An Assessment of the BC Forestry Riparian Program to Identify Opportunities for Monitoring Fish Habitats.

LWS 548 Major Project

By

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Executive Summary

The purpose of this white paper was to review the current monitoring of forestry activities in British Columbia riparian zones and its intent in protecting fish and fish habitats. Forests are one of the most important resources in supporting the BC's lumber industry. However, forestry activities have negatively impacted several major rivers and many small streams that are spawning and maturating habitats for fish species. Salmon resources are valuable in the BC fishing industry and indigenous peoples' livelihoods. Although sustainable forest management has been adopted including the need to protect vulnerable fish populations, the decline in salmon populations is alarming, and the forest monitoring protocol is not adequately successful for evaluating the conditions of fish habitats. This project identifies the strengths and opportunities for more effectively monitoring fish habitat conditions in logged riparian management zones.

A literature review of the BC Forest and Range Evaluation Program was conducted along with the riparian and aquatic habitat management protocols in Washington State (WA). In addition, this study assessed and compared a case study in each jurisdiction to identify potential improvements in BC's current management strategies. A contrasting analysis was conducted between the Memekay River (BC) under the Forest and Range Monitoring protocol and the Olympic Experimental State Forest Monitoring Protocol in WA. The differences between the scale and regulatory agencies of each jurisdiction monitoring program were identified and discussed. The present study identified shortcomings in addressing riparian and fish resource monitoring in BC.

Riparian ecosystems with high fish values demand a more sensitive method for determining optimal conditions. A site-specific technique and frequent sampling of the most critical indicators for fish habitats are required to detect small changes over time. The collection of long-term data would develop robust adaptive management protocol. All fish-bearing streams should have a reserve zone where logging is prohibited unless in-stream wood inputs are prescribed. Primary stream classes have a sufficient riparian management area for protecting fish habitats. However, the small-fish-bearing streams lack a reserve zone. In addition, large wood debris are a sensitive indicator of fish habitats, and their monitoring should not exclude length measurements.

Finally, the study recommends working on closer communication between the two jurisdictions to diagnose advancements and challenges related to the monitoring of riparian and fish habitats. Furthermore, it is recommended a more inclusive stakeholder representation that engages local communities and First Nations groups in riparian zone issues.

Introduction

Good quality riparian habitat ensures healthy fish populations. Salmon stocks in BC have declined due to habitat destruction and climate change (Bradford & Irvine, 2000). Riparian zones serve vital ecological chemical, physical, and biological services, such as nutrient processing, delivering woody debris and organic matter to streams, giving shade, stabilizing soils, and controlling microclimate. These vegetation strips run adjacent to ditches, streams, lakes, and wetlands, providing a buffer between waterways and land-use practices. (Naiman et al., 1993). Undoubtedly vegetation is a critical component of riparian ecosystems supporting aquatic, terrestrial, and amphibious wildlife habitat. Anadromous fish, a species that spawn in fresh water and matures in salt water (Opperman, 2006), is a keystone species of the BC coast. As they grow in the ocean, they accumulate vital nutrients in their bodies and deposit them in freshwater environments including riparian zones. (Naiman et al., 2002). This plays an essential role in ecosystem health, from the ocean to mountain streams and forests (Ocean Blue Project, 2019).

Common anadromous fish include salmon, steelhead, sturgeon, and lamprey (North Pacific Anadromous Fish Commission (NPAFC), 2017). However, Pacific salmon is one of the species most studied over the years due to its importance in the economy of First Nation Coastal Communities, such as the Coast Salish people that depend on salmon as a food source, as they have done for thousands of years. Salmon have served as a source of wealth and trade and deeply embedded in their culture and identity as First Nations people of Canada. Fish need suitable places to live, feed, and reproduce; moreover, open corridors to migrate and survive (Government of Canada (Gov.CA), 2019a). It is acknowledged that anadromous fish are at risk of becoming extirpated or extinct if they do not have access to productive habitats (Gov.CA 2019a).

Historically, British Columbia has lost hundreds of kilometres of riparian habitat in the past decades in the Lower Mainland alone (Goverment of British Columbia (Gov.BC), 2019b). Due to the development of l land-use activities such as agriculture, forestry, road construction and land development (Department of Natural Resources (DNR), 2006). The removal of riparian vegetation has directly impacted fish and fish habitats. Therefore, protecting riparian areas is a vital action of an integrated fisheries protection program (Gov.BC, 2019a). In BC, the Fisheries Act and the Species at Risk Act provide a holistic approach to conserving and protecting fish and fish habitats, supported by policies and programs that provide the long-term sustainability of freshwater and marine resources (Gov.CA 2019a).

The Riparian Areas Protection Regulation (RAPR) covers features, functions, and conditions vital for stream health and productivity (Gov.BC, 2021). However, accomplishing the protection of riparian areas and fish habitat is not straightforward and can become a jeopardized goal due to cumulative environmental effects (Plummer et al., 2005). Cumulative environmental effects are changes in the environment induced by past, current, and future actions in combination (Hegmann, et al., 1999). For instance, the cumulative effects of resource extraction, climate change,

overfishing, freshwater habitat deterioration and other human disturbances (Plummer et al., 2005) result in the decline of fish populations. However, natural shifts in marine ecosystems and climate can not be controlled; thus, monitoring land use activities should be prioritized to preserve aquatic resources in the short and long term.

Riparian ecosystems intersect with various land-use activities across British Columbia, such as forestry, agriculture, or urban development within city limits (Ball et al., 2012). Since the nineteenth century, coastal British Columbia's riparian forests have been heavily logged (Drushka, 1999). Coastal logging standards have been created to safeguard riparian forests near streams in British Columbia since 1986, but they have failed until a stricter code was implemented in 1995 (Poulin et al., 2000). Given the massive quantity of land logged before the Code, it is simple to foresee a significant number of riparian streams that require restoration (Poulin et al., 2000) Historic timber harvesting has been one of the causes of regional salmonid decline (Cederholm & Reid, 1987; Hicks et al., 1991). By changing species composition, decreasing abundance, changing the food basis, decreasing spawning success, or restricting fish access to upstream habitat (Cederholm & Reid, 1987; Sheer & Steel, 2006). The most common forest activities that endanger salmonids are land-use conversions; the amount and distribution of forest harvest; harvesting trees near to or through streams; the location of highways next to streams; stream road-crossings; splash damming, and wood removal from streams (Hicks et al., 1991). Negative consequences can last from a few years to centuries (Beechie et al., 2000). Therefore, the creation of evaluation programs to monitor logging activities and avoid fish habitat destruction has become extremely important.

British Columbia is a unique forest jurisdiction, and it contains vast and diverse forests and rangelands, and 95% of its land base is public land (Ten Brink, 2017). Much of this ecological diversity is a result of its northwest-southeast mountain topography, which has a significant influence on climate and vegetation. Conifers dominate the majority of British Columbia's forests (83%), with the most prevalent trees being lodgepole pine, spruce, fir, hemlock, redcedar, and Douglas-fir. (B.C. Ministry of Forests, Mines and Lands, 2010). Sustainable forest management is a priority for the government of British Columbia, and to achieve this, BC's forests are managed to sustain the multiple economic, social, and environmental benefits they provide to society and to minimize the environmental impacts of forest operations (Forest, Land and Natural Resource Operation, 2022).

British Columbia’s Forest and Range Evaluation Program (FREP) is the main legislative framework that provides results-based regulations to evaluate the status of resource values (fish/riparian) on public lands (Gov BC, 2003). The nature of the FREP monitoring program is based on averaged answers to several indicators/questions presented in a survey mode. It determines the success of forest and range operations (Gov BC, 2003) (Innes et al., 2020). However, despite BC forestry regulations and the protection of Riparian areas and fish habitats, monitoring is challenging, and the evaluation of the program is perhaps not compelling enough (J. Richardson, personal communication, April 29, 2022).

On the other hand, looking at a different jurisdiction, such as the Sate of Washington known for doing a more exhaustive monitoring (J. Richardson, personal communication, April 29, 2022) is key in the discussion of potential improvements in BC monitoring protocols. The State of Washington, with the support of agencies such as the Department of Natural Resources (DNR) are responsible for monitoring forestry activities on State lands (DNR, 2021). WA has several studies based on the county needs including the monitoring of riparian and aquatic habitat in the Olympic Experimental State Forest Monitoring Protocol (OESF) which describes how riparian and stream conditions are evaluated (Minkova, & Foster, 2017). The present study focused on logging activities and evaluation guidelines in BC riparian areas, contrasting them with monitoring guidelines from the State of Washington, U.S.A. The goal was to identify gaps in the BC Forestry Riparian Program and consider potential improvements in monitoring fish and fish habitats including the role of large woody debris in maintaining fish habitat and stream productivity.

Objectives

The study reviews the current Forest and Range Evaluation program (FREP) that monitors the condition of streams and Riparian areas. In addition, an analysis to evaluate potential improvements in the protocol by a comparison of the Washington State monitoring programs.

1. Include a review of the Forest practices protocol for evaluating the condition of streams and riparian management areas in British Columbia. Along with the riparian monitoring indicators/questions and their extent to protecting fish and fish habitat. And a review of Washington State's riparian and aquatic habitat management.
2. Employ one case study per jurisdiction for assessing the monitoring protocol performance. To better understand its strengths and identify potential improvements in the Forest and Range Evaluation Program.
3. Based on analysis and contrast, identify shortcomings in the monitoring indicators and the FREP protocol approach. Followed up by suggestions to improve the management of riparian zones, fish and fish habitats. Finally, the discussion will make a call upon to the New BC Ministry of Land, Water and Resource Stewardship as an opportunity to reinforce the current monitoring program of logging activities in riparian sites or nearby streams.

Methods

The study is based on a systematic literature review to acquire data and to provide a critical analysis, discussion, and recommendations.

1. Literature review of BC forestry activities and its monitoring program and a review of the Washington State Department of Natural Resources program. Through government documents and published references.
2. Compare the two case studies: using their respective protocol in the evaluation of habitat conditions and riparian management areas.
3. Present a discussion and further results of the most critical points of the riparian management program and the FREP monitoring protocol. Moreover, leading the results for the New BC Ministry of Land, Water and Resource Stewardship to re-evaluate the riparian management strategies and monitoring.

Literature Review

British Columbia: Forest and Range Evaluation Program fish/riparian monitoring

The Forest and Range Evaluation Program (FREP) was created in 2003 as a multi-agency program to monitor the standards and practices specified by the Forest and Range Practices Act (FRPA) (Gov BC, 2003). FREP's objective is to evaluate whether FRPA practices are satisfying the goal of the existing FRPA objectives and the government's broader intent for the sustainable use of resources (Tripp et al., 2022a). FREP has two main components: effectiveness evaluations and Resource Stewardship Monitoring. Effectiveness Evaluations are typically conducted at the provincial level and are intense in nature resulting in a detailed evaluation that includes quantitative data collection and analysis (Barber, 2004), At the district level Resource Stewardship Monitoring (RSM) comprises a routine and extensive overview monitoring of on-the-ground forest operations to assess if resource value objectives are being met (Barber, 2004). The RSM reveals "red flags" that may require further study and aids in the focus of more extensive effectiveness evaluations (Barber, 2004).

The Forest & Range Practices Act identifies and protects eleven resource values (Gov.BC, 2022a). A set of data collecting protocols are used to gather information on the resource values designed and delivered under the FREP (Gov.BC, 2022a). The resource values include biodiversity, water quality, soil, timber, fish/riparian, and others (Gov.BC, 2022a). The first objective of this document is to review and focus on the FREP fish/riparian monitoring, being more specific, the current protocol for Evaluating the Condition of Streams and Riparian Management Areas - Riparian Management Routine Effectiveness Evaluation (Tripp et al., 2022a). The FREP conducts annual resource value assessments in or near previously harvested regions (Nordin & Malkinson, 2021). The purpose of monitoring stream channels and associated riparian management areas is to establish if FRPA standards and practices are accomplishing the desired result of safeguarding fish values by maintaining channel and riparian functions (Tripp et al., 2022a). Indicators of biological

and physical processes are used to evaluate riparian management's efficiency in a stream and wetland functioning (Gov BC, 2003).

