

A Framework for Monitoring Wild Pacific Salmon Habitat

Prepared for:

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Introduction

In June 2005, Fisheries and Oceans Canada (DFO) released a strategy for managing the five species of Pacific salmon that is outlined in Canada's Policy for Conservation of Wild Pacific salmon (i.e., the Wild Salmon Policy (WSP); DFO 2005). The overarching goal of the WSP is to “*restore and maintain healthy and diverse salmon populations and their habitats*”, where “*conservation of their habitat is the highest priority for resource management decision making*” as balanced against biological, social, and economic consequences. Strategy 2 of the WSP specifically addresses the assessment of habitat, wherein it states that “*maintenance of sound productive salmon habitat...depends on good scientific information, timely measures to prevent habitat disruption, and compliance with regulatory directives*”. Strategy 2 outlines four action steps that together will improve DFO's capacity to proactively monitor and protect wild salmon habitat. The four action steps include:

- Step 2.1.:** Document habitat characteristics with CUs;
- Step 2.2.:** Select indicators and develop benchmarks for habitat assessment;
- Step 2.3.:** Monitor and assess habitat status; and
- Step 2.4.:** Establish linkages to develop an integrated data system for watershed management.

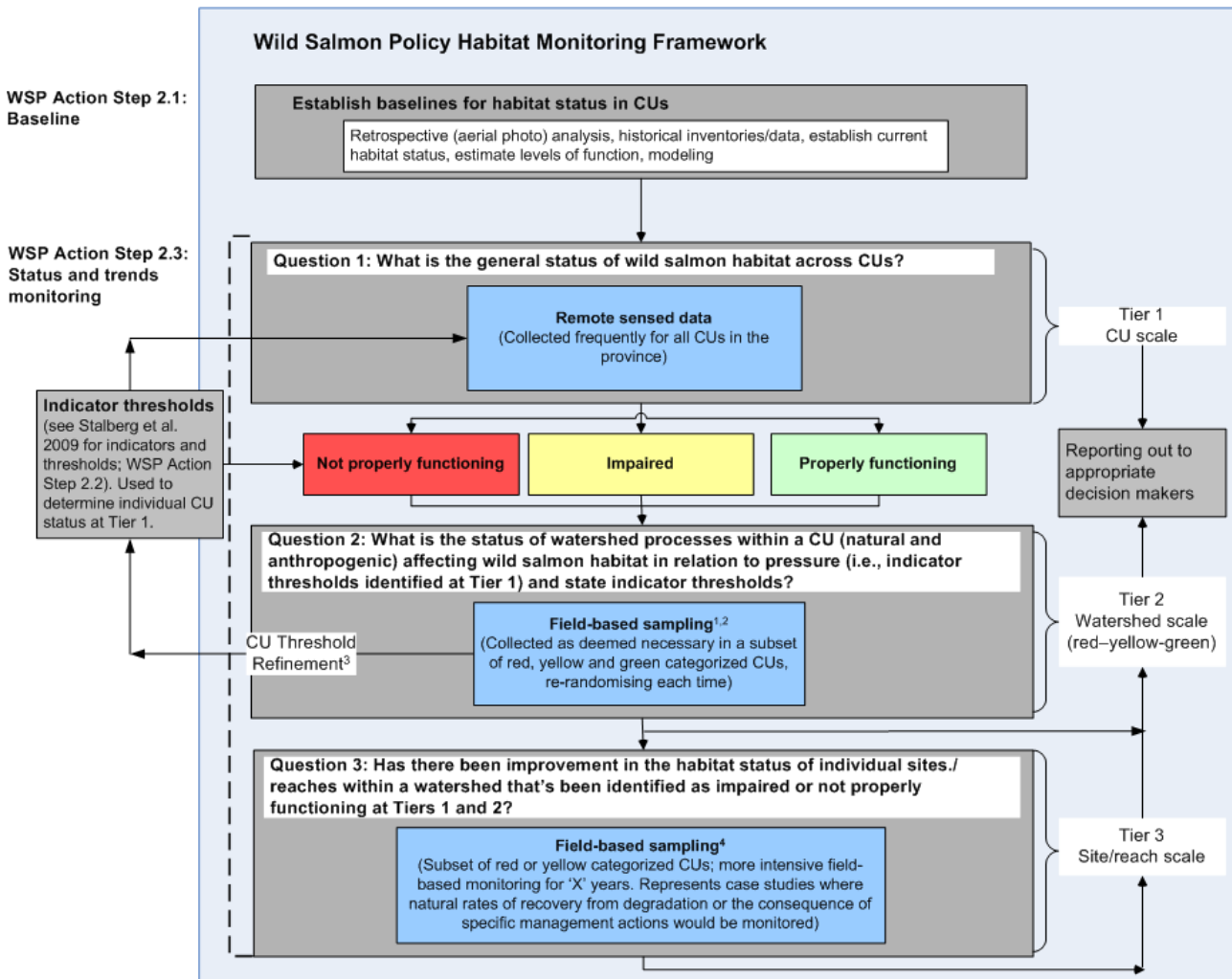
This purpose of this document is to outline a monitoring framework that speaks to Action Steps 2.1 and 2.3 of Strategy 2. With regards to Action Step 2.2, the progress made to date is summarized in Stalberg et al. (2009) which describes the indicators and benchmarks that will be used to inform the monitoring framework discussed herein.

Status and trends monitoring is required to identify changes in habitat condition over time as described in Action Step 2.3. Status/trends monitoring represents the foundation for tracking the overall performance of salmonid populations and their habitats as shaped by natural environmental factors, anthropogenic stressors, and management actions. Because the intent of status and trend monitoring is simply to describe existing conditions and document changes in conditions over time, it does not require all the elements of valid statistical design found in effectiveness monitoring studies (e.g., use of controls) where the goal is to establish cause and effect relationships. However, status and trend monitoring does require temporal and spatial replication and probabilistic sampling.

Status and trends monitoring can provide the foundation of a regional monitoring and evaluation (M&E) program but it must be integrated with action effectiveness monitoring. An integrated M&E program provides economy of scale, prevents duplication of effort, and is cost effective. Action effectiveness monitoring is more focused on specific questions that influence fish populations hence, it is typically of fixed duration and usually provides more precision. It can respond to adaptive management needs by focusing its efforts to address the mechanistic causes of uncertainty in the relationship between management actions and fish population responses.

Monitoring Framework

The framework described in **Figure 1** presents a nested, multi-tiered approach to CU status/trends monitoring. Each monitoring tier presented in **Figure 1** refers to the spatial scale (i.e., Individual CUs, watersheds within a CU, and sites/reach within a watershed) at which particular monitoring questions should be addressed. These questions will in turn dictate the monitoring components required. For the framework to be effective the monitoring components must be carefully designed to answer well-defined questions at different scales in an efficient manner.



1. Sampling design, effort, and frequency at Tier 2 to be determined. Monitoring protocols for all wild salmon habitat indicators have not been definitively identified. The Sensitive Habitat and Inventory Mapping (SHIM) may be a suitable method for collecting data for some indicators (http://www.shim.bc.ca/methods/SHIM_Methods.html).
2. Allocation of effort between CU categories (i.e., red, yellow, green) in Tier 2 has not yet been determined. For example, may choose to allocate equal effort across all three categories until data is available to inform how sampling effort should be allocated across watershed categories.
3. Tier 2 will provide validation monitoring for Tier 1 to ensure that red/yellow/green classifications are appropriate. In addition, Tier 2 sampling will provide a means to assess causes of indicator failure at the Tier 1 level. Thresholds may be specific to individual or groups of watersheds within CUs and/or CUs. Field-based sampling for threshold refinement purposes is temporary.
4. Tier 3 sampling design will be dependent on what causal factors were identified in Tier 2. Extrapolation of Tier 3 results will be dependent on the way in which case study CUs are selected (i.e., random vs. non-random).

Figure 1. Conceptual diagram of a monitoring framework incorporating multiple tiers of evaluation for monitoring status and trends within a CUs.

Management Questions

There are three tiers of “management questions” relating to status and trends monitoring that could inform the decision making process for CU habitat management. The **first tier** of management questions should evaluate the ongoing success of Strategy 2 of the WSP:

What is the general status of salmon habitat within CUs across the province (i.e., proportion of CUs are properly functioning, not properly functioning, and intermediate)?

Tier 1 monitoring is targeted at the CU scale (i.e., extensive monitoring) and would include all designated CUs. It is intended to assess status and trends of wild salmon habitat using pressure indicators identified in Stalberg et al. (2009). In addition, the information collected at Tier 1 will eventually be used to inform Strategy 5 of the WSP, Action Steps 5.3¹ and 5.4² (i.e., what is the general success of WSP with respect to status of salmon habitat across the province).

