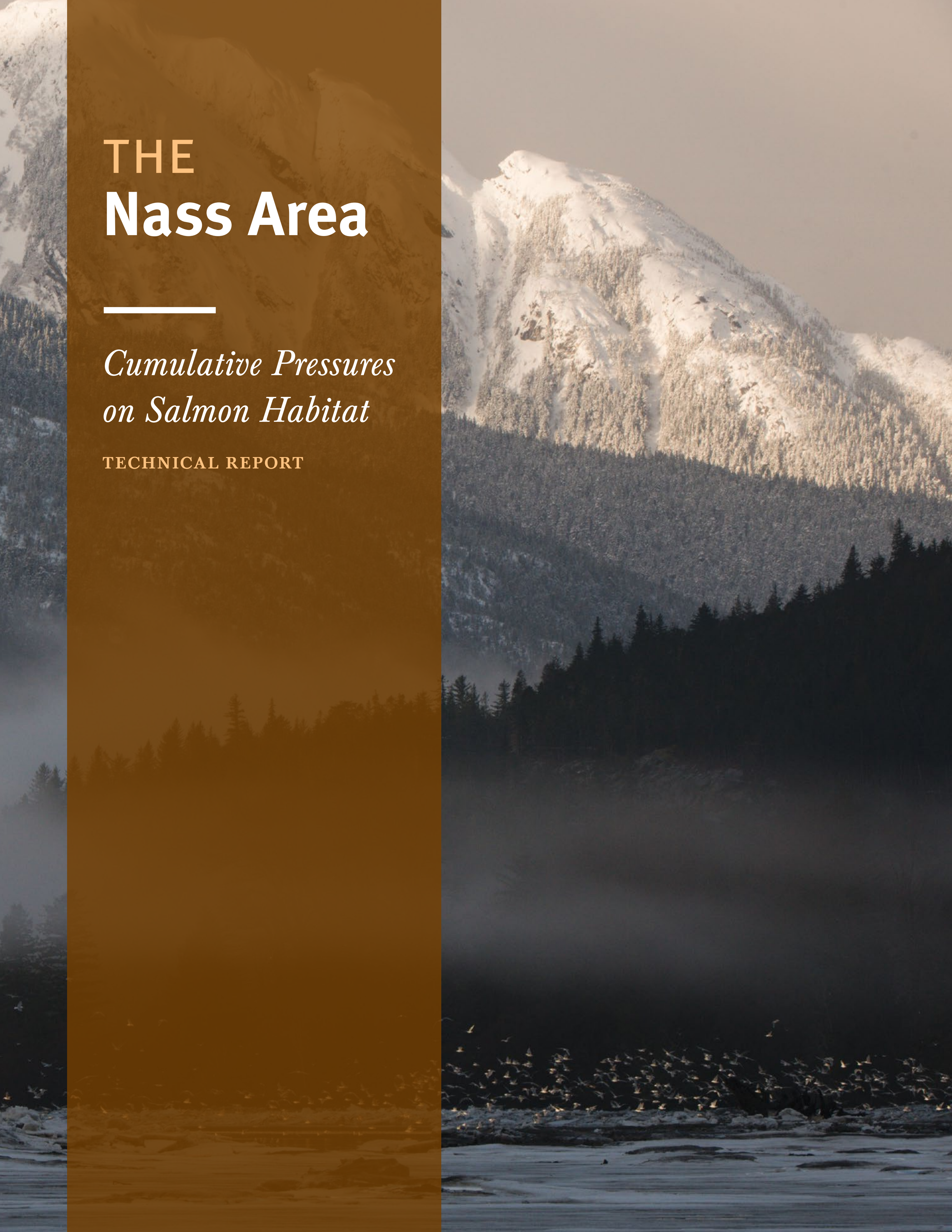
THE Nass Area

Cumulative Pressures on Salmon Habitat

TECHNICAL REPORT



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The Pacific Salmon Foundation led the implementation of this project by engaging with regional experts, coordinating technical work, facilitating a technical workshop, and finalizing project reporting and product design.

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More information about this project can be found in these publications:

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Table of Contents

List of Figures

List of Tables

GLOSSARY

Anadromous	Fish that mature in seawater but migrate to fresh water to spawn.
Benchmark	A standard (quantified metric) against which habitat condition can be measured or judged and by which status can be compared over time and space to determine the risk of adverse effects.
Connectivity	The lateral, longitudinal, and vertical pathways that link hydrological, physical, and biological processes.
Conservation Unit (CU)	A group of wild salmon sufficiently isolated from other groups that, if extirpated, is very unlikely to re-colonize naturally within an acceptable timeframe, such as a human lifetime or a specified number of salmon generations. A CU will contain one or more populations (see definition below).
Enhanced salmon	Salmon that originate directly from hatcheries and managed spawning channels.
Escapement	The number of mature salmon that pass through (or escape) fisheries and return to fresh water to spawn.
Fry	Actively feeding salmon that have emerged from the gravel and completed yolk absorption.
Indicator	Characteristics of the environment that, when measured, describe habitat condition, magnitude of stress, degree of exposure to a stressor, or ecological response to exposure. Within Strategy 2 of the Wild Salmon Policy indicators are intended to provide quantified information on the current and potential state of freshwater habitats.
Habitat restoration	The return of a habitat to its original structure, natural complement of species and natural functions.
Lake sockeye / lake-type sockeye	Sockeye belonging to one of the two distinct life-history types found among Nass sockeye CUs. After hatching, fry from lake-type sockeye CUs migrate to a rearing lake where they spend a year feeding and maturing into smolts. In contrast, juveniles from river-type sockeye CUs rear in flowing water and may smolt soon after emergence.
Life-history stage	An arbitrary age classification of salmon into categories related to body morphology, behaviour and reproductive potential,