Every year, each participating BC district will be given a population list of 200 sites (cutblocks) that is created at random (Tripp et al., 2022a). However, the random list has a condition: harvesting activities must occur within one to three years; thus, at least one storm season has occurred (Tripp et al., 2022a). The idea is to choose sites under recent harvest practices with a minimum level of weather impacts. From the master list, each district will choose 10 sample blocks and each block sample is selected based on several factors (Tripp et al., 2022a). For instance, at least one stream of a reasonable length must be present within or adjacent to the block (Tripp et al., 2022a). Moreover, samples should represent consistent riparian management on at least one bank for 100m or 30x channel widths, whichever is greater (Tripp et al., 2022a). Furthermore, if more than one stream reaches within a block, sample reach should not drain into another (Tripp et al., 2022a). Supporting the notion that all samples are statistically 'independent.' The protocol suggests choosing the highest riparian class over the lower options (e.g., S2 before S3, or S5 before S6) (Tripp et al., 2022a). The number of sites sampled may change yearly based on available resources. However, the minimum is 30 samples over the latest five years (Tripp at al., 2022a). A stream riparian class table is described for a proper understanding of the sample characteristics.

Table 1: Stream riparian classes and Riparian Management Area standards (Tripp et al., 2022).

Riparian class		Stream width (m)	RRZ (Reserve zone) width (m)	RMZ (Management zone) width (m)	Total RMA width (m)	Min. stream length (m)
Fish- bearing	S1	>20	50	20	70	600
	S2	>5 ≤ 20	30	20	50	150
	S3	1.5≤ 5	20	20	40	100
	S4	<1.5	0	30	30	100
Without fish	S5	>3	0	30	30	100
	S6	<3	0	20	20	100

Definition of terms

Stream width: The average distance between undisturbed stream banks (Tripp et al., 2022b). It is also known as the Default stream width per stream class (Tripp at al., 2022a).

Riparian Reserve zone: Measured from the stream bank perpendicular to the channel, where no-harvesting activities occur on both sides of the stream (unless approved by the government in specific circumstances) (Tschaplinski, 2010a). It is the zone adjacent to the waterway (classes S1, S2, and S3) for all fish-bearing streams 1.5 m wide or more extensive. (Tschaplinski, 2010a)

Riparian Management zone: Measured from the stream bank perpendicular to the channel (Tripp et al, 2022a). The outer riparian zone bordering the reserve zone is where harvesting activities might occur (Tschaplinski, 2010a).

Total Riparian Management Area: The sum of the RRZ and RMZ areas is identified by a specific stream width range (Tschaplinski, 2010a).

Minimum stream length: To be qualified, the stream reach length must be 100 metres or 30x channel widths, whichever is greater (Tripp et al., 2022b).

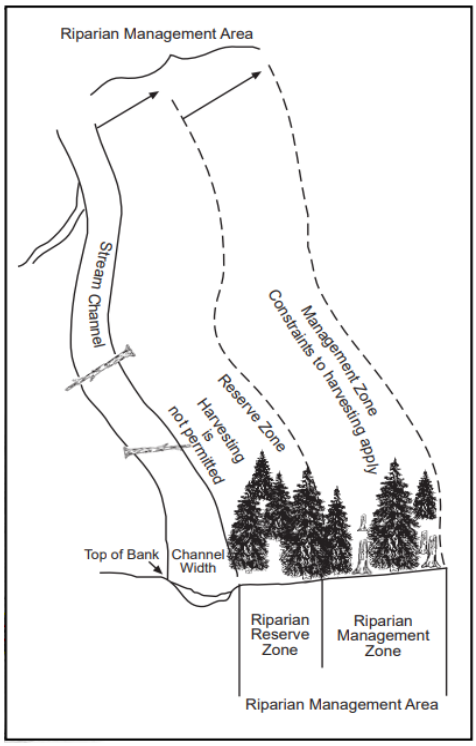

Figure 1. BC Riparian Management Area (FPB, 2021)

Indicator thresholds and origin

The Forest and Range Evaluation Program Riparian Protocol considers 15 indicator questions to assess the status or health of a stream reach (Tschaplinski & Brownie, 2010b). These are the kinds of questions that stream, and riparian professionals might ask themselves to assess a stream's condition or health at a given point (Tripp et al., 2022a). The 15 indicators were chosen by a multi-disciplinary and multi-agency FREP team of scientists and technical experts from the (former) British Columbia Ministry of Forests and Range (Research Branch), the British Columbia Ministry of Environment, the Forest Practices Board, the University of British Columbia, Fisheries and Oceans Canada, and biologists and geomorphologists (Tschaplinski, 2010a).

The origin of the 15 indicators started with a first set termed a “detailed” method developed for more intensive and quantitative measurements geographically (Tschaplinski, 2010a).
The first set consists of 22 “extensive-level." indicators where thresholds were envisioned to be adjustable geographically (Tschaplinski, 2010a). Therefore, the method was used by experienced specialists in post-harvested riparian areas and their adjacent streams and fish habitats (Tschaplinski, 2010a). The extensive-level method examined 61 prospective indicators from scientific and resource management literature (Tschaplinski, 2010a). For instance, references to other jurisdictions such as the “Montana method” (Hansen et al. 1995, 2000) concepts of proper functioning condition references by the United States Department of the Interior, Bureau of Land Management and several BC forest and environmental codes (Prichard et al., 1998). In order to assess riparian areas, streams, and fish habitats as accurately and rapidly as possible under FREP, the second set of indicators and techniques, known as the "routine-level" or Resource Stewardship Monitoring protocol, was developed and field-tested from the best features of the first set (Tschaplinski, 2010a).

The criteria utilized to select the most appropriate indicator thresholds were as follows: trustworthy scientific data; relevance and responsiveness to forestry practise, notably riparian management, and road systems; extensive geographic coverage; and the ability to assess changes in ecological processes and circumstances (Tschaplinski & Brownie, 2010b). The indicators are all interdependent due to the natural ecological linkages of stream-riparian systems (Tschaplinski & Brownie, 2010b). Therefore, the indicator questions should function for the whole province and different stream types (Tripp et al, 2022a). The FREP riparian protocol agrees that it would be ideal to have a nearby un-harvested reference or control when a harvested site is assessed (Tripp et al., 2022a). However, it is recognized that it is hard to implement a large-scale monitoring program because of the difficulties in locating suitable control streams and riparian regions to serve as reference sites (Tripp et al., 2022a). Therefore, it uses an alternative approach, based on threshold values of empirical data to add natural variation (Tschaplinski & Brownie, 2010b). This way, undisturbed conditions are produced, and the resulting conditions due to forestry practices can be determined (Tschaplinski, 2010a).

The empirical data is based on research BC studies conducted from 1970 to the present. This study involved a 15-year series of paired-watershed research (88 streams, unharvested vs. harvested) (Tschaplinski, 2010a). Ten major forested Biogeoclimatic Ecosystem Classification (BEC) zones and four physiographic zones throughout British Columbia focused on the physical attributes of streams (Tschaplinski, 2010a). The literature reviewed from the Montana method is based on thousands of observations of streams (Tschaplinski, 2010a). The Montana Method's thresholds were derived from thousands of observations of streams in various functioning stages across the western United States (Tschaplinski, 2010a). Threshold indicators values of fish habitat diversity, benthic invertebrate diversity, substrate embeddedness, aquatic connectivity, windthrow and vegetation form and vigour were partially derived from the conclusions of an experts' workshop (Tschaplinski, 2010a).

Evaluation questions

Resource Stewardship Monitoring (RSM) for streams and riparian areas is based on a checklist of 15 questions (Tschaplinski & Tripp, 2017). Nine questions are related to the stream channel and bank conditions, and six indicators are about riparian area conditions (Tschaplinski & Brownie, 2010b). For instance, channel bed disturbance, channel bank disturbance, LWD features, channel shape, aquatic connectedness, fish cover diversity, fine sediments, and aquatic invertebrate diversity were among the stream indicators (Tschaplinski, 2010a; Ball et al., 2012). Riparian area indicators included windthrow frequency; soil disturbance and bare ground; LWD supply/root network; shade and bank microclimate; disturbance increaser plants, noxious weeds, and invasive plants; and vegetation, form, vigour, and recruitment (Tschaplinski, 2010a). Each of the 15 questions in the riparian assessment requires a Yes (pass), No (fail), or not applicable (NA) response. The indicator statements for each question are more accurately referred to as "Logic" statements, where (Yes) always means "healthy" while (No) always means "not healthy" (Pickard

et al., 2014; Tripp et al., 2022a). The FREP Riparian Protocol requires addressing 15 questions (Table 6) relating to the characteristics of healthy streams and their aquatic and riparian habitats. Ten of the fifteen questions will apply to all sites (Tripp et al., 2022a). When a question is irrelevant is indicated as Not applicable (NA), five of the questions may be irrelevant (Tripp et al., 2022a). For example, Question four on stream morphology only refers to riffle/cascade-pool or step-pool streams. It does not apply if the stream is "non-alluvial" or in other words if a stream does not actively erode or deposit bank materials (Tripp et al., 2022a).

Nine out of fifteen questions in most streams require multiple No responses to a specific indicator before the question can be answered No (Tschaplinski & Tripp, 2017). The indicator sub-questions are linked to specific properties that can be objectively analyzed or measured to support the main questions' responses (Tschaplinski & Tripp, 2017). The 15 main questions are answered Yes or No based on the amount of Yes or No responses to indicator sub-questions (Tripp et al., 2022a). A stream riparian evaluation requires between 114 and 120 measurements and observations, depending on channel shape, substrate conditions, and fish use, and is based on 38-60 specific indicators covered by checklist statements that support the main checklist questions (Tschaplinski & Tripp, 2017). Measurements of channel width, depth, and gradient, as well as vegetation retention in the riparian area, are included in each assessment. (Tschaplinski & Tripp, 2017).

After the assessment of the 15 key indicators, a specific stream can be categorized into one of four possible outcomes based on the number of "no" responses:

- Properly Functioning Condition (PFC): From 0 o a maximum of 2, no responses or issues about the riparian and stream channel indicator (Pickard et al., 2014; Tripp et al, 2022a).
- Functioning at Risk (FR): Also known as (PFC) with limited impacts or PFC-L. It has from 3 to a maximum of 4 no responses or issues related to the riparian and stream indicator (Pickard et al., 2014; Tripp et al., 2022a).
- Functioning at High Risk (FHR): Also known as (PFC) with impacts or PFC-I. It has from 5 to 6 no responses or issues (Pickard et al., 2014; Tripp et al., 2022a).
- Not Properly Functioning (NPF): When a riparian reach has more than six no responses or issues (Pickard et al., 2014; Tripp et al, 2022a).

The PFC and FR outcomes correspond to the "very low" and "low" impact ratings used in FREP, respectively (Tschaplinski & Tripp, 2017). When a stream-riparian site with post-harvested conditions is classified as Properly Functioning Condition (PFC), it means that the stream, river, wetland, or lake and its riparian area can: withstand regular peak flood events without accelerated soil loss, channel movement, or bank movement; filter runoff, and store and safely release water (Tschaplinski & Tripp, 2017). Moreover, maintain stream connection, so fish habitat is not lost or separated because of management actions (Tschaplinski, 2010a). Furthermore, the riparian habitat can offer shade and minimize bank microclimate while maintaining an appropriate root network or large woody debris (LWD) supply. (Tschaplinski, 2010a). The Riparian Management Area

Guidebook (Province of BC 1995) states that riparian habitats will be maintained in proper functioning condition if the impacts of development on the attributes of the riparian area are (Gov.BC, 2022b):

1. Small or within the range of natural variability of the habitat, or
2. Large and beyond the range of natural variability in no more than a small portion of the habitat (Gov.BC, 2022b).