The analysis of pressure indicators informed by remote sensed data will provide a point of comparison for evaluating long-term trends in the status of CUs. Selected pressure indicators will also be used to define a baseline classification of monitored CUs (i.e., considered to be properly functioning (green) or not properly functioning (red)^{3,4}, or some intermediate category (yellow; signs of deteriorating condition but still considered functioning). Only those pressure indicators relevant to a particular CU will be considered for the Tier 1 assessment of that CU (e.g., CUs that do not experience vessel traffic will not be evaluated using this indicator).

From here on, properly functioning and not properly functioning will be referred to in this document as PF and NPF, respectively. The assignment of these categories will involve scientific judgments on what constitutes PF or NPF for a specific indicator, and how to appropriately combine indicators given varying conditions and differing levels of uncertainty in the assigned thresholds. It is anticipated that remote-sensed habitat indicators (i.e., pressure indicators) identified in Stalberg et al. (2009) will provide the foundation for categorizing CU habitat condition at the Tier 1 level. Where thresholds have not been identified, it will be helpful to look at similar monitoring programs operating in other jurisdictions (e.g., Oregon and Washington) and/or fields (e.g., Forestry and Fisheries Sensitive Watersheds).

The **second tier** of management questions would examine the condition of watersheds within a subset of CUs that are considered to be PF (i.e., green categorization at the Tier 1 scale) versus those that are considered to be NPF or impaired (i.e., red or yellow categorization at the Tier 1 scale):

What is the status of watershed processes in PF versus NPF or impaired CUs (i.e., what is causing particular watersheds within a CU to be classified as NPF or impaired at Tier 1)?

Tier 2 monitoring focuses on state indicators identified in Stalberg et al. (2009) and is designed to provide shorter-term information on ecosystem processes driving status and trends condition within a CU’s watersheds (i.e., intensive monitoring). Only those state indicators relevant to a particular CU will be

¹ Action Step 5.3 – *Plan and implement annual habitat management activities.*

² Action Step 5.4 – *Plan and implement annual enhancement activities.*

³ The terms properly functioning (PF), impaired, and not properly functioning (NPF) have not yet been defined for use within the WSP monitoring framework. Within the context of this report the terms are used to refer to categories of watersheds that have been demarcated using a set of defined criteria. The task of defining PF, impaired and NPF, as well as the refinement of criteria, is beyond the scope of this document, and will be developed within planned pilot studies. It is possible that a range of watershed categories will ultimately be developed, covering a gradient of condition (e.g., good, moderate, bad, etc.).

⁴ An initial starting point for a definition of properly functioning could be a watershed that safely stores and releases water, has vegetative cover that adequately balances exposed sediment sources, and has normal levels of connectivity between all aquatic components that are present in the watershed (as used in BC’s Forest and Range Evaluation Program (FREP)).

considered for the Tier 2 assessment of watersheds within that CU. As the WSP moves forward and Strategy 5 is implemented, Tier 2 and 3 monitoring can also be used to evaluate the effectiveness of habitat management and enhancement activities.

Tier 2 monitoring serves two functions. First, more detailed field-based monitoring will provide insight into the habitat risks and constraints that are adversely affecting salmon productivity (initially identified as red or yellow categorizations for the CU at the Tier 1 level) and identify CUs in need of protection to maintain salmon productivity. Continued monitoring will also provide information on the ongoing status of CUs with regards to a suite of key ecosystem processes and habitat attributes. Second, data collected from detailed monitoring of a varied set of CUs can be used to ground truth, refine, or revise initial threshold criteria used at the Tier 1 level for defining NPF or impaired watersheds. For example, Tier 2 monitoring may provide information suggesting that the magnitude/extent of a specific type of activity (e.g., land use - timber extraction) results in observed environmental degradation of magnitude/extent 'X' (e.g., sediment load and large woody debris). This information can then be used to refine the initial threshold for equivalent clear cut area (ECA) used at the Tier 1 level. It is plausible that strong linkages between Tier 2 state indicators and Tier 1 pressure indicators do not exist. If this case, other field based indicators known to have linkages to Tier 1 pressure indicators should be adopted to allow for refinement of Tier 1 thresholds. Monitoring additional indicators at Tier 2 for the purpose of Tier 1 threshold refinement is intended to be temporary, i.e., only until thresholds are refined and a high degree of confidence in classification of NPF, PF, and intermediate condition exists. Last, it is important to emphasize the need for random sampling at the Tier 2 level to ensure that the data collected in selected CUs is representative of the CU category as a whole (i.e., NPF, impaired, and PF).

The **third tier** of management questions asks how impacted/degraded areas of NPF or impaired CUs are recovering over time (either passively or as a result of directed management actions):

Has there been improvement in wild salmon habitat (as a result of changes in watershed processes) within individual CUs designated as NPF or impaired?

Tier 3 monitoring focuses on a further subset of CUs selected from those that were identified as NPF or impaired at the Tier 1 level and subsequently monitored in Tier 2. Monitoring at Tier 3 is at the site/reach scale in watersheds that make up a particular NPF CUs. The intention of Tier 3 management questions is to determine whether wild salmon habitat condition has improved (or at least stabilized) within watersheds of a given CU. Sampling is restricted to areas that have been identified as salmon habitat (rearing and spawning) and concentrates on those areas where habitat risks and constraints are most adversely affecting productivity⁵. Tier 3 monitoring can be used to identify areas where habitat restoration or rehabilitation would be most beneficial for restoring productivity. It is expected that sampling frequency and intensity in these focal areas would be greater than that undertaken as part of Tier 2 monitoring.

Tier 3 monitoring could also provide direct feedback to habitat managers on the general outcomes of a suite of restoration, rehabilitation, and/or enhancement actions that has already been undertaken in the area. It would also help DFO enforcement staff determine where to focus compliance efforts and could ultimately inform changes to regulations. At present, the scope of actions evaluated under Tier 3 would be restricted to those actions executed by DFO habitat management staff in response to strategic planning decisions and/or annual operations in habitat management. In the future, the scope may be expanded to include other factors/actors and could explicitly focus on project effectiveness.

⁵ Monitoring sites at Tier 3 should be randomly selected from a master list of identified spawning and rearing habitat within a CU. We recommend using intrinsic potential habitat mapping (see Burnett et al. 2007) to identify spawning and rearing habitat within CUs if this information is not already available for CUs.

The nature of the monitoring questions at this scale is dependent on which watershed processes (i.e., indicators) were originally identified as failing in response to the Tier 2 management question. In addition, depending on the nature of the management question at this Tier, it may not be necessary to select CUs at random (i.e., there may only be an interest in interpreting the results for the CU being monitored and not extrapolating up to a larger group of CUs).

Appendix A provides a hypothetical example of how the monitoring tiers would feed into each other, i.e., how information from CUs would be tracked and passed from one tier to another.

The proposed monitoring framework discussed in this report does not include any form of implementation and/or direct effectiveness monitoring of individual projects. Both effectiveness and implementation monitoring of the WSP come into play under Strategy 6 of the WSP and are compatible with the framework for status and trends monitoring we presented here. Determining which aspects of Strategy 2 were implemented as intended and more importantly which were effective at maintaining, or in some instances increasing, productivity will likely be difficult given the large suite of concurrent variables that will affect habitat, e.g., climate change, forestry, agriculture, etc.

Monitoring Questions

For each of the three broad “management questions” listed above there will be specific “monitoring questions” that will need to be asked. For example, at the Tier 1 scale it will be important to know the condition of CUs with respect to a specific indicator, or suite of indicators, that will inform the general designations of PF, NPF, or impaired. Managers may need the answers to monitoring questions such as:

What is the status of lake productivity, lakeshore spawning habitat, or land cover in sockeye CUs?

What is the status of water quality and water temperature in all CUs?

What is the overall status of spawning habitat in CUs?

Etc.

Indicator Development

Development of monitoring questions will require that specific indicators be chosen which will act as the basis for comparisons. Indicators to address these questions must be carefully selected to avoid ambiguous results (Mulder et al. 1999; Reeves et al. 2004). Numerous authors (e.g., Noss 1990; MacDonald 1991; Barber 1994) discuss the properties of useful monitoring indicators. Reid and Furniss (1998) summarize these discussions and suggest five key indicator properties:

1. An indicator must respond quickly enough to provide results in the time-frame desired;
2. The cause-effect relationships that control the indicator response must be well understood;
3. Changes in indicator values must be interpretable in terms of the objectives of the program;
4. The indicator signal must be separable from environmental noise; and
5. Indicator measurements must be cost-effective at the required level of precision and accuracy.