such as migration, spawning, egg incubation, fry, and juvenile rearing.

Mainstem The main channel of a river in a watershed that tributary streams and smaller rivers feed into.

Pacific Salmon Salmon of the Pacific Ocean regions, five species of which are managed by DFO in British Columbia: sockeye (*Oncorhynchus nerka*), pink (*Oncorhynchus gorbuscha*), chum (*Oncorhynchus keta*), coho (*Oncorhynchus kisutch*), and Chinook (*Oncorhynchus tshawytscha*).

Population A group of interbreeding salmon that is sufficiently isolated (i.e., reduced genetic exchange) from other populations such that persistent adaptations to the local habitat can develop over time.

Pressure indicator Measurable extent/intensity of natural processes or human activities that can directly or indirectly induce qualitative or quantitative changes in habitat condition/state.

Productive capacity The maximum natural capability of habitats to produce healthy salmon or to support or produce aquatic organisms on which salmon depend.

Riparian zone The area of vegetation near streams and other bodies of water that is influenced by proximity to water. For management purposes DFO guidelines generally recognize a defined riparian zone of 30m adjacent to waterbodies.

Risk For analyses undertaken in this report risk is defined as the likelihood of adverse effects to salmon habitats within a defined zone of influence (see definition below). Levels of increasing risk are defined based on the extent/intensity of impacts relative to defined benchmarks of concern (see definition above).

Salmon habitat Spawning grounds, nursery/rearing areas, food supply, and migration areas which salmon depend on directly or indirectly to carry out their full life cycle.

Smolt A juvenile salmon that has completed rearing in freshwater and migrates into the marine environment.

State indicator Physical, chemical, or biological attributes measured to characterize environmental conditions.

Status Condition relative to a defined indicator benchmark.

Tributary	A stream feeding, joining, or flowing into a larger stream at any point along its course, or directly into a lake.
Watershed	The area of land that drains water, sediment, and dissolved materials into a stream, river, lake, or ocean. Watersheds can be defined at various spatial scales (e.g. ranging from a watershed boundary delineated for a tributary stream to the watershed boundary delineated for the entire mainstem Nass River).
Vulnerability indicator	Measures of habitat quantity or quality that can be used to represent the intrinsic habitat vulnerability/sensitivity to watershed disturbances for each sockeye salmon freshwater life stage.
Wild salmon	Salmon are considered “wild” if they have spent their entire life cycle in the wild and originate from parents that were also produced by natural spawning and continuously lived in the wild.
Zone of influence	Areas delineated adjacent to and upstream/upslope of habitats used by salmon CUs that represent the geographic extent for capture/measurement of the extent/intensity of human pressures/stressors that could potentially impact these habitats.

EXECUTIVE SUMMARY

The Nass River watershed in northern British Columbia (BC) is one of the most important salmon watersheds in Canada. Known as the "River of Abundance," in reference to its large runs of salmon and eulachon, the Nass covers an area of 20,700 km^2 and flows 380 km from the Coast Mountains to Portland Inlet on the Pacific Ocean. The watersheds draining into Portland Canal and Observatory Inlet comprise an additional 6,000 km^2 and, along with the Nass River watershed, make up the "Nass Area". The Nass Area is home to five species of Pacific salmon (sockeye, coho, Chinook, chum, and pink), as well as steelhead, and provides extensive spawning and rearing habitat for multiple genetically and geographically distinct populations of wild salmon, called Conservation Units (CUs).

In recent years, concerns have been raised regarding the vulnerability of salmon populations and their freshwater habitats to increasing natural and anthropogenic pressures in the region. Cumulative pressures from multiple land-use activities, in combination with changing environmental conditions, can alter landscape and watershed processes, disrupt fish habitats, and ultimately affect the survival, distribution, and abundance of wild salmon populations.