The fundamental underlying assumption is that if the range of impacts attributable to the management activity affecting the riparian habitat lies "within the range of natural variability over the length of the stream being assessed, it is likely that the natural ecological functions of the habitat will be maintained." (Tschaplinski, 2010a). It is important to note that the assessment assumes no long-term data, such as basic water quality metrics, and that multiple trips will be impossible in virtually all circumstances (Tripp et al., 2022a). Hence the checks should be considered "snapshots" in time (Tripp et al., 2022a). The document Protocol for Evaluating the condition of streams and Riparian Management Areas, Riparian Management Routine Effectiveness Evaluation updated in March 2022 version 6.1(Tripp et al., 2022a) contains all the details about the 15 evaluation questions.

Types of Indicators.
The riparian checklist requests information or observations on three sorts of indicators: "Point," "Continuous," and "Other" (Tripp et al., 2022a).

Point Indicators: They are calculated at distinct positions along a traverse. At least six measurements should be taken at roughly equal intervals during the journey (Tripp et al., 2022a). Measures are averaged and must be conducted in riffles or shallow areas (Tripp et al., 2022a).

Continuous indicators: They are measured or estimated along the whole length of the reach. Precise measurements are required when the anticipated percent of the reach or riparian area represented by the indication is uncertain or close to the threshold (Tripp et al., 2022a).

Other indicators: are documented or counted during the traverse but do not have to be measured at five or six discrete sites or constantly during the trip (Tripp et al., 2022a). These indicators are best documented after an entire stream and riparian region examination before any specific measurements are taken (Tripp et al., 2022a).

A summary of the fifteen questions

The first question is about channel bed disturbance, which aims to identify the sediment supply in a stream system based on the reach length and the presence of channel bars (Tripp et al., 2022a). Bed disturbance is observed in watersheds with several recent or active slides, eroding roads, or

banks. Whether a channel is aggraded or filled in, its morphology becomes disturbed because the riffles extend longitudinally into pools (Tripp et al., 2022a). Undisturbed beds supply fish-friendly resting, spawning, and feeding sites (Tripp et al., 2022a). Channel bank is another aspect that should not be disturbed. Forest harvesting or overgrazing can decrease or eliminate the volume of deep-rooted vegetation on the banks of aquatic environments, reducing the banks' ability to resist erosion caused by fluvial action (Tripp et al., 2022a). Stream banks that have recently been disturbed usually cause the loss of a stable undercut bank or overhanging vegetation (Tripp et al., 2022a). Resulting in fish passage problems or channel bed changes downstream.

Large Woody Debris (LWD) is defined as branches or stems having a diameter equivalent to 10% of the channel depth at the crest of the riffles (Tripp et al., 2022a). The indicator's goal is to keep track of the LWD process, such as how, when, and where it enters (Tripp et al., 2022a). Moreover, the pieces' age, abundance, width, orientation, and distribution (Tripp et al., 2022a). In many streams, large woody debris is critical for channel creation as well as the diversity and stability of ecosystem elements (Tripp et al., 2022a). It improves fish habitat by lowering stream velocity and providing habitat cover and organic material for stream invertebrates (Tripp et al., 2022a). Whether streams are dependent or not on wood, changes in channel wood processes can significantly impact the fish habitat characteristics of streams (Tschaplinski & Brownie, 2010b). Channel morphology disturbance indicates the presence and breadth of pools and deep pools. One of the characteristics of productive fish streams is the frequent occurrence of pool-riffle sequences (Tschaplinski & Brownie, 2010b). Excess sediments (such as gravels, cobbles, or boulders) can block the distinctions between pools and riffles, reducing the productive fish habitat. (Tripp et al., 2022a; Tschaplinski & Brownie, 2010b)

The next indicator is Aquatic Connectivity which means the longitudinal connectivity in the channel, between the channel and its tributaries, and between the channel and its flood plain (Tripp et al., 2022a). Undisturbed channel connectivity allows regular and unimpeded movements of fish, organic debris, and sediments (Tschaplinski & Brownie, 2010b). Fish require seasonal habitat, while fish at different life stages require varied environments (Tripp et al., 2022a). For instance, freshly formed logjams can create sediment traps which might harm fish habitat in the short-term (<10 years) by preventing sediment flow downstream (Tschaplinski & Brownie, 2010b). Fish cover diversity evaluates the presence of seven different potential types of fish cover (Tripp et al., 2022a). Such as deep pools, stable unembedded boulders, stable root wads, woody debris, and other organic material (Tschaplinski & Brownie, 2010b).
Moreover, stable (usually vegetated) undercut banks, submerged or emergent aquatic vegetation, overhanging vegetation and stable unembedded gravels and cobbles with void spaces for fish to hide (Tripp et al., 2022a). A diversity of fish cover types in a stream result in more chances for fish to be protected from predators and currents (Tripp et al., 2022a).

Healthy moss on the boulders or cobbles of a stream riffle is a sign of clean water, stable flows, a stable streambed, and proper shade and nutrition levels (Tripp et al., 2022a). In addition, fish numbers and/or invertebrate productivity are linked to the abundance of moss on cobble or boulder-bedded streambeds (Tschaplinski & Brownie, 2010b).
Fine sediment presence is also part of the monitoring program. Excess sediments can cause channel aggradation affecting fish and invertebrate habitats by filling in the substrate's nooks and crannies or blanketing the surface (Tschaplinski & Brownie, 2010b). Only streams with a mineral substrate are addressed in this question (Tripp et al., 2022a). Aquatic invertebrate diversity is an indicator that can be quickly impacted by a wide range of substances such as sand, silt, poisonous chemicals, and inorganic or organic contaminants (Tschaplinski & Brownie, 2010b). The richness of the benthic invertebrate community can be a direct assessment of properly functioning conditions (Tripp et al., 2022a). A stream with stable gravel and cobble substrates will have a more diverse and abundant benthic invertebrate community than a streambed composed mainly of fines or organic detritus (Tripp et al., 2022a).

The amount of windthrow directly indicates the management zone's success in protecting the reserve zone (Tripp et al., 2022a). If a stream lacks riparian reserve, the management zone width is still present to protect key wildlife attributes of natural riparian systems surface (Tschaplinski & Brownie, 2010b). However, If the trees that have been retained are blown down, critical wildlife characteristics will likely be altered surface as well. Windthrow can cause considerable wood input into stream channels, leading to logjams and channel erosion surface (Tschaplinski & Brownie, 2010b). Riparian soil disturbance considers the total bare erodible ground in the riparian zone's first 10 m (from upslope sources) (Tripp et al., 2022a). Soil disturbance is caused by different stressors such as roads, animals, machinery and hydrologically connected bare ground surface (Tschaplinski & Brownie, 2010b). The exposed soil or erodible mineral deposits can be washed into a nearby stream (Tripp et al., 2022a). Any soil or fill with particles smaller than 4 mm (small "pea" gravel or coarse sand) that is not covered by plants, litter, lichens, moss, felled wood, coarser gravel, or boulders is referred to as bare erodible ground surface (Tschaplinski & Brownie, 2010b). Exposed soil that has been eroded leads to stream channel infilling and bank erosion, decreases sediment entrapment, changes rainfall-runoff rates, and allows vegetation invasion surface (Tschaplinski & Brownie, 2010b).

Retention in Riparian Areas for Root Networks and Large Woody Debris Supply: An appropriate root network is required to sustain bank strength in all streams (Tripp et al., 2022a). In conjunction with LWD, roots help retain the channel structure of many small streams (< 2 m wide) (Tschaplinski & Brownie, 2010b). A healthy root system will include various shrubs, understory and overstory trees (Tripp et al., 2022a). The first 10 metres of riparian vegetation are crucial for contributing big woody debris to the stream (Tripp et al., 2022a). However, the goal of this question is not to verify if a reserve zone (20 or 30 m) has been preserved but rather to ensure that the supply of LWD is adequate within the first 10 metres (Tripp et al., 2022a). The next indicator is shade and bank microclimate. Shade in riparian environments is essential for regulating air

temperatures and preserving soil moisture levels on hot days (Tripp et al., 2022a). A plant's shade depends on its type, height, and density (Tripp et al., 2022a). In addition, trees, shrubs, and grasses in riparian areas provide vegetative cover that reduces rain splash erosion on exposed soils while fulfilling various other purposes (Tschaplinski & Brownie, 2010b).

Disturbance-increaser species are native or introduced plants that can be absent or only present in small numbers in undisturbed environments (Tripp et al., 2022a). These plants quickly grow under a constant state of disturbance, such as grazing or active roads and trails, which can increase their prevalence (Tschaplinski & Brownie, 2010b). On the other hand, noxious weeds can also be disturbance-increaser species, but they are non-native (invasive) highly competitive species (Tripp et al., 2022a). Noxious weeds can quickly spread across huge regions, inhibiting the growth of healthy, natural riparian habitats (Tripp et al., 2022a). The goal of the question is to know if each plant group is under the minimum range in the first 10 m of the riparian zone (Tripp et al., 2022a). A high number of disturbance-increaser species and noxious weeds cause less soil-holding and sediment-trapping capabilities, affecting the water quality of the stream reach (Tschaplinski & Brownie, 2010b).

The final question is about riparian vegetation form and structure. Question 15 intends to know the vegetation status on the first 10 m of the stream reach and conclude if it is a healthy riparian area or not. Moreover, it indicates that a healthy riparian area usually has a tangle of herbaceous vegetation, shrubs, and trees (diversity) (Tripp et al., 2022a). In addition, the vegetation should exhibit good vigour and growth and controlled levels of disturbances such as grazing and browsing (Tschaplinski & Brownie, 2010b). The background of this question is based on how unmanaged riparian forests look in different Biogeoclimatic Ecosystem Classification systems (BEC) or BEC zone variants (Tripp et al., 2022a). Therefore, the protocol recommends looking at different BEC zones or the nearest unmanaged riparian area as a reference before initiating any riparian assessments (Tripp et al., 2022a).

Washington State: Monitoring of Riparian and Aquatic Habitat

The Forest Practices Act of Washington was established in 1974, and since then, forestry activities on non-federal public and private lands have been regulated. (McIntyre et al., 2018; DNR, 2021). The Forest Practices Rules protect resources such as soils, water, fish, and wildlife. The Act aims to safeguard public resources while sustaining the forest products business (DNR, 2021). In 1987, the TFW (Timber, Fish and Wildlife) agreement was created by the Washington Forest Practices Board (WFPB) to make the best judgments possible for forest-based natural resource management (McIntyre et al., 2018). All the Washington forests adopted the TFW agreement practises parties, including environmental groups, state agencies, the timber sector, and Native American tribes (McIntyre et al., 2018). A crucial result of TFW was creating an adaptive management program to bridge knowledge gaps and suggested prospective policy adjustments using data from ongoing research and monitoring (McIntyre et al., 2018). Research and monitoring needs were outlined in a work plan by the Cooperative Monitoring, Evaluation and Research Committee (CMER) (DNR, 2022b). As a result, the Forest Practices Board established the CMER to guarantee that the Forests and Fish Report's recommendations are carried out effectively (DNR, 2022b)

The Forests and Fish Report was issued in 1999 to protect water, aquatic species such as fish and riparian habitat of non-federal forestlands while keeping the Washington timber industry economically viable (DNR, 2022a). In 2001, the Forests and Fish Report became the Forests and Fish Law (McIntyre et al., 2018). The Forest and Fish Law focuses not only on the TFW protection agreement but also on the agreement's constraints (McIntyre et al., 2018). Including the establishment of a well-funded and functional adaptive management with the explicit intent of complying with the federal ESA (Endangered Species Act) and the CWA (Clean Water Act) (McIntyre et al., 2018). The purpose was to "create biologically sound and economically feasible methods for improving and protecting riparian habitat on non-federal forestlands in Washington. These regulations were created to help achieve the WFPB's four main objectives (DNR, 2022a):

a. Comply with the ESA for aquatic and riparian-dependent species (DNR, 2022a) (including Forests and Fish-designated stream-associated amphibians),
b. Restore and maintain riparian habitats to support a harvestable supply of fish (DNR, 2022a),
c. Meet the CWA's water quality requirements (DNR, 2022a) and
d. Maintain the state's timber industry's economic viability (DNR, 2022a).