The criteria used for indicator selection by the Habitat Working Group (HWG) take into consideration the above indicator properties (see Table 3.1 in Stalberg et al. 2009). More specifically, the HWG went through a rigorous 8 step process to select a set of habitat indicators for stream, lake, and estuary habitat (Figure 2, see Stalberg et al. 2009 for details). The HWG’s list of habitat indicators proposed is provided in Appendix B.

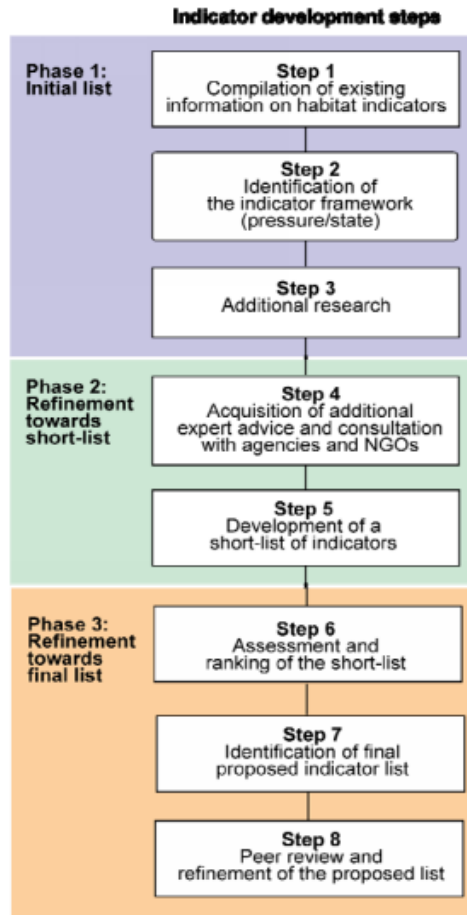


Figure 2 The eight steps used by the HWG in the habitat indicator development process (Stalberg et al. 2009)

A large suite of indicators will be needed to fully evaluate and answer the management questions at different tiers. Consequently, data aggregation strategies that pool multiple indicators (e.g., FREP, EPA, AREMP programs) to create composite scores for each tier will have to be developed. At the Tier 1 scale for instance, combining remote-sensed indicators of roads, vegetation cover, riparian disturbance, and land use into an overall score could provide the basis for a useful high level index for determining CU condition (e.g., red vs. yellow vs. green).

Choosing an appropriate probabilistic sampling design

Sampling research and development is typically focused on finding more efficient designs, where the goal is to obtain precise estimates without spending too much money. A simple random sample (SRS) approach assumes no knowledge of the system and allocates effort at random to the entire sampling frame. Other sampling designs and tools incorporate information like the cost of moving between sites and the recognition that not as many replicates are needed in relatively homogeneous strata. A SRS can always be used, but may not always be the most efficient choice. For example, for a fixed cost you can take more samples in a cluster survey, so the final precision can be better than from a simple random sample (SRS) of the same cost (Cochran 1977). Stratification on the other hand, may result in a more efficient design when there is less variability within strata than between strata (Cochran 1977; Lohr 1999). Stratification may also be useful if estimates for individual strata are desired as well as for the entire population. If the target population changes proportional to position (e.g., samples taken upstream vs. downstream) a systematic random sample (SysRS) may be an appropriate way to ensure spatial

coverage. If the population of interest is randomly distributed then the SysRS approximates the SRS (Lohr 1999). If the target population displays regular or cyclical characteristics then a SysRS is a poor choice. A generalized random-tessellation stratified (GRTS) design overcomes some of the shortcomings of both SRS (which tends to “clump” sampling sites) and SysRS by generating an ordered, spatially balanced and unbiased set of sites that represent the population from which the sample sites will be drawn. A brief introduction to GRTS is provided in Appendix C and a comparison of the three sampling approaches (SRS, SysRS and GRTS) is given in Appendix D.

Sampling Questions / Statistical Issues

The desired level of significance (alpha) to detect whether a difference exists and/or whether a threshold has been exceeded (i.e., whether or not we should reject the null hypothesis) for any particular indicator or suite of indicators remains to be defined. Framing this element requires development of “sampling questions”. A sampling question that takes into account the desired level of significance to detect a statistical difference at the Tier 1 monitoring level might be structured as follows:

We will accept only a 10% chance of saying that the status of a CU habitat indicator is changed when in fact it has not changed (i.e., 0.1 probability of having a false positive – Type I error)

A second sampling issue relates to statistical power, i.e., the ability to actually detect change in the condition of a CU when it occurs. Statistical power is affected by the following: i) measurement variability; ii) the probability of Type I error (alpha); iii) sampling intensity; and iv) the effect size (i.e., the larger the impact, the more likely it is to be detected) (Underwood and Chapman 2003). If the WSP Strategy 2 monitoring program intends to take a precautionary approach, then the sampling design should have considerable power. The structure for a sampling question addressing statistical power might be:

We want to be 80% certain of detecting a change in a CU habitat indicator when it has occurred (i.e., power of 0.8). This means that we are willing to accept a 20% chance of saying there has not been a change when one has occurred (i.e., 0.2 probability of having a false negative – Type II error).

The necessary sampling design/effort required to effectively address particular sampling questions with desired levels of both significance and power will have to account for several factors such as the sensitivity of the indicators employed, the resources available to the WSP habitat monitoring program, and the actual degree of certainty needed for the associated management decisions.

Remote Sensed Data Sources for Tier 1

Stalberg et al. (2009) provides a list of the pressure indicators that Strategy 2 of the WSP will use to monitor salmon habitat status and trends within CUs. Summaries of agency data sources that could inform these indicators (and possible metrics) are provided in Table 1. Practical assessments (i.e., contacts, data availability, data maintenance, cost, spatial extent/resolution, temporal extent/frequency of updates) are provided in Appendix E for each of these data sources. The information in Table 1 is intended to provide some bounds on what data sources are worth pursuing for the development of WSP Strategy 2 habitat indicators. It is important to note that the habitat working group has not yet formalized a list of metrics for the selected indicators. We selected the metrics given in Table 1 based on the results of our practical assessment of data sources and availability.

Table 1 List of indicators and metrics that can be calculated from remotely sensed / GIS sources, and their respective data sources.

Indicator	Metric	Preferred data source	Rationale	Additional comments
Total land cover alterations (stream and lake)	Percent by land use.	Baseline Thematic Mapping (BTM), Vegetation Resource Index (VRI), Freshwater Atlas (FWA) Wetlands, RESULTS Openings, Historical Fire Polygons.	Reliable and best available data sources for included monitoring metrics. Available free of charge, and regulated by notable agencies.	By using VRI, FWA wetlands, RESULTS Openings, and fire polygon layers to update the BTM data, a more up-to-date land use layer can be created. On an individual watershed scale, if local land use data exists that is more up-to-date, it should be incorporated into the land cover analysis.
	Equivalent clear cut area (ECA).	Vegetation Resource Index (VRI), RESULTS Openings.	Attributes of the VRI combined with RESULTS Openings allow for the calculation of regeneration growth for the ECA. Both sources are free and monitored by BC MOE.	
Watershed road development (stream and lake)	Road density.	Digital Road Atlas (DRA), Forest Tenure roads.	Reliable and best available data sources for included monitoring metrics. Available free of charge, and regulated by notable agencies.	
Riparian disturbance (stream and lake)	Proportion of stream length with disturbed riparian zone.	Freshwater Atlas (FWA) Stream Network, Baseline Thematic Mapping (BTM), Vegetation Resource Index (VRI), Freshwater Atlas (FWA) Wetlands, RESULTS Openings, Historical Fire Polygons.	Reliable and best available data sources for included monitoring metrics. Available free of charge, and regulated by notable agencies.	A 100 m buffer around the stream network can be used as an approximation to riparian area.
Accessible stream length, based on barriers	Linear length of streams accessible to salmon.	Freshwater Atlas (FWA) Stream Network, BC Historical Fish Distribution Zones (1:50K), BC Macro-Reaches (1:50K), Provincial Obstacles to Fish Passage.	Combining reach information, such as size and gradient, with known fish distribution zones and obstacles to fish passage should allow accessible stream reaches to be identified.	
Key spawning areas (length)	Linear length of streams used as spawning areas.	Freshwater Atlas (FWA) Stream Network, BC Historical Fish Distribution Zones (1:50K).	Reliable and best available data sources for included monitoring metrics. Available free of charge, and regulated by notable agencies.	