Through direction from the Nisga'a Lisims Government, and in collaboration with Gitanyow, Gitxsan, and Lax Kw'alaams First Nations, DFO, BC Ministry of Environment, ESSA Technologies, and other local experts, the Pacific Salmon Foundation coordinated an assessment of landscape-scale pressures on salmon habitat in the Nass Area. This project employed a variety of habitat pressure, and habitat quantity and quality (vulnerability) indicators for assessment of lake and stream, habitats. Publicly available provincial-scale agency data layers available for the current exercise were supplemented through local datasets provided by regional First Nations. Specific project objectives were to:

1. Develop a synoptic overview of habitat pressures and resulting risk within freshwater habitats used by sockeye (lake and river types), Chinook, coho, pink, and chum salmon CUs across the Nass Area; and
2. Develop map-based habitat report cards for each of these Nass salmon species that:
    a. Summarize the relative extents and intensities of landscape pressures on freshwater habitats used by key life-history stages (migration, spawning, rearing) for each Nass salmon CU in relation to defined indicator benchmarks of concern (i.e., habitat risk status);
    b. Summarize the relative vulnerability of habitats used by the different life-history stages (migration, spawning, incubation, rearing) for Nass salmon CUs based on habitat quantity and quality characteristics that relate to inherent sensitivity and resilience to habitat impacts.

This report describes the methods and results of the synoptic regional-scale overview of habitat pressures and vulnerabilities within defined zones of influence for eight lake sockeye, two river sockeye, two Chinook, three coho, three chum, and four pink CUs located in the Nass Area in northern BC. Using the best available data, a "report card" was generated for each Nass salmon CU.

Collectively, the report cards provide a snapshot of the current risks to salmon habitat in the Nass Area from different human and environmental pressures. This type of coarse-scale assessment is useful for building a common understanding of the pressures on freshwater salmon habitats and for informing land-use planning decisions and developing strategies that mitigate risks to freshwater salmon habitat.

1 Introduction

1.1 The Nass Area

The Nass River watershed is a large, relatively pristine watershed in northern British Columbia (BC) adjacent to southeastAlaska. The Nass River flows 380 km from the Coast Mountains southwest to Nass Bay, a sidewater of Portland Inlet, which connects to the North Pacific Ocean via the Dixon Entrance. The watersheds draining into Portland Canal and Observatory Inlet comprise an additional 6,000 km^2 and, along with the Nass River watershed, make up the "Nass Area." The Nass Area provides extensive spawning and rearing habitat for five Pacific salmon species (sockeye, coho, Chinook, chum, and pink) as well as steelhead and oolichan.

Unlike watersheds further south, there has historically been minimal development and relatively low pressure on freshwater salmon habitats in the Nass (Levy 2006). However there is growing concern that new development proposals for the region could present potential threats to the continued maintenance of healthy Nass fish habitats and associated populations. Such threats could be exacerbated by the as-yet-unknown effects of climate change in the region.

1.2 Nass Salmon Conservation Units (CUs)

Under Canada's Wild Salmon Policy (DFO 2005) management of Pacific salmon species is to be based on Conservation Units (CUs) that reflect their geographic and genetic diversity. A CU is defined as a group of wild salmon sufficiently isolated from other groups that, if lost, is very unlikely to re-colonize naturally within an acceptable timeframe, such as a human lifetime or a specified number of salmon generations (DFO 2005). A CU may contain one or more salmon populations with maintenance of CUs requiring management of multiple populations and the protection of fish habitat to support production and ensure connection between localized spawning groups (DFO 2005). While acknowledging that many of the defined CUs may be comprised of populations that may be demographically independent and genetically distinct, agencies for both Canada and BC have determined that management of salmon at the population level may not be practical in many cases (Parkinson et al. 2005).

Habitat risk status for a total of 22 distinct salmon CUs (Holtby and Ciruna 2007) within the Nass River Basin was evaluated for this project. These include eight lake-type sockeye CUs (Bowser, Damdochax, Fred Wright, Kinageese, Meziadin, Oweegee, Clements, and Leverson,), two river-type sockeye CUs (Lower Nass–Portland and Upper Nass River), two Chinook CUs (Portland Sound-Observatory Inlet-Lower Nass and Upper Nass), four Pink CUs (Upper Nass (even), Nass-Skeena Estuary (even), Nass-Portland-Observatory (odd), Upper Nass (odd)), three Chum CUs (Portland Inlet, Lower Nass and Portland-Canal-Observatory), and three coho CUs (Lower Nass, Upper Nass, and Portland Sound-Observatory Inlet-Portland Canal).