In response to the Federal listing of some vulnerable and endangered fish species, the Department of Natural Resources (DNR) produced the Forest Practices Habitat Conservation Plan (HCP) on behalf of the State of Washington (DNR, 2021). The HCP was approved by the US Fish and Wildlife Service and NOAA's Marine Fisheries Service in 2006 (DNR, 2021). It is a 50-year agreement that protects aquatic species habitat, supports economically viable and healthy forests and provides regulatory stability for landowners by including 60,000 miles of stream habitat across 9.3 million acres of private and state forestland (DNR, 2022a).

One of the outcomes of the TFW in 2001 was the establishment of Riparian Management Zones (RMZ) near the banks of rivers, streams and lakes (McIntyre et al., 2018). The RMZ standards for fish-bearing streams in western Washington (Type S and F waters) demand a three-zone buffer (Fairweather, 2001). Type S water (WAC 222-16-030) are all waters, within their bankfull width, inventoried as "shorelines of the state" under chapter 90.58 RCW and the rules promulgated under chapter 90.58 RCW, including periodically inundated areas of their associated wetlands (Minkova, & Foster, 2017). Moreover, Type F water (WAC 222-16-030 is within the bankfull width of defined channels and contains fish (Minkova, & Foster, 2017). The development of three zones was defined as a "riparian strategy," resulting from a series of conversations and compromises involving numerous stakeholders (Fairweather, 2001).

The zones are generally described as follows: the core zone, a 15 meters wide "no-touch area" adjacent to the stream; an inner zone, an area between 15 and 24 to 46 meters from the stream with restricted management activity; timber harvesting can occur in this zone if it follows the “Stand requirements” which are essential to meet the desired future condition (DFC) (WAC 222-30-021) (Fairweather, 2001). The term stand requirements mean the number of trees per acre, the basal area and the proportion of conifers in the combined inner zone and bordering core zone; thus, tree growth can fulfill desired future conditions (Fairweather, 2001). The DFC demands leaving the

riparian area in a condition that can replicate a natural forest stand at the age of 140 years (WFPA, 2022).

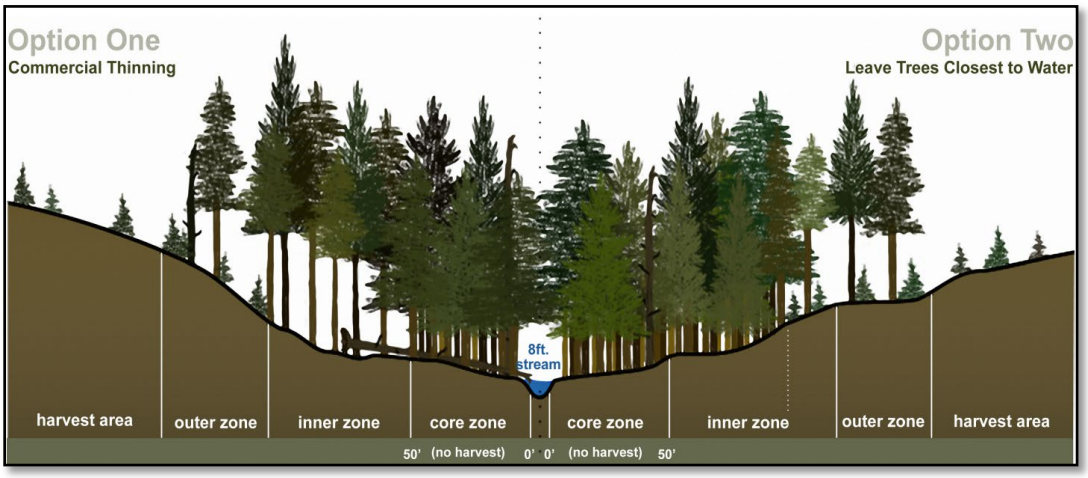

Figure 2. Washington State Riparian Management Zone and two approaches to forestry activities. (WFPA, 2022)

Finally, the outer zone extends from the outer edge of the inner zone to a distance equal to one site's potential tree height (SPTH) from the bankfull width or channel migration zone, whichever is greater (Fairweather, 2001). The outer zone can be managed, but it must retain 10 to 20 riparian trees per acre depending on additional management constraints in the stream channel, core, or inner zone (Fairweather, 2001). All distances are measured horizontally from the stream (Fairweather, 2001). The term "Site Potential Tree Height" (SPTH) refers to the expected height of a tree at stand age 100 for a given site class (Fairweather, 2001). Douglas-fir growth was used as a reference to calculate the SPTH (McConnell, 2010). These SPTH values correspond to the average total height of dominant and co-dominant trees at 100 years of age (McArdle & Meyer, 1961). Moreover, the two management options will achieve the DFC and have a core no-harvest zone of 50 feet or 15 meters. Option 1 calls for thinning to foster the growth of large trees more quickly and option 2 places additional trees along the stream (WFPA, 2022).

The table below summarises RMZ widths related to stream size, site class and management choice. The DNR State Lands uses a numerical system (one through five) to categorize streams based on their physical characteristics, such as stream width and steepness, whether fish are present or not (Devine et al., 2022). Type 1 streams are the largest and type 5 streams are the smallest (Devine et al., 2022).

Although the RMZ widths are initially measured in feet, this study uses meters as a unit for comparison purposes.

Table 2. Management Option 1 (Thinning from below in the inner zone) (Fairweather, 2001)

Site Class	RMZ Width or SPTH (m)	Core Zone Width (m)	Inner Zones Width (from the outer edge of the core zone) (m)		Outer Zone Width (from the outer edge of the inner zone) (m)	
			Stream width ≤ 3 (to 2/3 SPTH)	Stream width > 3 (to 3/4 SPTH)	Stream ≤ 3	Stream > 3
I	60	15	25	30	20	15
II	52	15	19	24	17	13
III	43	15	13	17	14	11
IV	33	15	7	10	11	8
V	27	15	3	5	9	7

Table 3. Management Option 2 (Leaving trees closest to water in the inner zone.) (Fairweather, 2001)

Site Class	RMZ Width (m)	Core Zone Width (m)	Inner zone width (m)				Outer zone width (m)	
			Stream width ≤ 3	Stream width ≤ 3	Stream width > 3	Stream width > 3	Stream width ≤ 3	Stream width > 3
			Measured from the outer edge of the core zone					
I	60	15	26	9	26	15	20	20
II	52	15	19.5	9	21	15	17	15
III	43	15	13.4	9	**	**	14	**

** Option 2 for site class III on streams > 3 m is not permitted because of the minimum floor (30m) constraint (Fairweather, 2001).

Case study: British Columbia

The following case study illustrates the use and results of the Forest and Range Evaluation Program (FREP) performed in the Memekay River watershed (Pickard et al., 2018). It is important to mention that the Memekay River case study is a watershed status evaluation report (Pickard et al., 2018). Therefore, it measures other indicators besides the riparian/stream condition. However, the protocol to monitor forestry activities in the riparian habitat is the same as discussed earlier in the literature.

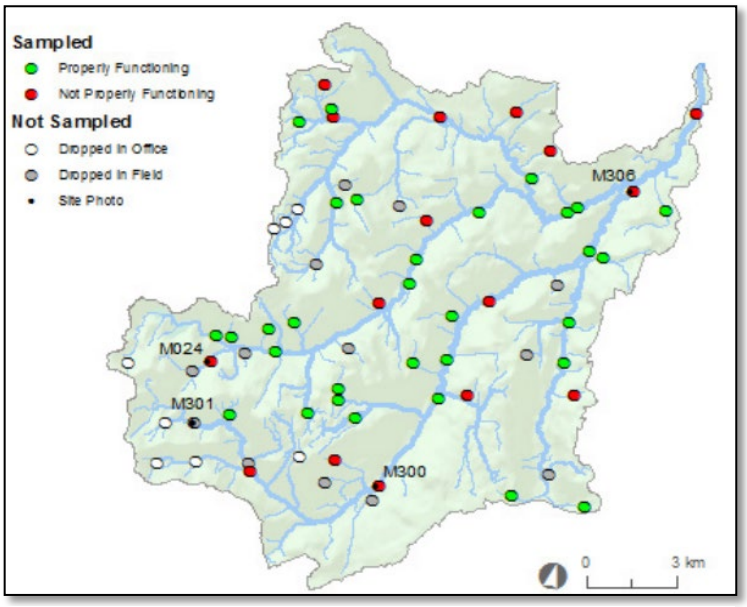

Figure 3. BC Riparian Management Area (FPB, 2021)

Study area and background

The Memekay River watershed is located north of Campbell River on Vancouver Island (Pickard et al., 2018). It is an essential habitat for several fish species such as Chinook, chum, pink, Coho salmon, steelhead trout, cutthroat trout, rainbow trout and Dolly Varden Char (Stewardson et al., 2000). In 2005, forest harvesting was first documented in the watershed in 1946, but it most certainly occurred earlier, and it is the principal activity in the watershed today (Pickard et al., 2018). According to satellite photos from 2006, a significant percentage of the watershed has been harvested. It was designated a Fisheries Sensitive Watershed because of its high fish value and natural terrain instability (Pickard et al., 2018).

Results

The study selected 48 random riparian reaches addressed under the FREP Riparian Management Evaluation Protocol. The 15 indicator-based questions assessed the health condition of each stream and its adjacent riparian area (Pickard et al., 2018).

Stream channel Functioning Condition	Result
PFC	16
PFC-L	15
PFC-I	11
NPF	6
Sites	48

Table 4. Summary of the health condition of the riparian sites in Memekay Watershed (Pickard et al., 2018).

The report classified three habitat categories based on the presence of fish habitat: non-fish habitat (NFH), Fish habitat first & second order and Fish habitat ≥ third order (Pickard et al., 2018). The

box plots in Table 5, show the riparian functional condition rating variation among assessed stream sites and habitat groups (Pickard et al., 2018).

	PFC (n=16)			PFC-L (n=15)		PFC-I (n=11)		NPF (n=6)			N
NFH		1	4	1	1		2	1			10
FH 1&2	2	1	3	2	3	2	2	2	1	1	19
FH ≥ 3	1	1	3	5	3	3	2		1		19
	0		2		4		6		8	10	

Table 5. Rollup of riparian samples. Each number in the table represents a number of survey sites receiving a corresponding number of "no" answers (x-axis) by strata (y-axis). Coloured columns represent functional condition categories (Pickard et al., 2018).