Indicator	Metric	Preferred data source	Rationale	Additional comments
Estuary habitat disturbance	Proportion of estuary foreshore altered.	Landsat, SPOT, Orthophotos	The limited spatial extent of estuaries lends itself to change detection analysis using remote sensing (satellite imagery). This can be carried out in a timely and cost effective manner, assuming sufficient data coverage.	
	Proportion of surface area disturbed in-shore.			
	Proportion of surface area disturbed off-shore.			
Estuarine habitat area (riparian, sedge, eelgrass and mudflat)	Percent by habitat area.	Landsat, SPOT, Orthophotos	The limited spatial extent of estuaries lends itself to a land cover analysis using remote sensing (satellite imagery). This can be carried out in a timely and cost effective manner, assuming sufficient data coverage.	

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Appendix A: Hypothetical example of nested Tiers 1 through 3 of the WSP habitat monitoring protocol for a subset of sockeye CUs in BC

NOTE: All numbers used in this example are illustrative in nature and are not representative of reality

CUs are identified as either properly functioning (PF), not properly functioning (NPF), or impaired at Tier 1 using WSP Strategy 2 habitat pressure indicator and associated thresholds.

e.g., 10, 35, 20 CUs are categorized as PF, impaired, and NPF, respectively.

Moving forward to Tier 2, a random sample of CUs would be taken from each category (i.e., PF, impaired or NPF). Watersheds within each of the selected CUs would then undergo more detailed field monitoring (the exact nature of Tier 2 monitoring remains to be determined, but will use WSP Strategy 2 state indicators and will be based on the management questions of interest, the sampling design, and the monitoring protocols chosen). In addition, sampling within a watershed should be done using a randomized approach for site selection to ensure that sites in the watershed are representative of the watershed/CU as a whole.

13 of the 35 CUs categorized as impaired and 10 of the 20 FSWs categorized as NPF⁶ are randomly selected. These 23 watersheds would then become the focus of Tier 2 monitoring⁷.

Based on Tier 2 sampling, the data collected may suggest that 50% of watersheds (i.e., 5 of 10) with NPF CUs have been classified NPF at the Tier 1 level because they have sediment loads greater than what would be considered to be within the natural range and spawning habitat is negatively affected. Habitat managers can then decide whether this is an issue worth exploring further in order to better inform habitat management actions.

One watershed is selected at random from the 5 NPF CUs with erosion problems to move on to Tier 3 monitoring⁸

Tier 3 monitoring would focus on the particular problem identified at Tier 2. The intention of Tier 3 monitoring is to get a better sense of the temporal variability in the watershed, to determine whether improvement (or at least stabilization) in the status of the individual watershed is occurring, and hopefully to learn how different management actions might improve the problem.

Figure 3 provides a map-based illustration of this design approach for a subset of FSW watersheds located in southeastern BC.

⁶ The desired amount of sampling effort within each category has not yet been determined. The numbers presented here are for illustrative purposes. Because the sample of CUs from each category was taken at random it is representative of the category as a whole.

⁷ The relative weighting of effort in PF, impaired, and NPF will depend on the type of question being asked and the desired level of power. The weighting of effort in this example is for illustrative purposes only.

⁸ The number of watershed that move onto Tier 3 and the number of sites within each watershed will depend on the resource availability

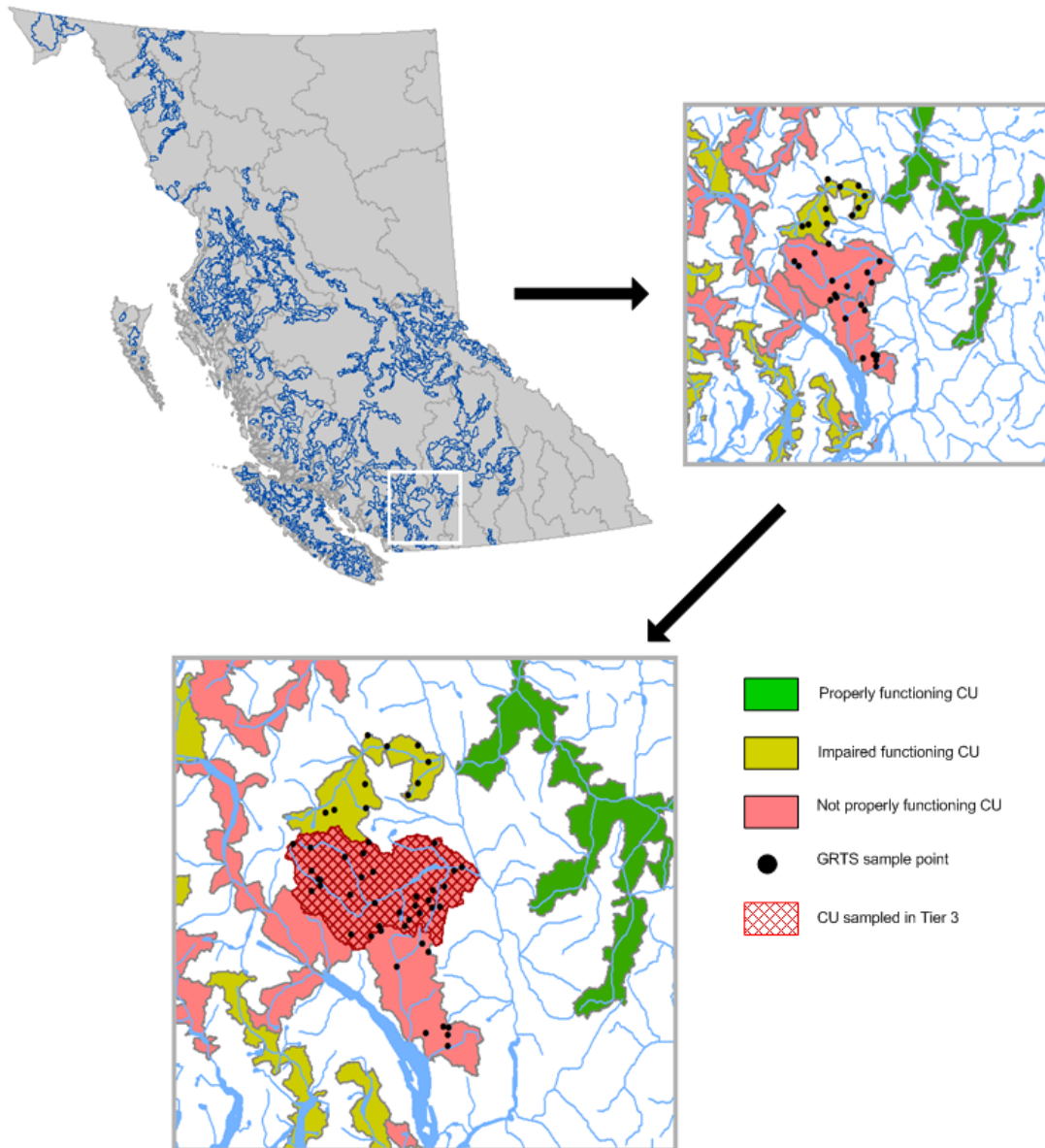


Figure 3 Hypothetical illustration of a nested multi-tiered status and trends monitoring framework to evaluate the status of wild salmon CUs. The top left panel shows all the Chinoock CUs that are currently identified in the province. In the top right and bottom panels, green CUs are those classified through Tier 1 monitoring as properly functioning (NPF), yellow CUs are those classified as impaired, and red CUs are classified as not properly functioning (PF). The top right panel shows a subset of Chinook CUs selected for more intensive field-based Tier 2 monitoring (black points represent potential randomized sampling locations within a watershed). The third panel shows a selected NPF CU (illustrated by cross-hatching) in which multi-year intensive monitoring will be undertaken to evaluate whether high priority sites in a watershed have stabilized or improved (either passively or in response to directed management actions). Management actions that could be evaluated may vary from status quo (i.e., no change in ongoing practices) to directed habitat.