1.3 Pressure/State Framework for Monitoring Habitat Indicators

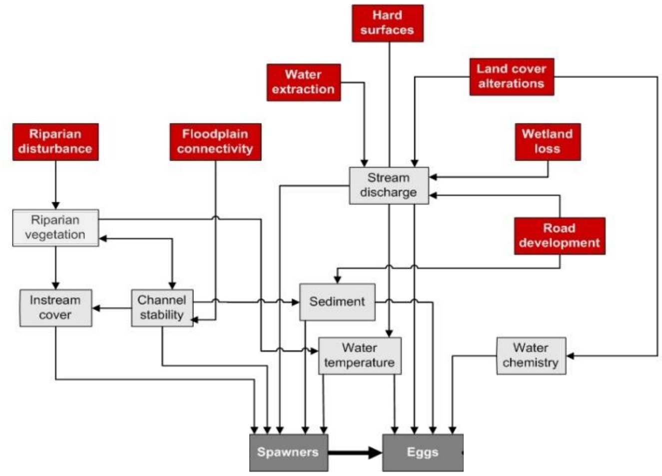
DFO has recommended that monitoring of freshwater habitats (i.e., streams, lakes, estuaries) used across salmon CUs should conform to the two-tiered pressure-state framework (Ironside 2003; Newton 2007) proposed by Stalberg et al. 2009 to guide salmon habitat monitoring under Action Step 2.2 of Strategy 2 of DFO's Wild Salmon Policy (WSP). Monitoring will be informed by information on habitat indicators: standard, quantified metrics against which habitat status can be measured or judged, and compared over time and space to determine the risk of adverse effects. Within Strategy 2 of the WSP, defined indicator benchmarks are intended to allow assessments of habitat status and identify if, when, and where status has changed significantly (DFO 2005). Benchmarks reflect DFO's intent within the WSP to take action to protect or restore habitat on a preventive basis as required, before salmon population abundance declines in response to degraded habitat (2005). Within the pressure-state monitoring framework, two types of habitat indicators ("pressure" and "state") are intended to inform two scales of decision making and management action: regional and local scales. At the regional scale, agencies and stakeholders will look to pressure indicators to understand general policies that could be affective in alleviating pressures/stresses on habitats across salmon CUs. At more local scales, state indicators will be used to assess actual habitat condition and better understand watershed-specific conservation and restoration priorities.

The first tier of information in the pressure-state framework is provided by pressure indicators that represent proactive measures of potential impacts on salmon habitats. Based principally on remote-sensed information, pressure indicators can be quantified and monitored over broad spatial extents. Pressure indicators are intended to inform CU Overview Reports that provide summaries of the degree of stress to key habitats sufficient to identify initial regional-scale priorities for habitat protection and restoration. In CUs where defined benchmarks for pressure indicators have been exceeded, the next level of decision is intended to be informed by monitoring of state indicators – more detailed descriptions (generally based on field measurement) of the actual "on-the-ground" condition (i.e., physical, chemical, biological) of salmon habitats in CU watersheds. State indicators describe habitat condition at a much more localized scale and can be monitored in areas where either pressure indicators identify potential problems, or a detailed watershed-scale Habitat Status Report has identified specific limiting factors. Habitat Status Reports would likely be developed only in identified higher-risk or higher-priority CUs where it is seen as critical to identify and explore the variety of mechanisms contributing to actual or potential impacts of concern, the interactions between these impacts, and the specific location of important salmon habitats with the CU (Stalberg et al. 2009).

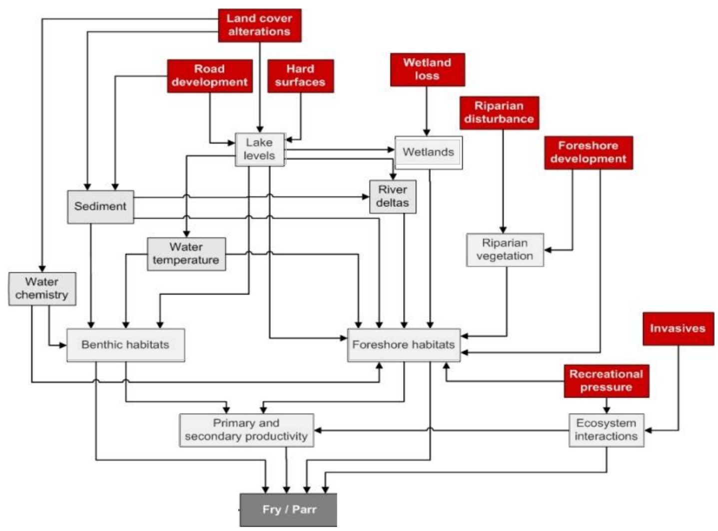
1.3.1 Linkage of Pressure-State Habitat Indicators

There is well-documented evidence that human-induced alterations in watershed processes caused either by physical modifications or chemical change can disrupt fish habitats and ultimately affect survival, distribution, and abundance of salmon populations (e.g. Levings et al. 1989, Hartman and Scrivener 1990, Gregory and Bisson 1997, Levy 1996). Based on such work, potential pathways of effects between landscape-scale pressures and subsequent impairments to salmon habitats can be modeled conceptually at broad scales. These pathways include effects on: (1) quantity and quality of spawning habitats; (2) productivity of nursery lakes for rearing; (3) habitat conditions within migratory corridors for smolts / adults; and (4) habitat conditions in estuary areas used for staging before ocean entry. Generalized cause-effect linkages between habitat pressure indicators, habitat state indicators, and (ultimately) fish population parameters will be unique to habitat types used by different salmon species. Figure 1 (modified from Nelitz et al. 2007) provides an overview of how a sequence of habitat-specific conceptual models would relate to use of habitats across different salmon life-history stages. For instance, salmon will use stream habitats for migration and spawning (Figure 1a), lake habitats (for some species) for juvenile rearing (Figure 1b), and estuary habitats while transitioning between freshwater and marine environments (Figure 1c). Within these model diagrams, potential cause-effect linkages are represented by a series of boxes and arrows illustrating interactions among system components. Indicators of habitat pressures are represented by dark red boxes, indicators of habitat status are represented by white or light grey boxes, and life stages affected are represented by dark grey boxes. To illustrate, in Figure 1a *land cover alterations* (an example of a pressure indicator) can affect *stream discharge* (a state indicator). This linkage is supported by an understanding that the amount of water in a stream can affect spawning success by dictating the extent and quality of spawning habitat as well as by influencing egg viability.