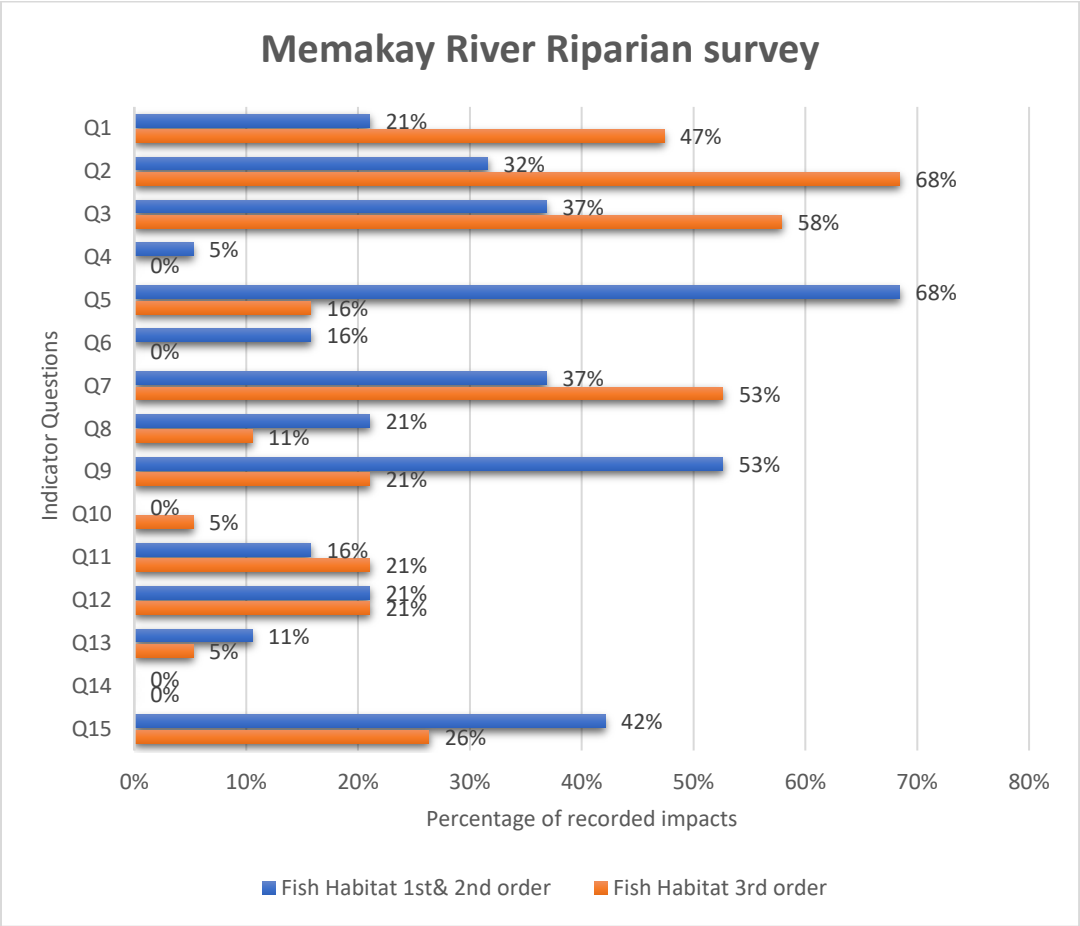

Chart 1: Summary of each channel and riparian question used in the riparian reach surveys. Increasing numbers indicate a higher frequency of recorded impacts related to each riparian question (Pickard et al., 2018).

Table 6. A total of fifteen questions were used to assess the relative health, or "functional condition," of a stream and its riparian ecosystem (Tripp et al., 2022a).

Q #	Riparian Question/ Indicator	Method	Results & Implications
	Four types of channel morphology are referred to in Questions 1 to 4. They include riffle-pool or cascade-pool type streams (Section A), step-pool streams (Section B), and non-alluvial streams (Section C). It was chosen and survey only one section based on channel type		
1	Is the channel bed undisturbed?	Measures mid-channel bars, lateral bars, and braided channel bars presence. Moreover, moss present along the channel bed.	Two Yes answers to the indicator sub-questions are required to answer a general Yes to the main question. The question is judged relatively leniently.
2	Are the channel banks intact?	Measures the length of a stream reach with recently disturbed banks, rooted vegetation, stable undercut banks and upturned root wads.	Indicates recent bank disturbance. Section A&B has four sub-questions; if the answer is Yes to 3 or more, it is marked as a main Yes. Section C has three sub-questions. Again, the main answer is yes if two or more are Yes.
3	Are channel LWD processes intact?	LWD is wood with a diameter of 10% or greater than the channel depth at riffles. Smaller-diameter components are not accepted. Length is irrelevant. It measures the No of wood accumulations, new and old wood accumulations and their orientations.	Categories A&B have up to five indicator sub-questions. If the answer is "Yes" to 4 or more, Q3 is marked as Yes. Category C has four sub-questions. If the answer is Yes to 3 or more, it is marked as a main Yes.
4	Is the channel morphology intact?	It is NA if the stream is "non-alluvial" It measures the number of deep pools and lengths.	It has three indicator sub-questions, two on pool habitats and one on sediment variability
5	Are all aspects of the aquatic habitat sufficiently connected to allow for normal, unimpeded movements of fish, organic debris, and sediments?	It evaluates current blockages to fish, such as sediments, debris, downcutting (the vertical movement of the channel), crossing structures, and water diverted by roads and trails.	Covered by eight indicator sub-questions. It always has high importance; thus, the answer to Question 5 is No if even one indicator sub-question is No.
6	Does the stream support a good diversity of fish cover attributes?	It is NA if the stream is non-fish-bearing. Detects the existence of seven distinct types of fish cover. Each cover should account for at least 1% of the channel area.	There are seven sub-questions, and if there are two sub-questions with No answers, the main question-answer is No.

7	Does the amount of moss present on the substrates indicate a stable and productive system?	It is NA if the streambed is naturally composed of muck, fines, or organics. Measured from the bottom of one bank to the bottom of the other. It is an estimated percent of moss coverage in a square plot (abundance) and the health condition.	Comprises three sub-questions. All of them need to be Yes to mark Q7 as a Yes.
8	Has the introduction of fine sediments been minimized?	It is NA if the streambed is naturally all muck, fines, sands, or organic material. It measured the percentage of fines or sands <2mm in diameter from the bottom of one bank to the bottom of the other in a straight line across the channel.	Four indicator sub-questions address sand and fine-size inorganic sediments. If the answer is No to any statement, Question 8 is No
9	Does the stream support a diversity of aquatic invertebrates?	It is NA if high water conditions prevent adequate sampling, or the stream is dry or has recently been dry or exposed to high flows due to natural conditions. This indicator records the number o sensitive invertebrate types, major groups, insects per type and total No.	There are four indicator sub-questions. Two of them or more need to be Yes to marked Q9 Yes.
10	Has the vegetation retained in the RMA been sufficiently protected from windthrow?	It measures the total number of standing trees and new and old windthrow. The applicability of the sub-questions will depend on the presence of a reserve zone (no harvest) or only a management zone.	Three indicator sub-questions, and only one or two can apply to any given stream. Therefore, if the answer is No to any statement, Q10 is No.
11	Has the amount of bare erodible ground or soil compaction in the riparian area been minimized?	It measures Bare soil and disturbed ground in the first 10m (m2), plus all bare soil and disturbed ground hydrologically connected to the first 10m (m2).	Four sub-questions and all of them need to be Yes to mark Q11 Yes.
12	Has sufficient vegetation been retained to maintain an adequate root network or LWD supply?	Retention levels are estimated visually in the first 10m of the riparian zone.	It has seven indicator sub-questions based on the stream classification and retention levels. All of them need to be answered Yes to consider Q12 Yes
13	Has sufficient vegetation been retained to provide shade and reduce bank microclimate change?	Shade is measured at a 60-degree angle to the E, S, and W, looking through a circle made by thumbs and forefingers angle. It is an entirely visual method of estimation	Four indicator sub-questions about shade and moisture in a riparian area. Three or more of the sub-questions need to be answered Yes
14	Have the number of disturbance-increaser plants, noxious weeds and/or invasive plant species present been	Records the percentage of disturbance plants and noxious weeds within the first 10 m of the riparian area on each side of the stream. All	Two indicator sub-questions about disturbance-increaser plants and noxious weeds or invasive species. All

	limited to a satisfactory level?	lines should be perpendicular to the main axis of the stream reach.	statements need to be answered Yes.
15	Is the riparian vegetation within the first 10m from the edge of the stream generally characteristic of what the healthy unmanaged riparian plant community would normally be along the reach?	It recognizes ten vegetation types: gaps, snags, dominant and co-dominant trees, understory trees, tall and low shrubs, herbaceous vegetation, ground cover, lichens, and CWD. Estimates the abundance, browse level and vigour of each type.	Four sub-questions serve as indicators. Question 15 is marked Yes if there are three or more answers.

BC Case study conclusions and recommendations

The study compared harvested sites in two eras prior to the establishment of the Code and post-code (Pickard et al., 2018). The Memekay study mentioned eleven unlogged sites as a visual reference, but they were not part of the 15 indicator questions analysis (Pickard et al., 2018). The riparian and stream channel conditions revealed the Memekay watershed to be impaired (Pickard et al., 2018). An analysis of the causal factors concluded that were related to old (pre-1995) harvesting (32%), unknown upstream factors (31%) and natural conditions (27%) (Pickard et al., 2018). Post harvesting (after 1995) and roads represent 5% each. As a result of these impacts, unstable substrates, channel widening, and unusual wood composition and distribution have occurred along stream channels (Pickard et al., 2018).

Additionally, many harvested riparian areas are too young to function thoroughly, and the forest lacks the structure to generate LWD that would maintain stream banks and create habitat complexity. However, the visual conditions of the unlogged riparian sites were often fully functional, supporting various processes that improve stream channel conditions. Therefore, future operating actions should emphasize tree retention of all streams and restoration of affected riparian habitats throughout the Memekay watershed to support recovery (Darcy Pickard, 2018).

Case study: Washington State

Status and Trends Monitoring of Riparian and Aquatic Habitat in the Olympic Experimental State Forest Monitoring Protocols (OESF) (Minkova, & Foster, 2017) is a document that describes nine indicators and their background and metrics with a detailed field data management procedure. The objective is to evaluate riparian and stream conditions within the OESF- 110,000 ha managed by the Washington State Department of Natural Resources (Minkova, & Foster, 2017). This document could be equivalent to the British Columbia riparian habitat monitoring protocol. However, WA monitors studies through agencies such as the Department of Natural Resources, which usually implements long-term projects depending on the county's needs, in this case, the Olympia Region.

Background

The long-term OESF program studied Type 3 streams' riparian and aquatic ecosystems of small, fish-bearing streams ranging from 0.2-7.9 km2 (Minkova, & Foster, 2017). Streams in 50 watersheds managed by the DNR and 12 watersheds as references are monitored to document habitat under forestry management versus unharvested conditions (Devine et al., 2022). In each watershed, nine aquatic and riparian habitat indicators are sampled in stream reaches near the outlet (Devine et al., 2022). The monitoring program collected data from 2013 until 2020 based on a set of habitat indicators metrics chosen for their importance in forest management, and it contains a habitat condition assessment which combines several indicators to generate a habitat condition score for each monitored stream (Devine et al., 2022). The background of the nine indicators used in the OESF study is a compound of literature review and other protocols used in previous studies, such as the Columbia Habitat Monitoring Program (Bouwes et al., 2011) or the Aquatic and Riparian Effectiveness Monitoring Program (AREMP) for the Northwest Forest Plan (Lanigan et al., 2012). Which resulted in nine protocols, each one developed and peer-reviewed (Minkova, & Foster, 2017). The nine protocols/indicators can be updated as technology progresses, learning new knowledge, and field procedures are perfected (Minkova, & Foster, 2017).

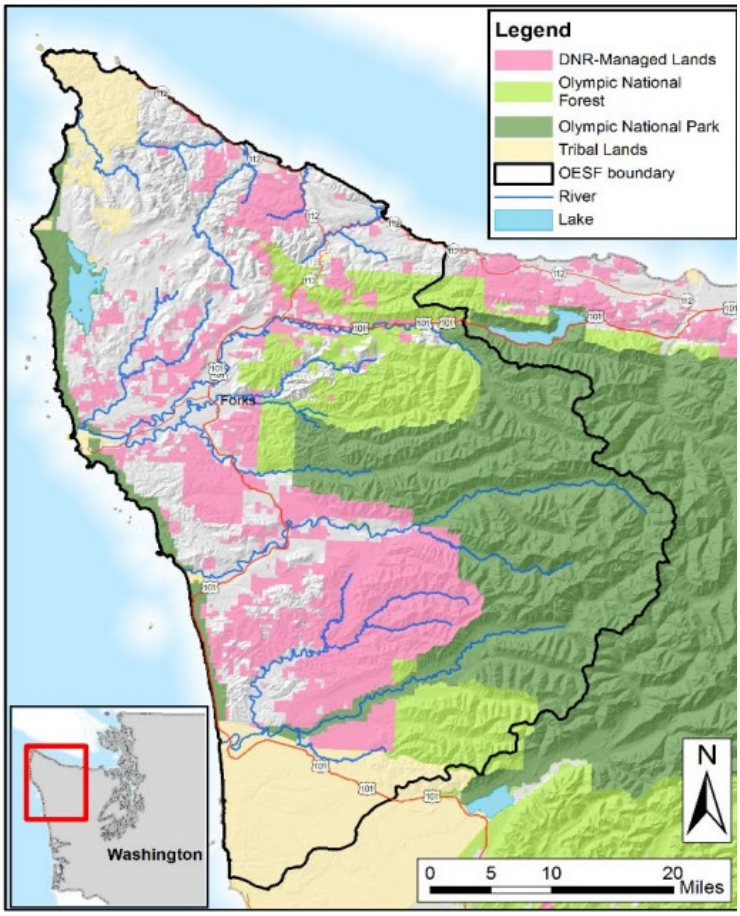

Figure. Olympic Experimental State Forest map showing public and tribal land ownership.