Appendix B: List of proposed habitat indicators for WSP habitat monitoring

Table 2 List of proposed habitat indicators for WSP Strategy 2 habitat monitoring

Indicator type	Indicator	Coastal coho	Interior coho	Ocean type chinook	Immediate type chinook	Stream type chinook	Lake rearing sockeye	Estuary rearing sockeye	Northern chum	Southern chum	Pink
Pressure	Total land cover alteration	X	X	X	X	X	X	X	X	X	X
Pressure	Watershed road development	X	X	X	X	X	X	X	X	X	X
Pressure	Water extraction	X	X	X	X	X	X	X	X	X	X
Pressure	Riparian disturbance (streams)	X	X	X	X	X	X	X	X	X	X
Pressure	Riparian disturbance (lakes)		X	X			X	X	X		
Pressure	Permitted waste management discharges (estuaries)	X	X			X	X				
Pressure	Permitted waste management discharges (lakes)	X	X	X	X	X	X	X	X	X	X
Pressure	Permitted waste management discharges (streams)	X	X	X	X	X	X	X	X	X	X
Pressure	Marine vessel traffic (estuary)	X	X	X	X	X	X	X	X	X	X
Pressure	Disturbance of riparian, intertidal and sub-tidal habitats (estuary)	X	X	X	X	X	X	X	X	X	X
State	Suspended sediment (streams)	X	X	X	X	X	X	X	X	X	X
State	Water quality (streams)	X	X	X	X	X	X	X	X	X	X
State	Chemistry and contaminants (estuaries)	X	X	X	X	X	X	X	X	X	X
State	Water temperature (streams), coho juvenile rearing	X	X	X	X	X					
State	Temperature (streams), migration spawning all species	X	X	X	X	X	X	X	X	X	X
State	Discharge (streams)	X	X	X	X	X	X	X	X	X	X
State	Coldwater refuge zone (lakes)	X	X				X				
State	Productive capacity (lakes)	X	X			X	X				
State	Dissolved oxygen (estuaries)	X	X	X	X	X	X	X	X	X	X
Quantity	Accessible stream length (based on barrier location)	X	X	X	X	X	X	X	X	X	X
Quantity	Length of key spawning areas (streams)	X	X	X	X	X	X	X	X	X	X
Quantity	Length of shore spawning areas (lakes)						X				
Quantity	Estuarine habitat area (riparian, sedge, eelgrass, and mudflats)	X	X	X	X	X	X	X	X	X	X

Appendix C: A brief introduction into generalized random-tessellation stratified (GRTS) sampling approach for population and habitat monitoring

The Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP) has developed a general approach for selecting sites along stream networks incorporating randomization and spatial balance, called GRTS (Generalized Random-Tessellation Stratified design; Stevens and Olsen 2004). GRTS is a GIS-based approach and lends itself to a relatively broad application by many users (Firman and Jacobs 2001). GRTS-based designs allow one to make a statistical inference about the status and trend of habitat attributes within predefined habitat strata or habitat networks (e.g. network of stream reaches). GRTS designs have been successfully used to evaluate the status of, for example, stocks of salmon and trout in the US Pacific Northwest (e.g., coastal coho, Jacobs et al. 2002; Lower Columbia coho, Suring, et al. 2006), redband trout, Dambacher and Jones 2007; bull trout, Starcevich et al. 2004)). To assist with the development of specific survey designs in stream networks, the application of GRTS requires users to define the area of interest, the appropriate digital representation of a target stream network and/or habitat strata of interest, and the size and density of sample sites. GRTS also allows the selection of a "master sample", a number of sites well in excess of the number needed for a particular survey. The list is ordered in a way that allows the selection of a subset of spatially balanced sites that might be needed for any particular survey. A GRTS design is spatially explicit, unbiased, and has reasonably high power for detecting trends. A GRTS-based site-selection approach supports sampling at varying spatial extents and is sufficiently flexible to use on the scale of multiple large river basins. GRTS-based designs have been used successfully by agencies across the US Pacific Northwest to help determine the numbers of adult salmon returning each year, the distribution and rearing density of juveniles, the productivity and relative condition of stream biota, and the condition of freshwater habitats..

Appendix D: Choosing an appropriate probabilistic sampling design⁹

1.1.1 Basic probabilistic sampling designs

The *target population* can be defined in several ways: 1) the complete collection of individuals we wish to study (Lohr 1999); 2) the population about which information is wanted (Cochran 1977); and 3) the complete set of units about which we want to make inferences (Elzinga et al 2001). Regardless of definition, in order to make inferences about the entire target population, all individuals within the target population must have some chance of being selected in the sample. The *sampling population* or *sampling frame* is the collection of all possible sampling units that might have been chosen in a sample, or can alternatively be described as the population from which the sample was taken (Lohr 1999). Probabilistic sampling refers to designs in which each sampling unit within the sampling frame has a known and non-zero probability of being selected. There are two probabilistic sampling designs that are most commonly used and form the basic building blocks of most sampling designs: simple random sampling (SRS), and systematic random sampling (SysRS). SRS refers to the situation where a random sample of all sampling units within the sampling frame is selected, e.g., drawing numbers from a hat. SysRS refers to the situation where sampling units are selected at regular intervals using a randomly selected starting point, e.g., reading every tenth name from the phone book or taking a sample every ten metres.

1.1.2 Variations on the basic probabilistic designs

There are multiple variations of these basic designs that have been developed to address particular situations including: cluster sampling, adaptive sampling, and distance sampling. In a cluster sample, an initial random sample of sites is chosen and then a census is completed within that site (e.g., a random sample of pools with a census of body weight/length of all fish found in the pool). Adaptive sampling begins like any other sampling design with a random selection of sampling units, but additional sampling units may be added based on the observed values in the initial sample (Thompson 1990). Generalized random-tessellation stratified (GRTS) designs are a recent approach that draws on the strengths of each of the basic designs. GRTS designs are spatially-balanced probabilistic surveys developed by the US Environmental Protection Agency (EPA) under their Environmental Monitoring and Assessment Program (Stevens & Olsen 2004). Stratification is a tool which can be applied to any sampling design. In a stratified random design the sampling frame is divided into non-overlapping groups (strata) based on some characteristic such as habitat type. A random sample is then chosen from each of the strata. Any combination of these designs can be used in a multi-stage sampling design. For example, a simple random sample of streams could be chosen from each stratum within the target population. A systematic random sample of reaches within each stream could then be selected, followed by a census or sample of a particular metric (e.g., large woody debris) within each reach. Calculating an estimate of the mean from a multi-stage sample is fairly intuitive, but the variance calculations are more complicated. The typical mistake made is to treat all of the observations as though they were drawn at random from the target population. In reality the secondary sampling units (reaches in this case) are a sample from the stream, not the population. This is one form of pseudo-replication discussed by Hurlbert (1984). Increasing the number of reaches within streams helps improve the precision of the estimate for the single stream, but will not necessarily improve the estimate of the strata unless additional streams are sampled.

1.1.3 Comparison of SRS, SysRS, and GRTS

The WSP Strategy 2 monitoring program has a broad geographic scope (province of BC); consequently, the cost of moving between sites will likely be substantial. In addition, the diversity of ecosystems present in BC (14 bio-geoclimatic zones) makes it important to ensure proper spatial coverage of sample sites across CUs. The GRTS approach provides a nice alternative that can deal with some of the complications

⁹ Modified from Pickard (2008).

that arise in practice when using either SRS or SysRS. We provide a brief comparison of these three approaches (Tables 2 to 9).

Table 3 Comparison of SRS, SysRS, and GRTS estimates of precision

Approach	Description
SRS	Simple to compute
SysRS	A proper estimate of precision is very difficult to compute for a (single) systematic sample unless you are willing to make strong assumptions about self-randomization (in which case a systematic sample is equivalent to an SRS) or have knowledge about any "trend" in the population that the systematic sample can measure. To get around these issues, replicated systematic samples are often done. For example, rather than taking a single systematic sample of size 100, you may take 4 independent systematic samples of 25. Compute an estimate from each systematic sample of size 25 and then the variance in the 4 estimates can be used to get an overall SE
GRTS	Slightly more complicated to deal with, but Stevens and Olsen (2004) give details on computations of simpler forms and the R library (spsurvey) documents the analytical tools.

Dealing with "refusals" or "non-response": In many cases, after the sample points (locations) have been selected it is not possible to use them because landowners will not give permission, they are inaccessible, or the location is not safe. Each approach deals with this scenario differently and some are more robust to the problem than others (Table 3).

Table 4 Comparison of SRS, SysRS, and GRTS under "refusals" or "non-response" scenario.

Approach	Description
SRS	Simply draw a new point at random. There is no impact on variance computations.
SysRS	Non-response is a problem for this design. You cannot simply choose another point and all the formulae for estimates are affected because of the missing data. You could over sample, but now the gaps will be unequally spaced in the data.
GRTS	Robust to this problem because it allows over sampling (Theobald <i>et al.</i> 2007). Simply choose the next point (after reverse hierarchical ordering). This is equivalent to SRS simply choosing another point.

Accommodating different sampling intensities: In some cases, two different "surveys" are to be conducted simultaneously with different sampling intensities. For example, you may wish to sample 25 points for survey A and 100 points for survey B. Each sampling method requires a slightly different procedure that is outlined in Table 4.

Table 5 Procedure for accommodating different sampling regimes when using SRS, SysRS, and GRTS.

Approach	Description
SRS	Draw 100 points for survey B, and then randomly select 25 from those 100 for survey A. This way 25 points get both A and B; and the remaining 75 points get B only. Both are SRS so it is easy to compute estimates and variance.
SysRS	Draw SysRS of size 100, and then do a second SysRS of size 25 from those 100 points chosen. Both are systematic samples with same problems in dealing with missing data and variance computation.
GRTS	Draw first 100 in reverse hierarchical ordering for B. Use first 25 for A. Both samples are GRTS, so no problems in computing estimates and variance.