1a – Stream/river habitats



1b – lake habitats



1c – estuary habitats

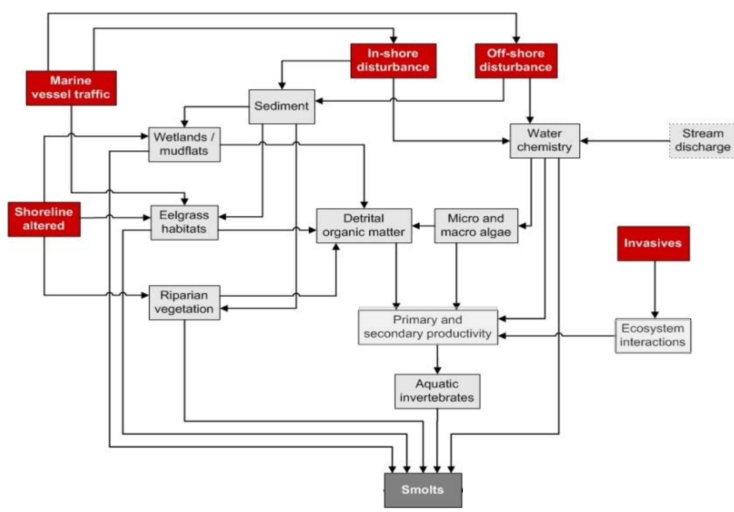


Figure 1 Examples of potential linkages between habitat pressure indicators (red boxes), habitat state indicators (light gray boxes), and salmon life-history stages (dark gray boxes) in stream/river (a), lake (b) and estuary (c) habitats (modified from Nelitz et al. 2007).

1.4 Project Background

The primary goal of this project was to undertake a "first cut" evaluation of the extent and intensity of landscape-scale pressures affecting freshwater habitats used by Nass Area salmon CUs. This goal is consistent with the first tier of DFO's recommended two-tiered pressure/state habitat monitoring framework. The results of this project are intended to provide a summary of the regional pressures facing Nass salmon habitats and a description of relative habitat risk for individual Nass CUs (i.e., analogous to a CU Overview Report). Project methodology was based on approaches used recently for broad-scale evaluations of the status of freshwater habitats for salmon in the Skeena River drainage (Porter et al. 2013b; 2014). This project employed a varied suite of habitat pressure and habitat quantity and quality (vulnerability) indicators for assessment of lake and stream habitats as recommended in Nelitz et al. 2007, Stalberg et al. 2009 and Robertson et al. 2012. Publicly available provincial-scale agency data layers available for the current exercise were supplemented through local datasets provided by regional First Nations. Specific project objectives were to:

1. Develop a synoptic overview of habitat pressures and resulting risk within freshwater habitats used by sockeye (lake and river types), Chinook, coho, pink, and chum salmon CUs across the Nass River Basin; and

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This report describes the methods and results of the synoptic regional-scale overview of habitat pressures and vulnerabilities within defined zones of influence (ZOIs) for eight lake sockeye, two river sockeye, two Chinook, three coho, three chum, and four pink CUs located in the Nass Area in northern BC. The list of Nass salmon CUs evaluated for this project is provided in Appendix 1.

2 Methods

2.1 Data Processing

All GIS data processing and map production was implemented using ESRI's ArcMap Desktop software, version 10.0. CU report cards were developed using Microsoft Publisher software and R programming language. Appendix 2.**List of databases and GIS layers used or created for this project and the associated processing steps**lists the GIS layers and databases used or created for this project and the associated data processing steps used for generation of derived habitat indicators. Data set abstracts and attribute descriptions are also provided in project geodatabases and associated metadata files, which are available for download from the Pacific Salmon Foundation's Skeena Salmon Program website: www.skeenasalmonprogram.ca.

2.2 Habitat Indicators

The synoptic overview of Nass salmon habitat status undertaken for this project used a core set of habitat pressure, habitat quantity, and habitat quality indicators which have been recommended for addressing WSP Strategy 2 monitoring and evaluation of salmon habitats in Stalberg et al 2009. These were supplemented with additional indicators from a broader suite of suggested salmon habitat indicators identified in Nelitz et al. 2007, and are the same indicators developed recently for salmon habitat assessments undertaken by Nelitz et al. 2011 and Porter et al. 2013a; 2013b; 2014. Report summaries on the status of habitat indicators within the Nass are based on novel analyses undertaken for this project. The agency information used for habitat indicator analysis and reporting was supplemented with local datasets from regional First Nations as possible, particularly in regards to identifying/mapping locations in the Nass where salmon spawning has been known to occur.

The following sections provide definitions and rational for each habitat indicator that was used for this project.

2.2.1 Habitat Pressure Indicators (current)

Watersheds/CU ZOIs

Total Land Cover Alteration (%): the percentage of the total watershed area that has been altered from the natural landscape by human activities (a sum of the indicators for forest disturbance, urban land use, agricultural and rural land use, mining development and other smaller types of development).