Study Area

The OESF is limited to the West by the Pacific Ocean, on the north by the Strait of Juan de Fuca, on the east by the Olympic Range crest, and on the south by the Quinault River watershed (Devine et al., 2022). The OESF is home to several fish species including chinook salmon, coho salmon, sockeye salmon, pink salmon, steelhead/rainbow trout, coastal cutthroat trout, bull trout and mountain whitefish (Devine et al., 2022). Extensive clearcutting in the OESF peaked in the 1960s and 1980s. As a result, impacting many streams and riparian zones (Devine et al., 2022). Moreover, timber harvesting and road construction activities resulted in significant erosion and sediment delivery to streams, which caused a landslide, debris flows and reduced stream shading (Devine et al., 2022). Furthermore, the report includes a well-explained history of the watershed and riparian zone management and their physical attributes.

Methodology

Nine aquatic and riparian habitat indicators were measured in the stream sample (Devine et al., 2022). The indicators were chosen based on their relevance to the study's aims, indicator sensitivity, and sampling practicality under the consultation of subject-matter experts and reference models (Devine et al., 2022). While seven of the nine habitat indicators were measured in all 62 monitored watersheds, two indicators, riparian microclimate and stream flow were measured in subsets of these watersheds (10 and 14, respectively) (Devine et al., 2022). These two indicators required a significant monitoring expense per watershed in terms of equipment and personnel time (Devine et al., 2022).

Monitoring over time

Since the OESF study is a long-term study, it has a consecutive sampling methodology over the years. Moreover, the nine indicators are sampled at different time intervals depending on their variation rate (Devine et al., 2022). For instance, stream temperature, riparian microclimate, and stream flow are continuously measured with sensors (Devine et al., 2022). The other five indicators, in-stream wood, channel habitat units, substrate, morphology, and stream shade, are measured during "stream surveys" (Devine et al., 2022). Finally, riparian vegetation is measured every ten years because of its slow variation rate (Devine et al., 2022). The main objective of the OESF is to record data, analyze it and then conclude the condition of the riparian sites. The stream survey indicators are a 1 to 2 days process, repeated every 1 to 5 years at a reach (Devine et al., 2022). A table that summarizes the indicator methods is presented below.

Indicator	Reaches sampled	Frequency of sampling
In-stream wood	62	1-5 years[1]
Channel habitat units	62	
Channel substrate	62	
Channel morphology	62	
Stream shade	62	5 years
Riparian vegetation	62	10 years
Water temperature	62	Hourly, year-round
Riparian microclimate	10	Every 2 hours, for 3 years (2013-2015)
Steam flow	14	Every 15 minutes, year-round

Table 7. The sampling frequency of the nine indicators (Devine et al., 2022)

Table 8. The OESF nine indicators and its sampling method and results were obtained (Devine et al., 2022).

Indicators	Method	Results & Implications
In-stream wood	Every piece of wood is at least 10 cm in diameter and at least 2 m long. It analyzed the frequency of pieces, average diameter, length and stage of decay, species class, pool formation and storage sediment.	Old harvesting interfered with an existing cycle of wood inputs. Investigating riparian forest management approaches to accelerate the old-forest growth and yield in-stream wood inputs of historical magnitude and frequency.
Channel habitat units	Also known as pool habitat, each unit's length and width along the reach are measured. Three metrics were analyzed: pool frequency, area, and residual pool depth.	Pool frequency decreased in the DNR-managed watersheds over the observation period, but the pool area did not change. Future Status and Trends Monitoring studies will examine the links between observed in-stream wood and pool habitat at the stream level.
Channel substrate	In each channel substrate survey, 21 random streambed particles were sampled. Based on two statistics, scientific literature calculated median particle size and percent fines.	Since 2013, the current channel substrate composition has mainly remained consistent. Therefore, the sampling methods used may not be sensitive enough to detect small changes in fine sediments, which are known to be challenging. However, the substrate was above the 30mm threshold for all channels, which suggested optimal gravel for spawning.
Channel morphology	Channel width and depth were measured at six permanent cross-sections within each sample reach. Along the whole sample reach, bank erosion was measured on both sides of the stream.	There were no increases in width: depth, or bank erosion, which would have indicated potential natural or human-caused sediment increases in the stream. Additional years of monitoring will be used to evaluate channel morphology and bank erosion.
Stream shade	Six locations along each stream sample measured canopy closure using hemispherical photography. Photos were processed with Hemisfer software.	The level of canopy closure reported suggests that the stream buffers implemented as part of the OESF Riparian Management Strategy have been effective in providing stream shade. However, many streams are in a phase of maximum canopy closure and minimum light. Therefore, riparian thinning and gap creation have been proposed to accelerate the development of riparian forest structures.
Riparian vegetation	In each sample reach, two rectangular plots were designated to assess riparian forest overstory. Each plot was divided into three zones based on distance from the stream. These zones were used to compare overstory composition based on distance from the stream. Trees with a minimum diameter, stream species, zone, and condition (living or dead) were noted.	Almost 84% of plots on DNR-managed lands belonged to one of the three conifer groups. There were three stages of stand development, ranging from tightly spaced smaller trees to the largest conifers in the conifer-large group. The next stage in this research is to use the riparian plot data to determine the relationship between stand conditions and riparian forest functionality.
Water temperature	Small dataloggers fixed to tree roots or boulders collected data throughout the	The strongest predictors of maximum temperature were watershed solar exposure and

	year. A second datalogger recording air temperature is placed to verify that the water loggers are always covered. The temperature records from the paired air and water dataloggers are then compared. If the values are similar, the water datalogger was likely out of the water. Such information is omitted from the analysis.	bedrock substrate, while there was evidence that temperature was influenced by elevation (higher elevation/lower temperatures). Therefore, these variables can predict whether a stream will have relatively high summer water temperatures.
Riparian microclimate	Air temperature and humidity were monitored every two hours throughout the year in 10 of the 50 DNR-managed sites. In addition, two sampling transects were installed on opposite banks of the sample reach. Instead of analyzing relative humidity, air moisture data was analyzed because it has a more direct biological relevance than relative humidity.	Uncertainties about riparian microclimate gradients have been raised due to this monitoring effort. However, the data and insights from this study could be used in future modelling of riparian microclimate in the OESF. For example, the slope above a stream, elevation, and solar exposure should be considered in future riparian microclimate models. Before, it used to rely only on the distance from the stream.
Stream flow	Flow rates and cumulative totals were compared to daily average precipitation. In addition, annual extreme low and high flow statistics were tallied for each water year. A water year is defined as October 1 to September 30 of the following year. Daily average precipitation is from the PRISM Climate Group 2021 (spatial climate datasets).	Initial findings suggest that precipitation rates or runoff mechanisms may be more attenuated at three study sites. Peak flow rates (Q-max) appear to be unrelated to annual maximum peak precipitation rates. Future publications will attempt to quantify this uncertainty and distinguish between hydrologic and measurement-caused variability in hydrographs.

Habitat Condition Assessment

The habitat condition evaluation studied each stream as an individual unit and obtained overall habitat condition scores by combining different habitat indicators. The model framework was modified from a similar modelling method, known as Ecosystem Management Decision Support modelling, utilized in the Northwest Forest Plan Aquatic and Riparian Effectiveness Monitoring Plan (AREMP) (Reeves, 2004) and by DNR on dispersal habitat for the northern spotted owl (Gordon & Gallo, 2011). The AREMP is a multi-federal agency monitoring effort that began in 2000 to examine the status of watersheds within the Northwest Forest Plan area (NWFP) by gathering data on upslope, riparian, and in-channel features within each watershed. The NWFP encompasses 10 million hectares across Western Oregon, Washington, and a little portion of Northern California (DellaSala et al., 2015).

The habitat model focuses on the habitat of salmonids, specifically the most abundant species such as steelhead/rainbow trout, cutthroat trout, and coho salmon (Devine et al., 2022). The model focuses on habitat characteristics and conditions shared by all three fish species (Devine et al., 2022). The model employs average habitat indicator values for the 62 streams during the 2013-2020 monitoring period (Devine et al., 2022).

The habitat model generates an overall habitat condition score for each of the 62 sample streams that have been observed. This overall score is calculated using 11 selected habitat indicators divided into four habitat categories (Devine et al., 2022). Some indicator metrics were previously recorded in the OESF monitoring (e.g., water temperature, canopy closure), whereas others were not (e.g., percent boulders in substrate, habitat unit frequency) (Devine et al., 2022). Each indicator metric produces an indicator habitat score for each stream, ranging from -1 to 1, with -1 indicating the lowest quality and 1 the highest quality (Devine et al., 2022).

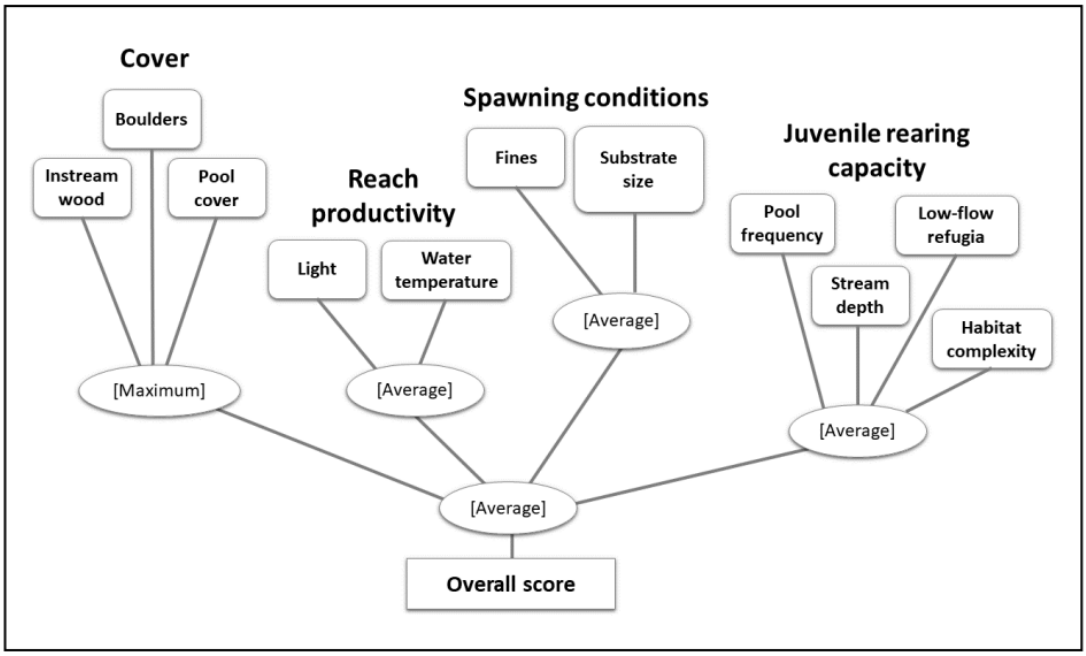

Figure. Habitat condition model : four habitat categories contain eleven habitat indicators (Devine et al., 2022).

There are considerable changes in habitats related with variances in stream gradient in the evaluated Type 3 streams. Stream gradient differences are represented by three-stream channel types: pool-riffle, step-pool, and cascade (Devine et al., 2022). Specific ecological characteristics, including channel substrate, in-stream timber, and bank erosion, have been demonstrated to differ between channel types (Devine et al., 2022). Because of these intrinsic variations, the 62 streams were categorized by channel type within the habitat model, and the scores of individual streams were only compared to those of other streams (Devine et al., 2022). The overall habitat condition scores for pool-riffle, step-pool, and cascade channel types were 0.04, 0.36, and 0.46, respectively (Devine et al., 2022).