Spatial coverage: If there is correlation among units (i.e., units close together will tend to be more similar than units further apart), then a sampling design with good spatial coverage is a good thing. When spatial correlation exists there is no need to sample two points very close together as they will tend to have the same response and would lead to "wasting" of samples. Generally, when a correlation between units is present, designs that are more spatially spread out will tend to have better precision (i.e., lower SE) than SRS because there is no "wasting" of samples at points that are close together. Table 5 outlines the ability of each approach to take into account spatial coverage.

Table 6 Comparison of spatial coverage of SRS, SysRS, and GRTS approaches.

Approach	Description
SRS	Poor spatial coverage. Any single realization of a SRS often results in areas with clusters of samples and areas with no samples (Theobald <i>et al.</i> 2007).
SysRS	High spatial coverage. The problem with SysRS designs is that in the presence of "correlation" among units, it is not clear how to compute the variance for a systematic design.
GRTS	Intermediate between both. The way the GRTS is taken tends to spread samples out more than an SRS but not as regularly as a SysRS.

Variable selection probabilities: For example, if sampling units are of different sizes, e.g., CUs and/or watersheds, it may be preferable to have the probability of selection proportional to the size of the CU/watershed, under the assumption that larger CUs/watersheds contribute more to the overall quality of a regional habitat than very small watersheds. The ease of varying selection probability using each method is discussed in Table 6.

Table 7 Comparison of SRS, SysRS, and GRTS approaches when using variable selection probabilities.

Approach	Description
SRS	Need to switch selection probabilities so they are proportional to size, but computations are straight forward.
SysRS	Need to switch to a systematic sample on the size variable, but now estimates and variance issues are much more complicated.
GRTS	Need to switch selection probabilities so they are proportional to size, but computations are straight forward.

Inverse sampling: When using inverse sampling, units are selected one at a time until some preset criteria is met, i.e., at least 10 sites with a special attribute that cannot be identified in advance. If you could identify the attribute in advance, then it is more efficient to use the attribute as a stratification variable. Table 7 outlines the relative ease or difficulty of using inverse sampling with each approach.

Table 8 Comparison of SRS, SysRS, and GRTS approaches and inverse sampling

Approach	Description
SRS	Not a problem, just draw one unit at a time.
SysRS	Not clear how to do this.
GRTS	Not a problem, just select units one at a time in reverse hierarchical ordering. Some care needs to be taken in computing variances as "n" is now random, but this is usually ignored and the actual sample size "n" is treated as specified in advance.

Stratification: Stratification can be a useful tool for improving the efficiency of a design (see Table 8 for a comparison of stratification using alternative methods).

Table 9 Comparison of SRS, SysRS, and GRTS approaches and stratification.

Approach	Description
SRS	No problem
SysRS	No problem
GRTS	No problem; can be applied to the GRTS in much the same way as any other design.

Dealing with continuous sampling units: The target population and sampling unit need to be defined for any type of monitoring/sampling design. In some cases the target population does not have any obvious splits to separate into sampling units. For example, rivers are "continuous", i.e., they do not have fixed sampling stations, so how should a river be split into sampling units? Table 9 lists how each method would deal with continuous sampling units

Table 10 Comparison of SRS, SysRS, and GRTS approaches with continuous sampling units.

Approach	Description
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SRS	Discretize streams into individual points, or arrange on a line (like GRTS) and take SRS of points on the line.
SysRS	Same as above.
GRTS	Same as above.

Creating and implementing a GRTS design can be difficult, as the estimate and variance calculations are complicated and hand computations are not really feasible. It is also difficult to generate a spatially explicit sampling frame for a large geographic scale; however, GIS technology has made this possible and relatively straightforward. The actual generation of sampling frames depends on the study objectives, target populations, and the extent to which the digital coverage reflects the target population (as it would with any design). The selection of a GRTS sample and the computations have been automated to a great extent. Software packages required to create GRTS designs include psurvey.design (free for download from the U.S. Environmental Protection Agency (EPA) Aquatic Resources Monitoring website (http://www.epa.gov/nheerl/arm/designing/design_intro.htm), R statistical package and ArcGIS)

Appendix E: Practical assessment of remote sensed data sources for Tier 1 monitoring

Data Source: *Baseline Thematic Mapping (BTM) (version 1)*

Summary table of indicators informed by the data source:

Indicator	Indicator Type	Habitat	Metric	Comments
Riparian Disturbance	Pressure	Stream, Lake	Proportion of stream length with disturbed riparian zone.	With BTM there is a potential for misidentification or oversight of smaller riparian areas due to the scale of mapping.
Total Land Cover Alterations	Pressure	Stream, Lake	Percent by land use.	

Description of Data Source

Data Source:

The Baseline Thematic Mapping (BTM) layer represents land use polygons as determined by a combination of analytic techniques, mostly using Landsat 5 image mosaics. BTM 1 was done on a federal satellite image base that was only accurate to about 250m. The images were geo-corrected, not ortho-corrected, so there is distortion in areas of high relief.

Contact: Malcolm Grey, Crown Registries and Geographic Base Branch (ILMB).
Telephone: (250) 387-9365
Email: Malcolm.Grey@gov.bc.ca

Data Availability:

The BTM layer is available for use from the Land Resource Data Warehouse (LRDW) (<http://www.lrdw.ca>).

Relative Cost:

Data purchase / collection: The BTM layer is freely available from the LRDW.

Data / indicator maintenance: To reproduce the BTM map of land use for the province would be multimillion dollar investment. To use the BTM as part of a land use map which is updated with other data sources would be low cost, though its relevance is continually decreasing as it gets older.

Total cost: Low. Cost is in the effort required to combine the data with other sources.

Spatial extent/ resolution:

The BTM layer covers the entire province of BC. Resolution: 1:250,000.

Temporal extent/ frequency:

The digitisation of imagery required to create the BTM layer has only been undertaken once. Images used were from the period 1992-1997. It is unknown when the province will update the BTM for the entire province as it is an expensive endeavour. Currently, the lower Thompson region and the Sunshine Coast have been the only two regions to have been updated with new BTMs.

Data Source: *Vegetation Resource Index (VRI)*

Summary table of indicators informed by the data source:

Indicator	Indicator Type	Habitat	Metric	Comments
Riparian Disturbance	Pressure	Stream, Lake	Proportion of stream length with disturbed riparian zone.	
Total Land Cover Alterations	Pressure	Stream, Lake	Percent by land use.	
			Equivalent clear cut area (ECA).	

Description of Data Source

Data Source:

Contact: Tim Salkeld, BCGOV FOR Forest Analysis and Inventory Branch.
Telephone: 250 387-6736
Email: Tim.Salkeld@gov.bc.ca

References: GeoBC

Website:

<https://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=47574&recordSet=ISO19115>

http://www.for.gov.bc.ca/hts/vridata/standards/datadictionary/rpt_vri_datadict0505_draft1.0d.pdf

VRI Data Dictionary

<https://apps.gov.bc.ca/int/ilmbrobread>

ILMB Oracle Designer 10g CASE Repository

Data Availability:

Available for public access.

Relative Cost:

Data purchase / collection: Free.

Data / indicator maintenance: Data Custodian Organization: BCGOV FOR Forest Analysis and Inventory Branch.
 Ongoing resource status.

Total cost: Low (1 week): Estimated Cost of Data Interpretation/ Extraction: Medium to High because of large size of dataset and complexity of monitoring metrics.

Spatial extent/ resolution:

Full provincial coverage.

Temporal extent/ frequency:

Created on 10/15/2006, resource status is ongoing.

This dataset is revised on an annual basis to provide a complete and accurate VRI database for the entire province of British Columbia.

Data Source: 1:20,000 Freshwater Atlas: Stream Network

Summary table of indicators informed by the data source:

Indicator	Indicator Type	Habitat	Metric	Comments
Riparian disturbance	Pressure	Stream, Lake	Proportion of stream length with disturbed riparian zone.	
Accessible stream length, based on barriers	Quantity	Stream	Linear length of streams accessible to salmon.	
Key spawning areas (length)	Quantity	Stream	Linear length of streams used as spawning areas.	