- *Total land cover alteration captures potential changes in cumulative watershed processes such as peak hydrologic flows and sediment generation that can affect downstream spawning and rearing habitats (Poff et al. 2006 as cited in Stalberg et al. 2009).*

Mining Development (# of mines): current active and past producing coal and mineral mine sites within a watershed

- *Mining development can potentially cause loss of salmon habitat directly through the footprint of the mine site, tailings ponds and other infrastructure, or more indirectly through disruption of stream beds and inputs of fine sediment or other contaminants (Meehan 1991; Nelson et al. 1991; Kondolf 1991).*

Impervious Surfaces (%): the percentage of total watershed area represented by hard, impervious development. [Note: Impervious Surface Coefficients (ISCs) for land types used for this analysis were not specific to the Nass River Basin, and were instead based on ISCs determined for watersheds in Connecticut (Prisloe et al. 2003) which had roughly equivalent population densities and therefore patterns of urban/rural development that were presumed generally similar to that within the Nass River Basin].

- *Impervious surface is a calculated term that reflects the amount of man-made structures (e.g. paved roads, sidewalks, driveways, buildings, etc.) that are covered by impervious materials (e.g. concrete, asphalt, concrete, brick, etc.). Extensive hard impervious surfaces from urban and rural development in a watershed can alter natural flow patterns and lead to stream degradation through changes in geomorphology and hydrology, and are also associated with increased loading of nutrients and contaminants in developed areas (Rosenau and Angelo 2009). Although the size of the urban/rural footprint may be smaller relative to other activities (e.g. forestry) the intensity of disturbance is generally regarded as higher, in part, due to the concentration of activities and irreversibility of disturbance associated with the built environment (Schendel et al. 2004; Schindler et al. 2006; Smith et al. 2007; Jokinen et al. 2010 and Paul and Meyer 2001 as cited in Nelitz et al. 2011).*

Linear Development (km/km^2): density of all linear developments (roads, utility corridors, pipelines, railways, power lines, telecom infrastructure, right of ways, etc.) within a watershed.

- *Linear development represents a general indicator of level of overall development from a variety of resource activities with associated potential impacts to salmon habitats (WCEL 2011, FLNRO 2012).*

Forest Disturbance (%): the percentage of total watershed area in which forest has been disturbed. Includes logged areas (clearcut, selectively logged) and recently burned areas.

- *Disturbances to the forest canopy due to logging or other processes can change the hydrology of a watershed by altering interception, transpiration, and snowmelt processes, resulting in potential impacts to* *salmon habitat through altered peak flows, low flows, and annual water yields (MOF 1995a, Smith and Redding 2012).*

Equivalent Clearcut Area (ECA) (%): the percentage of total watershed area that is considered comparable to a clearcut forest. ECA is a calculated term that reflects the cumulative effect of harvesting and second-growth forest regeneration in terms of its hydrological equivalent as a clearcut.

- *A derived measure of forest disturbance, ECA reflects pressure on salmon habitat principally from potential increases to peak flow (MOF 2001; Smith and Redding 2012).*

Riparian Disturbance (%): same disturbance sub-components (i.e., urban, mining, agricultural and rural, forest) as used for Total Land Cover Alteration as described above, but captured only within a 30m riparian buffer zone defined around all streams, lakes and wetlands existing within a watershed (as depicted in the 1:20,000 Freshwater Atlas (FWA) GIS layer).

- *Disturbances to riparian zones (i.e., land adjacent to the normal high water line in a stream, river, lake, or pond) can affect salmon habitats by destabilizing stream banks, increasing surface erosion and sedimentation, reducing inputs of nutrients and woody debris, and increasing stream temperatures through reduced streamside shading (Meehan 1991; MOF1995a). These changes have the potential to affect the growth and survival of salmon eggs and juveniles.*

Insect and disease defoliation (%): the percentage of pine stands within a watershed that have been killed by insects or disease.

- *While different than forest disturbances caused by logging or fire (as insect damaged forests retain standing timber and understory vegetation), forest defoliation from insects or disease can similarly decrease canopy interception of precipitation and reduce transpiration, resulting in increased soil moisture. This in turn can affect salmon habitats through potential changes to peak flows and groundwater supplies (Uunila et al. 2006; EDI 2008 as cited in Nelitz et al. 2011). Hydrological processes within insect/disease-affected stands are considered to be somewhere between a mature forest and clearcut, with hydrologic recovery taking between 20-60 years (FPB 2007). In addition, salvage harvest of affected forests can have the same watershed effects as clear cut logging.*

Road Development (km/km^2): the average density of all roads within a watershed.