The following graph shows a distribution of the overall habitat conditions scores of the streams sampled. The stream samples are grouped into three-channel types. Moreover, each three-channel type represents a different habitat with different ranges of scores; thus, scores should not be compared between groups (Devine et al., 2022).

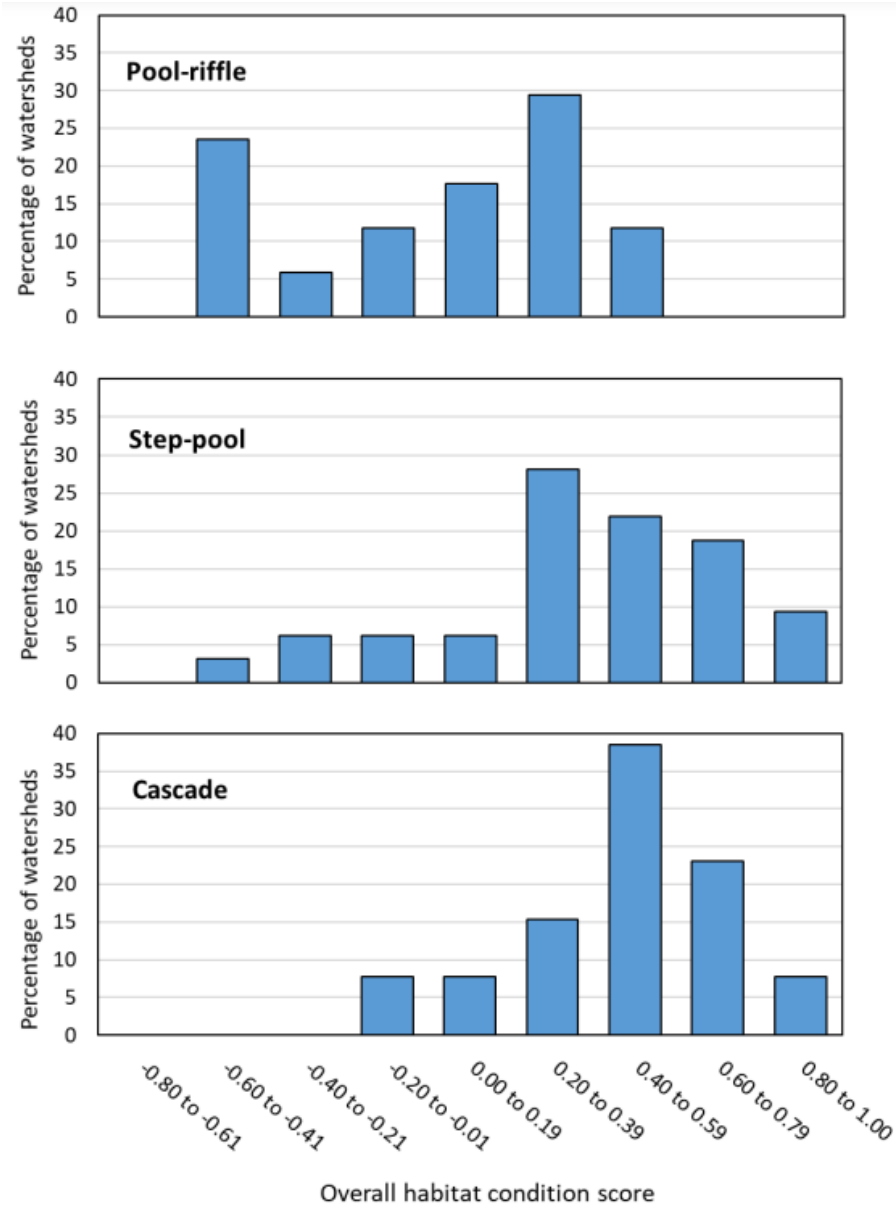

Figure. Distribution of the overall scores within each channel type

The OESF report stated that the model described is the first attempt at modelling habitat quality regarding fish habitat needs. Moreover, the study expects to have a better understanding of habitat indicators over time and with the collection of more data to improve modelling methodologies (Devine et al., 2022).

Results and Discussion

Washington State has regulated forest practices longer than British Columbia, Canada. The Forest Practices Act of Washington was established in 1974 (McIntyre et al., 2018) compared to BC Forest Practices Code in 1996, and it was not until 2003 that it became the Forest and Range Practices Act (Tschaplinski & Tripp, 2017). Therefore, it is expected to find a more advanced and scientific monitoring program that oversees fish and fish habitats.

The Washington State Department of Ecology is the lead ecosystem monitoring agency. However, other agencies are involved, such as the WA Department of Natural Resources (mostly forestry-related, on state forestry lands) and the WA Department of Fish & Wildlife (mostly related to fisheries habitat and protected wildlife species such as salmon) (DNR, 2021). Among these three departments, there is much overlap in their collaboration (H. Mackay, Re: Washington State Riparian Monitoring programs, June 17, 2022). Nonetheless, it is still a reasonable effort. Therefore, finding a homolog document with a single protocol at the State level (like the FREP monitoring program in BC) to evaluate forestry activities in riparian habitats was found to be impossible. As the protocols in Washington State vary depending on the scale and resolution of the monitoring programs.

A Provincial-level Protocol

Washington State develops site-specific scientific studies depending on the county's needs, whose indicator measurements might be modified based on the site's needs. For instance, the WA case study explained in this document which is the OESF program is a clear example. British Columbia also performs several site-specific assessments, depending on the district's needs, such as the Campbell River District, MacKenzie District, Thompson River District and more (Gov.BC, 2022c). They are developed through the FREP Multiple Resource Value Assessments (MRVA), which considers fish/riparian habitats and other resources such as water quality, timber, soils and others among the eleven-resource values list (Gov.BC, 2022c). However, the indicators measurements to evaluate the fish/ riparian resource are not modified and are based on the standard 15 indicator questions. This is because the FREP monitoring program is a general protocol used at a province/state level which facilitates the integration of results and comparison at a broad level.

The limitations of snap-shot results

The Washington State Department of Natural Resources monitors the Status and Trends of Riparian and Aquatic Habitats in the Olympic Experimental State Forest (OESF), a long-term study evaluating watershed habitat conditions (Devine et al., 2022). The OESF study did also evaluates random sites like the FREP program. However, one of the most important differences between these two jurisdictions is the scale and goals of their protocols. British Columbia uses a standard method for any study regardless of its importance level: the FREP protocol. Therefore, the Memekay River case study was not the exception which means an evaluation with no long-term goals despite that the Memekay River is a fish-sensitive zone (Pickard et al., 2018).

Moreover, limiting the study to only snap-shots results (Tripp et al., 2022a) rather than providing a systematic review over a period of time. On rare occasions, a site has been reviewed over time to see if conditions have improved, remained the same or deteriorated (Nordin & Malkinson, 2021). Therefore, frequent sampling would provide a long-term perspective on recovery trends, which is critical for forest ecosystems that evolve with stand age (Nordin & Malkinson, 2021).

Measurements are important

Another limitation of the FREP program is the nature of its survey procedure. It considers that making measurements could be unnecessary when it is evident (based on visual experience) that an indicator will be over or under the threshold values used in the indicator questions (Tripp et al., 2022a). However, it requires at least some measurement until the thresholds are exceeded. It also introduced the idea that complete measurements for the entire reach are best since that data can be used in future analyses (Tripp et al., 2022a). Unfortunately, these two statements can be ambiguous and leave the practitioners on the easy path of skipping data collection.

The importance of reference sites

The FREP monitoring program states that adopting a reference or undisturbed site is not always possible (Tripp et al., 2022a). However, it recommends having prior visual references of natural riparian conditions before evaluating a site (Tripp et al., 2022a). For instance, if the person who performs the monitoring is unexperienced can have a clearer idea of natural site conditions. The Memekay study identified eleven unharvested sites as a visual reference (Pickard el al., 2018). However, the sites were not used in the data analysis of the 15 indicator questions. On the contrary, the long-term monitoring OESF program included 12 reference sites (Devine et al., 2022). In fact, the data collected from the reference sites were analyzed to create threshold indicator values focused on the requirements of the most abundant fish species in the zone (Devine et al., 2022). Once a long-term monitoring is adopted is important to consider having a robust habitat condition comparison between harvested sites and existent control sites within the same area.

Riparian Management Areas in BC versus WA

The riparian buffer zone and its management have different backgrounds and considerations in each jurisdiction. For instance, British Columbia has six riparian classes based on a default stream width (Table 1) (Tripp et al., 2022). The Riparian Management Area (RMA) is the total area of a two-zone buffer: the Riparian Reserve Zone (RRZ): adjacent to the stream where there is no harvest activity, and the Riparian Management Zone (RMZ). The RMZ is the extended area from the outer edge of the RRZ where harvesting activities can occur.

On the other hand, WA has five site classes based on the riparian management zone (RMZ) or SPTH (Table 2) (Fairweather, 2001). The Site Potential Tree Height (SPTH) is the expected height of a tree at stand age 100 for a given site class (Devine et al., 2022). The RMZ is the total area of a three-zone buffer: the core zone, also known as the "no-touch area" adjacent to the stream, which is present in all the site classes (Fairweather, 2001). An inner zone is split into two groups depending on the stream width. The inner zone might have one management option: thinning from below (Option 1) and leaving trees closest to the water (Option 2) (Fairweather, 2001). Lastly, the

outer zone is also classified into two groups (stream ≤ 3 and stream > 3) from the outer edge of the inner zone. The outer zone can be managed, but it must retain 10 to 20 riparian trees per acre. (Fairweather, 2001).

The values of BC riparian classification in the total riparian management area are similar to Washington State, known as the total riparian management zone. However, the area of no-touch is different. In WA, the core zone or reserve zone (named in BC) can represent up to 55% of the total management zone. For instance, the lowest core zone extension is 25% for site class 1, within 60 meters of the total RMZ. The core zone width is 15 meters in all the site classes despite the stream type and RMZ width. Therefore, the core zone extension is more prominent when the RMZ widths are lower, which does not occur in BC protocols. BC leaves a reserve zone extension proportional to the total riparian management area. In BC, all fish-bearing streams except stream class S4 have a reserve zone width. Streams S5 and S6 do not have reserve zone, but they are not part of this study's focus since they are non-fish-bearing streams. The reserve zone extension represents a minimum of 50% of the total management area and, in the S1 case, represents 71% of the total RMA. However, in a riparian class (S4) is 0%.

Small-fish-bearing streams S4 are not protected.

The management area in BC where logging activities are allowed (the inner zone plus the outer zone in WA) has a lower extension than in WA. Therefore, it can be concluded that the BC management objectives for riparian reserves 50, 30, and 20 m wide on S1, S2, and S3 maximun streams go beyond the need to protect stream channels and aquatic habitats (Tschaplinski, 2010a). However, small fish-bearing streams (S4) do not have a reserve zone, whereas WA leaves a reserve zone in all of their streams, whether fish is present or not (Devine et al., 2022).

Logging based on Desired Future Conditions

The forestry activities performed in the riparian management zone of each jurisdiction are regulated under a maximum retention level within the riparian management zones. For instance, the BC Riparian Management guidebook established a maximum overall retention of 50% in stream classes S1, S2, and S3 (Gov.BC, 2022b). Stream classes S4 and S5 are 25%, and S6 is 5% (Gov.BC, 2022b). Moreover, the riparian guidebook provides other range-use guidelines for forest practices within the RMA, fisheries-sensitive, and marine-sensitive zones (Gov.BC, 2022b). However, the Department of Natural Resources (WA) uses a computer program design for logging in the riparian management zone to reach a Desired Future Condition (DFC) (Fairweather, 2001). This method helps to know the harvesting extent to apply in the RMZ. Which estimates a target basal area per acre and the proportion of conifers in the combined core and inner zone at age 140 years for the given site class (Fairweather, 2001). The age was stablished to be old enough to provide the shade and LWD requirements (Fairweather, 2001). It would be convenient for BC to adopt a computer model to reach a natural stand condition at a certain age rather than retention guidelines.

