partner_Organizations	Name of organizations or persons that collaborated on the project
Total_Cost	Information related to the dollar amount spent in carrying out the project
Funding_Source	Information of funding streams and where the funding came from
Logging_Data	Historical data related to the logging that has happened in the various project sites
Type_of_Watershed_ Degradation	Damage created by historical logging practices
Ecosystem_Type	Defined bio-geoclimatic (BEC) zone classification
Land_Owners	Who holds the lease of the land or control its ownership
Target_Species	Which species are the treatments trying to support
Restoration_Goals	Description of restoration goal and desired end results of restoration work
On_land_Restoration_ Methods	Restoration methods implemented to prevent the delivery of eroded sediment to stream systems as well as restore beneficiary ecological features to the boundaries between the aquatic and terrestrial areas
In-Stream_Restoration_ Methods	Restoration methods implemented to change the fluvial geomorphology, hydraulics, hydrology, and aquatic biologic attributes of a stream
Monitoring_Data	Description of the type of monitoring applied
Map_Reference_#	This attribute allows the reader to find a map referenced categorized by a numeral
Output_Estimates	Numerical results of the restoration project
Past_Work	Highlights the past restoration work done in the watershed/ stream
Future_Proposed_work	Discuss work that may follow the work that has been done in the stream

ARCGIS StoryMap Development:

From the outset, it was understood that the story must be engaging, memorable and compelling for the audience to connect with it. The pre-production phase identified the target audience, defined key takeaways, created a content inventory, and helped produce an impactful outline. This StoryMap helps the reader see themselves as part of the narrative as they are confronted with the issues salmon currently face in the region. This StoryMap serves as a roadmap for someone who wants to learn about the implications of silvicultural practices on salmon ecosystems and a resource for restoration practitioners who want to access information about restoration practices in the field. By using images and videos, we can capture the attention of the readers. Using maps and data analysis, we can inform and increase the audience's awareness of the topic.

The StoryMap begins by situating this issue in a historical context setting up the reader to understand the extent of the issue and the cumulative impact of past silviculture practices on all of Vancouver Island. The StoryMap then flows into explaining the overall environmental impacts of silviculture practices in Salmon ecosystems. Using maps within StoryMaps paints a picture of the geographical distribution of the projects being studied and allows access to the project reports from the pop-up window in the embedded map. Therefore, readers are encouraged to review the supporting documents found as points in the maps to review the specific watershed qualities and issues discussed to determine whether the information presented applies to their particular watershed restoration issues. The StoryMap then distill the information found in these reports and highlights the significant restoration practices while summarizing key restoration strategies.

Results:

This project compiled 46 project reports highlighting the restoration of salmon habitat degraded by silviculture practices on Vancouver Island (Image 8). The StoryMap present case studies to examine the biological benefits of watershed restoration at a watershed– or reach–level. Readers eplore each of the dots to learn more about each project. The StoryMap can be found here:

https://storymaps.arcgis.com/stories/38244da024ba4f2e9e293264aedd8875

After examining the project reports, restoration practices were separated into two overarching areas representing On-land and In-stream restoration methods. These two groups are then subdivided into subgroups to highlight the most common restoration techniques utilized in the field.

In-Stream Restoration

By far, the most common restoration methodology used. In-stream restoration work involved creating new fish habitat and either reconstructing or increasing the river systems' productive capacity. The three most common In-Stream Restoration actions found in this research are habitat complexing, bank erosion prevention, and wetted area development.

Habitat Complexing: Habitat complexing is the most commonly used restoration practice encompassing the creation of new fish habitat and either reconstructing or increasing the system's productive capacity by providing improved spawning and rearing habitat. LWD is introduced in the system to restore natural riffle/pool sequences and mitigate erosion and bedload movement while increasing habitat complexity. These LWD additions provide cover and re-establish natural channel geometry recreating deep pools mixed with shallow bubbling riffles to mix oxygen in the water.

Bank Erosion Prevention: LWD positioned instream and on banks are set in place to prevent erosion, provide bank support, deflect water, create scour, provide cover habitat, and lead to the formation of large pools. Boulder and rock clusters also serve as bank protection structures and fish habitat. In some cases, bank reconstruction is necessary, placing logs end to end and backfilling with rip-rap to reconstruct the natural structure and reduce further erosion.

Development of Wetted Area and Channels: Channels and wetted areas serve a crucial role in increasing favourable salmonids' conditions by providing year-round spawning and rearing habitat. Channels provide connectivity, maintain flows to secondary drainages and creating wetted habitat. Channels also allow a controlled water flow and stable salmon rearing conditions year-round.

On Land Restoration Methods

Restoration methods focus on the recovery of forest characteristics that reduce stream bank erosion, increase infiltration, and improve water quality by planting for biodiversity, to create cover, shade, and refuge from predators. Slope rehabilitation and road deactivation are also standard On Land restoration methods. The four most common On-Land Restoration actions found in this research are revegetation, complexing adjacent forests, road deactivation, and landslide revegetation.

Revegetation: The most common On-Land restoration practice is the revegetation of disturbed soils by preparing exposed soil for successful reforestation. Areas that were disturbed during the in-stream restoration require proper revegetation to provide bank stabilization and speed up the natural forest recovery process. Riparian revegetation requires seeding the disturbed areas with native plants such as:

- Native grasses and legume seed mixes
- Native bushes such as ocean spray (Holodiscus discolor), red osier dogwood (Cornus sericea) and salmonberry (Rubus spectabilis).
- Native tree seedlings of cottonwood whips (Populus balsamifera spp. trichocarpa), willow whips (Salix spp.), red alder (*Alnus rubra*), hemlock (Tsuga heterophylla), Sitka spruce (Picea sitchensis), western red cedar (Thuja plicata), and West Coast Hemlock (Tsuga heterophylla).