- *Road development can interfere with natural patterns of overland flow through a watershed, interrupt subsurface flow, and increase peak flows* (*Smith and Redding 2012). Roads are also one of the most significant causes of increased erosion, as road construction exposes large areas of* *soil to potential erosion by rainwater and snowmelt while the roads themselves intercept and concentrate surface runoff so that it has more energy to erode even stable soils (MOF 1995a). The eroded fine sediments can be easily delivered to water courses during wet periods, where they can cover salmonid spawning redds, reduce oxygenation of incubating eggs and increase turbidity which reduces foraging success for juveniles (Meehan 1991).*

Stream Crossing Density (#/km): the number of stream crossings per km of the total length of modeled salmon habitat in a watershed (salmon habitat defined based on a gradient criteria filtering of the province's Fish Habitat Model – Version 2).

- *Stream crossings at roads can (dependent on the type and condition of the crossing structure) create fish passage problems by interfering with or blocking access to upstream habitats that include spawning or rearing areas and reduce the total amount of available salmonid habitat in a watershed (Harper and Quigley 2000; BC MOF 2012). Stream crossings can also influence the efficiency of water delivery to the stream network so that high densities can increase peak flows and become a chronic source of fine sediment delivery to streams (MOF 1995a; Smith and Redding 2012).*

Permitted Water Licenses (#): the total number of water licenses permitted for withdrawal of water for a variety of consumptive and non-consumptive uses (e.g. domestic, industrial, agriculture, power, and storage) from points of diversion within a watershed. Status of this indicator is evaluated at the scale of within-watersheds for all salmon CUs, while for lake sockeye (only) the number of water licenses is also summed across the full extent of all watersheds in the CU migration corridor ZOI (i.e., to capture the possible composite effect of water extraction pressures on mainstem water levels along the mainstem river routes of lake sockeye migration). [Note: water licenses represent only the amount of water allocated through provincial permitting processes, not actual use (i.e., monitoring of water use and compliance with water license conditions does not generally occur). Additionally, information describing water licenses (long term use) does not account for water allocated through temporary water permits (short term use) which is a regulatory tool used in the oil and gas sector and is currently difficult to track].

- *Heavy allocation (and presumed use) of both surface and hydraulically connected subsurface water for human purposes can affect salmonid habitats at critical times of year by reducing instream flows to levels that could constrain physical access to spawning and rearing habitats or potentially dewater redds, while reductions in both surface water and ground water supplies can increase water temperatures with resultant impacts on all salmonid life stages (Richter et al. 2003 and Hatfield et al. 2003 as cited in Stalberg et al. 2009; Douglas 2006).*

Permitted Wastewater Discharges (#): the number of permitted wastewater management discharge sites within a watershed. [Note: The provincial dataset available to support this indicator only identifies the number of permitted discharge sites. However the actual risks and impacts to salmon habitat will also be determined by the respective volumes and nature of the actual discharges and not simply the number of discharge points, and those supporting elements are not captured within this analysis].

- *High levels of wastewater discharge from municipal and industrial sources could impact the water quality of salmonid habitats either through excessive nutrient enrichment or chemical contamination. Some industrial waste products can directly injure or kill aquatic life even at low concentration (US EPA 2008) while excessive nutrient levels (eutrophication) can result in depletion of the dissolved oxygen in streams and lakes, starving fish and other aquatic life (Zheng and Paul 2007).*

Migration Obstructions (#): the total number of identified "obstructions" in agency GIS layers (FISS, FWA) that are located along the CU's distinct mainstem migration corridor and that could represent potential obstacles to adult migration (applied to lake sockeye CUs only).

- *Obstacles/obstructions along the adult migration route could potentially impede, delay, or even temporarily block passage (dependent on obstruction type and seasonal water levels) to spawning streams and lakes with consequent impacts to sockeye spawning success.*

2.2.2 Habitat Pressure Indicators (Future)

Whole drainage

Proposed Future Resource Development (#/extent): The number, length, or area of different key resource development-related indicators (i.e. mines, water licenses, power tenures (wind and water), pipelines, and forestry) known to be planned (as of 2016) across the Nass drainage. Proposed transmission lines were also evaluated but there appear to be no current plans within the Nass for new transmission lines (at least that are documented). Proposed development was also characterized for the Skeena drainage, as the Nass-Skeena Estuary Pink (even) CU also extends into the lower part of the Skeena.

- *Information on proposed development activities will be important to consider/evaluate from a longer term cumulative effects perspective (i.e. habitat status of watersheds currently experiencing limited pressures could potentially change in the future given proposed regional resource development/extraction activities).*

2.2.3 Vulnerability Indicators (Measures of Habitat Quantity and Quality)

A broad suite of habitat pressure indicators have been quantified for this report and used to define relative risk of adverse effects to salmon habitat within CU watersheds. Increasing intensity or extent of habitat pressures is considered representative of increasing risk of adverse effects. However, it must be noted that the actual "risk" to salmon populations using these habitats will be a combination of both the intensity and extent of habitat pressures and life-stage-specific vulnerabilities. Vulnerability can be defined in relation to the degree of intolerance of the habitat or of individual species within the habitat to external impacts (physical, biological, chemical) (ICES 2002). Results for the status of Nass salmon habitat indicators were therefore augmented with information on the relative vulnerability of CUs to these habitat pressures. Here vulnerability is based on CU-specific life-history characteristics and broader scale habitat influences. This approach, is intended to provide an additional filter by which to identify CUs that may be at highest potential risk from the impacts of habitat degradation.