Audience Reach

A clear difference between BC and WA riparian monitoring protocols is the layout and audience reach. The BC monitoring protocol document is written in an understandable style, even for non-scientists. The communication style has a lot to do with the project goals and the structure of each program. The FREP protocol monitoring document is for anyone with a basic working knowledge of streams and riparian habitats and is written in an easily understandable style. Resulting in a higher audience reach than the Washington State protocol, which is directed to a scientistic audience.

Best Monitoring Times

The time spent doing the stream survey was the same for both monitoring programs (1-2 days) (Tripp et al., 2022a; Devine et al., 2022). However, the number of indicators cover per stream survey is different. For instance, the fifteen indicators of the FREP program were all measured during the stream survey. On the contrary, the OESF program measured only five indicators known as "stream survey indicators" (in-stream wood, channel habitat units, substrate, morphology, and stream shade) (Devine et al., 2022). The other OESF four indicators are not measured during the stream survey; instead, they are measured based on the rate at which they are expected to change (see table 7). In addition, both monitoring programs suggested an ideal time to sample stream reaches. The protocols were conducted when stream flow was low. The monitoring occurred at or near its annual base flow, from June through September (Devine et al., 2022), when the streambed, stream banks and ground in the riparian region are visible. Moreover, the stream is running, and the flora foliage has completely formed (Tripp et al., 2022).

Wood length should be measured in the protocol.

One of the common indicators in both jurisdictions is large wood debris. The OESF protocol mentioned that channel morphology and deep pools are influenced by in-stream wood (Devine et al., 2022). In addition, the riparian habitat assessment considered a high-quality salmon habitat, a stream with many pieces of wood, a large stream size, and complex stream channels (Devine et al., 2022). The LWD to be measured are only old pieces of wood at least 10 cm in diameter and 2 m long that were within or suspended above the stream channel with a zone of the log still submerged in the wetted channel (Schuett-Hames et al., 1999). However, the FREP-BC protocol accounted for only old LWD present in the channel with a diameter equal to 10% of the channel depth at the crest of the rifles (Tripp et al., 2022a). For example, if it is a small channel depth (15cm), the wood would be 1.5 cm in diameter, and the length is irrelevant (Tripp et al., 2022a). Based on anadromous fish requirements, larger pieces have the most impact on channel shape and give the most habitat advantages, as well as remaining in streams for far longer than smaller pieces (Devine et al., 2022). Moreover, larger parts are frequently referred to as "key components" (Opperman, 2006). Therefore, measuring wood length should be consider for performing a more suitable monitoring of fish habitats.

In general, there are several inconsistencies across studies in the type of variables measured and measurement (Wohl et al., 2010). A study presented by Wohl et al. (2010) calls for standard agreement on the measurement and reporting of variables to better understand in-stream wood

patterns. In addition, up to 35 in-stream wood variables, mostly based on quick visual assessments, should be considered in order to develop a robust in-stream wood monitoring model (Gregory et al., 2003).

LWD or In-stream wood

"In-stream large wood is the indicator name for the DNR-WA protocol, which is worth discussing. Because the FREP-BC protocol uses the terminology Large Woody Debris as an indicator name, the word debris can take certain misperceptions and may be mistaken as a synonym for the word "garbage." (Opperman, 2006). The story started when Europeans settled in the West. As they encountered big rivers full of large trees and jams of LWD, they did "stream cleaning" to improve river navigation resulting in significant changes in the diversity of riverine habitats (Opperman, 2006). Moreover, the timber harvesting era affected the process by which new wood was recruited, resulting in the deposition of dense logging debris, known as slash, which constituted a barrier to fish migration (Opperman, 2006). Further wood removal operations were needed, which cleaned up not only slash but also naturally occurring wood and debris jams (Opperman, 2006). The overall effect was the decline of large wood pieces and the misconception that debris jams impede fish mobility (Opperman, 2006). Therefore, a renaming the indicator will bring an organic approach to the monitoring.

Different aspects of British Columbia Forest practices and its monitoring program should be taken into consideration for improvement under the new BC Ministry of Land, Water and Resource Stewardship. The new Ministry might use this discussion of opportunities to re-evaluate the effectiveness of the current Forest and Range Monitoring protocol.

Conclusions

In summary, the current FREP monitoring protocol has allowed the province of British Columbia to have a repeatable methodology that broadly evaluates post-harvest activities in Riparian areas. Moreover, the FREP assessment has been essential in communicating and providing timely feedback to forest licensees on management strategies. However, a general protocol that occurs only once per sample reach might not be the best for evaluating the conditions of fish habitats.

Riparian habitats with high fish values require a more sensitive method to evaluate proper functioning conditions. Such a site-specific protocol and frequent sampling of the most critical indicators for fish habitats to detect slight changes over time. The long-term data acquired would be used in making inferences about the effects of forestry management over time. Moreover, repeated sampling will reveal if the circumstances have improved, remained the same, or deteriorated. In addition, the results of these data can contribute to developing effective adaptative management.

The FREP monitoring protocol acts as a survey procedure where visual measurements can be adopted without collecting data, even though collected data could be mined for future analysis. In addition, the survey protocol does not require reference sites during the analysis of stream reaches. However, sensitive fish habitats should be compared to control sites whenever practicable.

British Columbia possesses a proper riparian management area where the reserve zone for classes S1, S2, and S3 fish-bearing streams are large enough to protect stream channels and fish habitat. However, small-fish-bearing streams S4 are not being protected and lack of a reserve zone. The BC forestry guidebook governs the forestry activities in the riparian management zone. However, because forest ecosystems evolve with stand age, adopting a formal technique to forecast a stand future condition is more suitable. In addition, the indicator LWD should be renamed to avoid misunderstandings and demonstrate that large wood is a good sign of healthy fish habitats. Finally, the current wood monitoring system does not include length measurements in its analyses which might be ineffective. More compelling data collection and analyses are required to develop a robust in-stream wood model.

In conclusion, forestry activities in Riparian areas have been regulated under a sustainable approach for several years. However, it is important to recognize that these regulations have already modified natural stream conditions. Therefore, establishing more long-term studies in high fish and fish habitat ecosystems where it is possible to understand the adaptation of fish in disturbed habitats against natural conditions would reinforce current threshold indicator values. Resulting in more effective monitoring of the forestry activities in BC.

Recommendations

Based on the comparison between Washington State and British Columbia Forest management strategies it is recommended:

- Improved communication between the two jurisdictions to identify successes and emerging challenges related in the monitoring of riparian and fish habitats,
- A more inclusive stakeholders' representation should be adopted that in addition to academics, forest certification agencies and Government personnel, it also includes local communities and First Nations groups, interested in addressing the concerns regarding the riparian zone,
- Future research should investigate if all species require the same stream habitat, and
- Continue to evaluate the effectiveness of the present monitoring protocols in both jurisdictions to develop a "living" document for informing management strategies.

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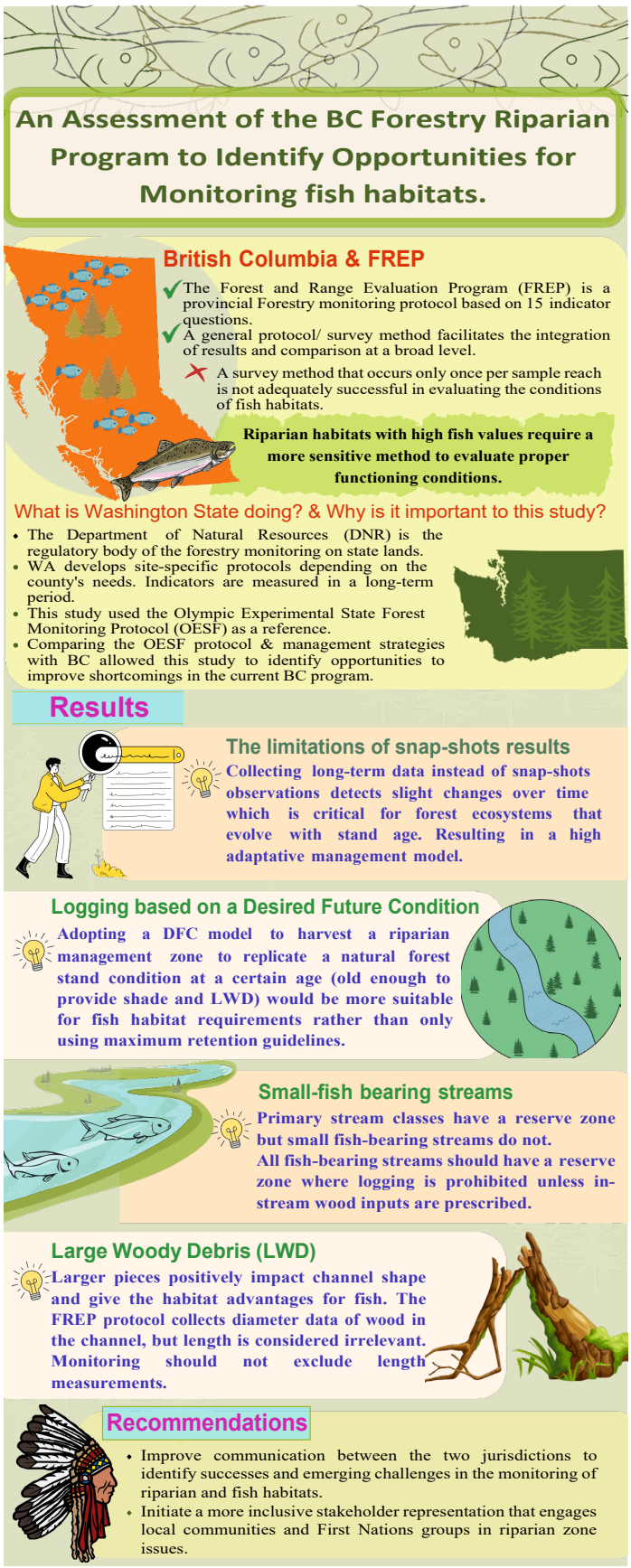
Appendix


An Assessment of the BC Forestry Riparian Program to Identify Opportunities for Monitoring fish habitats.
British Columbia & FREP
The Forest and Range Evaluation Program (FREP) is a provincial Forestry monitoring protocol based on 15 indicator questions.
A general protocol/ survey method facilitates the integration of results and comparison at a broad level.
A survey method that occurs only once per sample reach is not adequately successful in evaluating the conditions of fish habitats.
Riparian habitats with high fish values require a more sensitive method to evaluate proper functioning conditions.
What is Washington State doing? & Why is it important to this study?
The Department of Natural Resources (DNR) is the regulatory body of the forestry monitoring on state lands.
WA develops site-specific protocols depending on the county's needs. Indicators are measured in a long-term period.
This study used the Olympic Experimental State Forest Monitoring Protocol (OESF) as a reference.
Comparing the OESF protocol & management strategies with BC allowed this study to identify opportunities to improve shortcomings in the current BC program.
Results
The limitations of snap-shots results
Collecting long-term data instead of snap-shots observations detects slight changes over time which is critical for forest ecosystems that evolve with stand age. Resulting in a high adaptative management model.
Logging based on a Desired Future Condition
Adopting a DFC model to harvest a riparian management zone to replicate a natural forest stand condition at a certain age (old enough to provide shade and LWD) would be more suitable for fish habitat requirements rather than only using maximum retention guidelines.
Small-fish bearing streams
Primary stream classes have a reserve zone but small fish-bearing streams do not.
All fish-bearing streams should have a reserve zone where logging is prohibited unless in-stream wood inputs are prescribed.
Large Woody Debris (LWD)
Larger pieces positively impact channel shape and give the habitat advantages for fish. The FREP protocol collects diameter data of wood in the channel, but length is considered irrelevant. Monitoring should not exclude length measurements.
Recommendations
Improve communication between the two jurisdictions to identify successes and emerging challenges in the monitoring of riparian and fish habitats.
Initiate a more inclusive stakeholder representation that engages local communities and First Nations groups in riparian zone issues.