Complexing Adjacent Forests: The health of waterways is very dependent on the adjacent forest. The idea behind complexing adjacent forests is to create an uneven-aged coniferous riparian zone resembling old-growth characteristics. Spacing, thinning, and managing for mixed wood improves diameter growth and species composition of conifer and deciduous trees. Modifying trees' components by topping and pruning allows birds, bats, and small mammals to populate the adjacent forest. Forest complexing strategies such as planting for biodiversity to create cover, shade, and refuge from predators also reduce stream bank erosion, increase infiltration, and improve water quality.

Road deactivation: Deactivation of the highest risk roads must be completed first, working from consecutively towards, but not necessarily including, the lower risk roads. Road and slope deactivation, stabilization, and rehabilitation are required to prevent landslides and further erosion. Grass-seeding and fertilizing slopes speed up the stabilization of slopes.

Landslide Revegetation: Bioengineering techniques stabilize active or high-risk slides in the watersheds. Native tree planting and live-willow staking stabilize the slopes and speed up the natural forest recovery process. Live willow cuttings forming Live Gully Breaks (LGB), Modified Brush Layer

(MBL), Live Pole Drain (LPD) develop self-maintaining, retaining walls. Open slope failures are hydro-seeded with a mixture of grass seed (native seed when available) with slow-release fertilizer and mulch to help prevent future erosion.

Discussion:

The past 150 years of colonial settlement, urbanization and industrialization have transformed ecosystems all across Vancouver Island. Historical logging practices have altered most salmon ecosystems across the island and would benefit from ecological restoration. Currently, there are many initiatives to restore salmon habitat, but the majority of the knowledge gained in these restoration projects remains mostly inaccessible or difficult to find. This project developed a StoryMap to bring together valuable information gathered from restoration projects to inform future restoration endeavours. The scope of information presented in the StoryMap is limited, but it presents project reports created from observations in the field that may help inform restoration in the future.

There are a few weaknesses to the methods presented in this project. One of the main drawbacks is the difficulty in accruing data. Data gathering is a slow process given that the data on habitat restoration projects is uncoordinated and difficult to access. It required a lot of digging and contacting the various organization and people to gather the data. Reports created before the 1990s are difficult to access as there are only physical copies of these reports scattered throughout the region. Many of these reports were not made on a computer and have never been digitized. Restoration practitioners and organizations mentioned that they also had many physical copies of older reports but that it would take a substantial amount of time to digitize them. Another weakness of this project is that it currently requires substantial effort to update the database and the StoryMap (Appendix 1). The databases used to create the maps in StoryMaps do not update automatically, and updating them is a time-consuming process.

Although this project's overall goal encompassed assessing various restoration practices' success, the lack of monitoring results found in these reports made comparing results a difficult task. The data gathered from these restoration reports is mostly qualitative, making a thorough statistical analysis of the information gathered difficult. Furthermore, monitoring results are not available in many of the project reports making it difficult to analyze the various approaches' success rate. Without proper monitoring, there is a tendency to repeat treatments without questioning their efficacy or future restoration projects' applicability.

Recommendations

For this StoryMap to become a useful tool, the updating process for both the database and the StoryMap must be streamlined and simplified. The ideal scenario would be a standardized online form filled by the restoration practitioners, which in turn updates the database and StoryMap. By integrating a practitioner self-evaluation system with the online database, the project could capture what is happening on the ground around the island in real-time. This platform could also help to highlight the work from restoration practitioners and create further links with in the restoration community. There is a growing opportunity to increase coordination and collaboration between governments, NGOs, First Nations, private practitioners and private firms towards meaningfully restoration of salmon ecosystems.

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Appendix:

How to Update Story Maps' Maps

1. **1.** Research for grey literature on this specific restoration topic.
    - Review projects from 'local experts, content experts and stakeholders to learn about other sources of grey literature they felt would be important to include in the review.
    - Search online databases with customized terms search using the "OR" and "AND" features whenever possible. The databases to be searched are:
    - Cross-Linked Information Resources (CLIR)
    - Fisheries Information Summary System (FISS),
    - Fisheries and Oceans Canada Library,
    - Web of Science
    - SCOPUS
    - Conduct methodological searches for grey literature in popular Web search engines such as Google.ca and Google Scholar (http://scholar.google. com/). Perform searches in the advanced search mode to control for specific vocabulary ("logging restoration salmon British Columbia"; "forest restoration salmon British Columbia"; "forest management salmon British Columbia"; etc.)

2. Input new data into GitHub .csv file on your desktop app

3. Open https://www.arcgis.com/home/user.html

4. Sign-in to ArcGIS

5. Open **Salmonid Ecosystem Restoration** Web Map on ArcGIS map viewer

6. Click on the 

button to Add Layer From File

7. Choose file from the GitHub folder that has previously been updated and click the IMPORT LAYER button

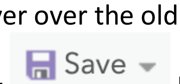
a. Change the "**Choose an attribute to show"** to Project ID #

b. Select Drawing Style: Types (Unique Symbols) >> Options

c. Go to the bottom of the list and click the  **Move All Values Out** button and click OK

d. Select DONE

8. Hover over the old layer and Click on , scroll down and click Remove

9. Click 

button and Save

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