Description of Data Source

Data Source:

Contact: Malcolm Gray, Crown Registries and Geographic Base Branch (ILMB).
Telephone: 250 952-6573
Email: Malcolm.Gray@gov.bc.ca

References: GeoBC

Website:

<https://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=50648&recordSet=ISO19115>

<https://apps.gov.bc.ca/int/ilmbroread>

ILMB Oracle Designer 10g CASE Repository

<ftp://ftp.geobc.gov.bc.ca/pub/outgoing/FreshWaterAtlasDocuments/FWAv1.3-SDE.WarehouseModelSpecification.rev3.doc>

GEOBC FTP site for Freshwater Atlas Documentation

<ftp://ftp.geobc.gov.bc.ca/pub/outgoing/FreshWaterAtlasDocuments/FWARoutingDocumentation.doc>

GEOBC FTP site for Freshwater Atlas Documentation

Data Availability:

Available for public access.

Relative Cost:

Data purchase / collection: Free.

Data / indicator maintenance: Data Custodian Organization: BCGOV ILMB Crown Registry and Geographic Base Branch (CRGB). Ongoing resource status.

Total cost: Low (1 week): Estimated Cost of Data Interpretation/ Extraction: Low to Medium.

Spatial extent/ resolution:

Full provincial coverage. 1:20 000 scale.

Temporal extent/ frequency:

Revised on 09/01/2008, next scheduled revision 12/15/2008, resource status is ongoing.

This dataset is revised on an “as needed” basis to provide a complete and accurate Stream Network database for the entire province of British Columbia.

Data Source: 1:20,000 Freshwater Atlas: Wetlands

Summary table of indicators informed by the data source:

Indicator	Indicator Type	Habitat	Metric	Comments
Total Land Cover Alterations	Pressure	Stream, Lake	Percent by land use.	

Description of Data Source

Data Source:

Contact: Malcolm Gray, Crown Registries and Geographic Base Branch (ILMB).
Telephone: 250 952-6573
Email: Malcolm.Gray@gov.bc.ca

References: GeoBC

Website:

<https://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=50648&recordSet=ISO19115>

<https://apps.gov.bc.ca/int/ilmbrobread>

ILMB Oracle Designer 10g CASE Repository

<ftp://ftp.geobc.gov.bc.ca/pub/outgoing/FreshWaterAtlasDocuments/FWAv1.3-SDE.WarehouseModelSpecification.rev3.doc>

GEOBC FTP site for Freshwater Atlas Documentation

<ftp://ftp.geobc.gov.bc.ca/pub/outgoing/FreshWaterAtlasDocuments/FWARoutingDocumentation.doc>

GEOBC FTP site for Freshwater Atlas Documentation

Data Availability:

Available for public access.

Relative Cost:

Data purchase / collection: Free.

Data / indicator maintenance: Data Custodian Organization: BCGOV ILMB Crown Registry and Geographic Base Branch (CRGB). Ongoing resource status.

Total cost: Low (1 week): Estimated Cost of Data Interpretation/ Extraction: Low to Medium.

Spatial extent/ resolution:

Full provincial coverage. 1:20 000 scale.

Temporal extent/ frequency:

Revised on 09/01/2008, resource status is ongoing. This dataset is revised on an “as needed” basis.

Data Source: *RESULTS Openings*

Summary table of indicators informed by the data source:

Indicator	Indicator Type	Habitat	Metric	Comments
Riparian Disturbance	Pressure	Stream, Lake	Proportion of stream length with disturbed riparian zone.	
Total Land Cover Alterations	Pressure	Stream, Lake	Percent by land use.	
			Equivalent clear cut area (ECA).	

Description of Data Source

Data Source:

Contact: Caroline MacLeod: BCGOV FOR FS Division Forest Practices Branch
Telephone: 250 356-2094
Email: Caroline.MacLeod@gov.bc.ca

References: GeoBC: Ministry of Forests and Range Data Models
Website: <https://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=52583&recordSet=ISO19115>

Data Availability:

Relative Cost:

Data purchase / collection: Free.

Data / indicator maintenance: Data Custodian Organization: BCGOV FOR Forest Practices Branch

Total cost: Low (1 week): Estimated Cost of Data Interpretation/ Extraction: Medium, due to large size of dataset and complexity of monitoring metrics.

Spatial extent/ resolution:

Full provincial coverage.

Temporal extent/ frequency:

Database created on 11/27/2003. Resource status is complete. Daily update cycle.

Data Source: *Fire Perimeters - Historical*

Summary table of indicators informed by the data source:

Indicator	Indicator Type	Habitat	Metric	Comments
Riparian Disturbance	Pressure	Stream, Lake	Proportion of stream length with disturbed riparian zone.	
Total Land Cover Alterations	Pressure	Stream, Lake	Percent by land use.	

Description of Data Source

Data Source:

Contact: Mike Winder: BCGOV BCGOV FOR Protection Branch
Telephone: 250 387-8730
Email: mike.winder@gov.bc.ca

References: GeoBC
Website: <http://apps.gov.bc.ca/pub/geometadata/metadadataDetail.do?recordUID=57060&recordSet=ISO19115>

Data Availability:

Relative Cost:

Data purchase / collection: Free.

Data / indicator maintenance: Data Custodian Organization: BCGOV FOR Wildfire Management Branch

Total cost: Low (1 week): Estimated Cost of Data Interpretation/ Extraction: Low.

Spatial extent/ resolution:

Full provincial coverage.

Temporal extent/ frequency:

Database created on 07/31/2009. Resource status is on going. Monthly update cycle. On April 1 of each year the previous year's fire perimeters are merged into this dataset.

Data Source: *Digital Road Atlas (DRA)*

Summary table of indicators informed by the data source:

Indicator	Indicator Type	Habitat	Metric	Comments
Watershed road development	Pressure	Stream, Lake	Road density.	

Description of Data Source

Data Source:

Contact: Carol Osborne, Team Lead – Base-Mapping: BCGOV ILMB Crown Registry and Geographic Base Branch (CRGB).

Telephone: 250-952-6557

Email: carol.osborne@gov.bc.ca

References: GeoBC

Website: <https://apps.gov.bc.ca/pub/geometadata/metadetail.do?recordUID=45674&recordSet=ISO19115>

For information on the fully attributed and up-to-date DRA data, please visit:

http://ilmbwww.gov.bc.ca/bmgs/products/mapdata/digital_road_atlas_products.htm

Data Availability:

Available for public access.

Relative Cost:

Data purchase / collection: Free.

Data / indicator maintenance: Data Custodian Organization: Base Mapping and Cadastre Section (ILMB).

Total cost: Low (1 week): Estimated Cost of Data Interpretation/ Extraction: Low.

Spatial extent/ resolution:

Full provincial coverage.

Temporal extent/ frequency:

Published on 11/15/2004, last revised on 05/01/2010.

This dataset is revised on an annual basis to provide a complete and accurate road networking database for the entire province of British Columbia.

Data Source: *Forest Tenure Road Segment Lines*

Summary table of indicators informed by the data source:

Indicator	Indicator Type	Habitat	Metric	Comments
Watershed road development	Pressure	Stream, Lake	Road density.	Provides additional logging and forest access roads not covered by the DRA.

Description of Data Source

Data Source:

Contact: Jayne Wynrib, Decision Support Branch.
Telephone: 250-952-4776
Email: Jayne.Wynrib@gov.bc.ca

References: GeoBC
Website: <https://apps.gov.bc.ca/pub/geometadata/metadadataDetail.do?recordUID=51944&recordSet=ISO19115>

Data Availability:

Available for public access.

Relative Cost:

Data purchase / collection: Free.

Data / indicator maintenance: BCGOV FOR Resource Tenures and Engineering (RTEB).

Total cost: Low (1 week); Estimated Cost of Data Interpretation/ Extraction: Low.

Spatial extent/ resolution:

Full provincial coverage.

Temporal extent/ frequency:

Created on 04/18/2008. Resource status is on going. Daily update cycle.

Data Source: 1:50,000 BC Historical Fish Distribution Zones

Summary table of indicators informed by the data source:

Indicator	Indicator Type	Habitat	Metric	Comments
Accessible stream length, based on barriers	Quantity	Stream	Linear length of streams accessible to salmon.	
Key spawning areas (length)	Quantity	Stream	Linear length of streams used as spawning areas.	

Description of Data Source

This is a provincial coverage of inland waters fish species distribution, mapped as stream segments or zones. These fish zones are geo-referenced to the digital stream centreline network of the BC Watershed Atlas 50K. This theme is based on data from the Fisheries Information Summary System (FISS) database that was compiled prior to the year 2000. Each zone represents a section or length of stream where a fish species has been identified and, where known, the extent of its spawning, rearing and holding activities. For mapping purposes each fish species has been assigned to one of three categories: Salmon, Sport Fish or Other Fish. For anadromous Salmon species only, additional zones have been created to show the extent of their upstream migration from the ocean. The upstream and downstream boundary of each fish zone is located on a stream by its distance, in metres, from the stream mouth.

Data Source:

Contact: David Tesch, BC Ministry of Environment, Ecosystems Branch.
Telephone: (250) 387-9588
Email: David.Tesch@gov.bc.ca

References: GeoBC

Website:
<https://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=47234&recordSet=ISO19115>

Data Availability:

Available for public access.

Relative Cost:

Data purchase / collection: Free.

Data / indicator maintenance: Data Custodian Organization: BCGOV ENV Ecosystems Branch (MOE).

Total cost: Low (1 week): Estimated Cost of Data Interpretation/ Extraction: Low to Medium.

Spatial extent/ resolution:

Full provincial coverage. 1:50 000 scale.

Temporal extent/ frequency:

Published on 03/16/2006. Resource status is completed, with no planned updates.

This theme is based on data from the Fisheries Information Summary System (FISS) database that was compiled prior to the year 2000. Fish Distribution Zones based on 1:50,000 NTS mapping. Each zone represents a segment of a stream where a fish species has been identified and, where known, the extent of its spawning, rearing, or holding activities.

Data Source: *Provincial Obstacles to Fish Passage*

Summary table of indicators informed by the data source:

Indicator	Indicator Type	Habitat	Metric	Comments
Accessible stream length, based on barriers	Quantity	Stream	Linear length of streams accessible to salmon.	

Description of Data Source

The Provincial Obstacles to Fish Passage theme presents records of all known obstacles to fish passage from several fisheries datasets. Records from the following datasets have been included: The Fisheries Information Summary System (FISS); the Fish Habitat Inventory and Information Program (FHIIP); the Field Data Information System (FDIS) and the Resource Analysis Branch (RAB) inventory studies.

Data Source:

Contact: Gordon Oliphant, Knowledge Management Branch (MOE).
Telephone: 250-356-9938
Email: gord.oliphant@gov.bc.ca

References: GeoBC

Website: <https://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=50219&recordSet=ISO19115>

Data Availability:

Available for public access.

Relative Cost:

Data purchase / collection: Free.

Data / indicator maintenance: Data Custodian Organization: BCGOV ENV Ecosystems Branch (MOE).

Total cost: Low (1 week): Estimated Cost of Data Interpretation/ Extraction: Low to Medium.

Spatial extent/ resolution:

Full provincial coverage. 1:50 000 scale.

Temporal extent/ frequency:

Created on 06/18/2007. Resource status is ongoing, with daily updates.

Data Source: 1:50,000 BC Macro-Reaches

Summary table of indicators informed by the data source:

Indicator	Indicator Type	Habitat	Metric	Comments
Accessible stream length, based on barriers	Quantity	Stream	Linear length of streams accessible to salmon.	

Description of Data Source

This is a provincial coverage of stream macro-reaches. A macro-reach is a homogeneous stream segment delineated through interpretation of reach attributes from the 1:50,000 National Topographic Series (NTS) of mapsheets. Reach attributes include gradient (as derived from contour interpolation), channel pattern, size of stream, order of stream, major falls, position of the stream in the landscape, and inferred bank materials. These macro-reaches are geo-referenced to the stream centreline network of the BC Watershed Atlas 50K.

Data Source:

Contact: David Tesch, BC Ministry of Environment, Ecosystems Branch.
Telephone: (250) 387-9588
Email: David.Tesch@gov.bc.ca

References: GeoBC

Website: <https://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=47094&recordSet=ISO19115>

Data Availability:

Available for public access.

Relative Cost:

Data purchase / collection: Free.

Data / indicator maintenance: Data Custodian Organization: BCGOV ENV Ecosystems Branch (MOE).

Total cost: Low (1 week): Estimated Cost of Data Interpretation/ Extraction: Low to Medium.

Spatial extent/ resolution:

Full provincial coverage. 1:50 000 scale.

Temporal extent/ frequency:

Published on 11/09/2005. Resource status is completed, with no planned updates.

Data Source: *Landsat Orthoimagery*

Summary table of indicators informed by the data source:

Indicator	Indicator Type	Habitat	Metric	Comments
Estuary habitat disturbance	Pressure	Estuary	Proportion of estuary foreshore altered.	
			Proportion of surface area disturbed in-shore.	
			Proportion of surface area disturbed off-shore.	
Estuarine habitat area (riparian, sedge, eelgrass and mudflat)	Quantity	Estuary	Percent by habitat area.	

Description of Data Source

Data Sources:

Contact: GeoBase Technical Support.
Telephone: +01-819-564-4857 / 1-800-661-2638 (Canada and USA)
Fax: +01-819-564-5698
Email: SupportGeoBase@nrcan.gc.ca

References: GeoBase
Website: <http://geobase.ca/geobase/en/data/imagery/landsat/index.html>

Data Availability:

Available for public access.

Relative Cost:

Data purchase / collection: Free.

Data / indicator maintenance: Data Custodian Organization for GeoBase: Government of Canada, Natural Resources Canada, Earth Sciences Sector.

Total cost: Low (1 week): Estimated Cost of Data Interpretation/ Extraction: Varies.

Spatial extent/ resolution:

Full provincial coverage. Landsat 7 data offers 1 panchromatic band (15m), 6 multispectral bands (30m) and 2 thermal infrared bands (60m).

Temporal extent/ frequency:

GeoBase offers a complete set of cloud-free (less than 10%) Landsat 7 orthoimages covering the Canadian landmass using data from the Landsat 7 satellite. Landsat 7 images used to produce this data set were captured between 1999 and 2003. Imagery updates are unknown.

Data Source: SPOT Orthoimagery

Summary table of indicators informed by the data source:

Indicator	Indicator Type	Habitat	Metric	Comments
Estuary habitat disturbance	Pressure	Estuary	Proportion of estuary foreshore altered.	
			Proportion of surface area disturbed in-shore.	
			Proportion of surface area disturbed off-shore.	
Estuarine habitat area (riparian, sedge, eelgrass and mudflat)	Quantity	Estuary	Percent by habitat area.	

Description of Data Source

Data Source:

Contact: GeoBase Technical Support.
Telephone: +01-819-564-4857 / 1-800-661-2638 (Canada and USA)
Fax: +01-819-564-5698
Email: SupportGeoBase@nrcan.gc.ca

References: GeoBase
Website: <http://geobase.ca/geobase/en/data/imagery/imr/index.html>

Data Availability:

Available for public access.

Relative Cost:

Data purchase / collection: Free.

Data / indicator maintenance: Data Custodian Organization for GeoBase: Government of Canada, Natural Resources Canada, Earth Sciences Sector.

Total cost: Low (1 week): Estimated Cost of Data Interpretation/ Extraction: Varies.

Spatial extent/ resolution:

GeoBase: Full provincial coverage. 10m panchromatic spatial resolution and 20m multispectral spatial resolution.

Temporal extent/ frequency:

GeoBase: Dataset offers a complete set of medium resolution orthoimagery based on SPOT 4 / 5 covering all of Canada south of the 81st parallel. The first SPOT images of this dataset were collected in 2005 and the imagery collection is scheduled to be complete in 2010. Imagery updates are unknown.

Data Source: *Orthophoto Imagery (for purchase)***Summary table of indicators informed by the data source:**

Indicator	Indicator Type	Habitat	Metric	Comments
Estuary habitat disturbance	Pressure	Estuary	Proportion of estuary foreshore altered.	
			Proportion of surface area disturbed in-shore.	
			Proportion of surface area disturbed off-shore.	
Estuarine habitat area (riparian, sedge, eelgrass and mudflat)	Quantity	Estuary	Percent by habitat area.	

Description of Data Source**Data Source:**

Contact 1: GeoBC Service.
 Email: GeoBC.ServiceDesk@gov.bc.ca
Contact 2: Basemap Online Store Customer Support.
 Email: BMOS@geobc.gov.bc.ca

References: GeoBC

Website:
<http://archive.ilmb.gov.bc.ca/crgb/products/imagery/orthomosaic.htm>

Data Availability:

Available upon purchase.

Relative Cost:

Data purchase / collection: \$500.00 for each 20k digital orthophoto mosaic map sheet.
 Incorporates up to 25 individual 20X compressed TRIM 20K map sheets that fall within a Quarter NTS letter block, 1m resolution (e.g., 82E/SW)

Data / indicator maintenance:

Total cost: Low (1 week): Estimated Cost of Data Interpretation/ Extraction: High Cost, especially at provincial scale.

Spatial extent/ resolution:

1m spatial resolution. Extent: Not fully provincial. Low provincial coverage of recent (less than 5 years old) orthophotos.

Temporal extent/ frequency:

Updated orthophotos for change-detection available upon purchase. Most available images for purchase range in age from 1995 to 2007.