Species CU habitat risk "status" is therefore defined by the combined ratings of the watershed pressure indicators and the assessed vulnerability indicators. CUs considered at greater potential risk (to one or more life-history stages) might then warrant more thorough field-based assessment of habitat condition.

The following section provides detail on the vulnerability indicators that were used in this analysis.

A. Lake Sockeye:

Migration Period

Total Migration Distance (km): the length of the lake sockeye CU's migration distance as measured from the mouth of the Nass River to the outlet of the CU rearing lake.

- *Lengthy migrations can increase levels of stress and the exposure to pre-spawning mortality factors for adult sockeye moving upstream (Crossin et al. 2004; Crossin et al. 2008), or plausibly affect mortality of smolts during downstream migration or fitness once they reach the ocean.*

Migration Length that is Summer Low Flow Sensitive (km): the length of the lake sockeye CU's migration route that is considered summer low flow sensitive based on BC MOE's ecoregional flow sensitivity model and associated mapping. The greater distance that an adult sockeye must migrate through flow sensitive areas increases the potential duration of exposure to summer low flow conditions.

- *Flow sensitivity in the province's flow model is characterized by streams with 30-day baseflows in 1 or 2 year frequencies that are ≤20% long term mean annual discharge (MAD) (R. Ptolemy, unpublished). The summer baseflow period is July-October. High water temperature, low levels of* *dissolved oxygen, and deleterious levels of toxins can all be exacerbated by low stream flow in the summer (Nelitz et al. 2011). Moreover, the quantity, quality and connectivity (e.g. for fish migration) of aquatic habitats are also influenced by the amount of flow. Areas rated as flow sensitive would therefore be considered relatively more vulnerable to additional freshwater habitat pressures than areas considered non-sensitive.*

Migration Length that is Summer Low Flow Sensitive (%): the percentage of the lake sockeye CU's migration route that is considered summer low flow sensitive based on BC MOE's ecoregional flow sensitivity model and associated mapping. The greater percentage of an adult sockeye's migrate route that is considered to be flow sensitive increases the likelihood of being consistently exposed to low flow conditions during the migration period.

- *Flow sensitivity in the province's flow model is characterized by streams with 30-day baseflows in 1 or 2 year frequencies that are ≤20% long term mean annual discharge (MAD) (R. Ptolemy, unpublished). The summer baseflow period is July-October. High water temperature, low levels of dissolved oxygen, and deleterious levels of toxins can all be exacerbated by low stream flow in the summer (Nelitz et al. 2011). Moreover, the quantity, quality and connectivity (e.g. fish migration) of aquatic habitats are also influenced by the amount of flow. Areas rated as flow sensitive would therefore be considered relatively more vulnerable to additional freshwater habitat pressures than areas considered non-sensitive.*

<u>Spawning Period</u>

Total Spawning Length (km): the total length of sockeye spawning (as mapped in the province's Fisheries Information Summary System (FISS) and supplemented by local datasets) that is located within the CU's defined rearing lake ZOI. For spawning data that was represented only by location points (as opposed to mapped linear spawning zones covering that area) each location point was considered to represent 100 m of linear spawning extent (as a default generalized assumption for the purposes of comparative analyses within this project).

- *The total length of areas of identified lake sockeye spawning indicates the full scope of known spawning for each Nass lake sockeye CU.*

Length of Lakeshore Spawning (km): total length of all areas of lake spawning known for the CU.

- *Reflects the known amount of lakeshore spawning habitat used by each Nass lake sockeye CU.*

Length of Tributary/Lake Inlet Spawning (km): total length of all tributary/lake inlet spawning known for the CU.

- *Reflects the known amount of tributary and lake inlet spawning habitat used by each Nass lake sockeye.*

Length of Mainstem/Lake Outlet Spawning (km): total length of all mainstem/lake outlet spawning known for the CU.

- *Reflects the known amount of mainstem and lake outlet spawning (i.e. lake-influenced) habitat used by each Nass lake sockeye CU.*

Ratio of Lake-influenced to Total Spawning Length (0 to 1): the ratio of all lake-influenced (i.e. lakeshore and mainstem/lake outlet) spawning relative to the total length of all spawning habitat known for the CU.

- *Lakes stabilize discharge by buffering flood effects, thereby reducing stream bank erosion and bedload movement compared to streams with more variable discharge regimes (Montgomery et al. 1996). Thus, spawning habitat quality and egg-to-fry survival should be less affected by disturbances where spawning occurs in lakes or in channels buffered by lake influences rather than in small, non-lake moderated tributaries (Chapman 1988; Northcote and Larkin 1989; Montgomery et al. 1996). This measure of the relative proportion of lake and lake-influenced spawning therefore reflects the beneficial buffering effect of lakes against upstream habitat impacts (i.e. lake buffered sockeye spawning areas are considered less vulnerable to upland disturbances than are tributary spawning areas).*

Accessible Stream Length (km): the total length of stream within a lake sockeye CU's rearing lake ZOI that is considered potentially accessible to salmon based on gradient/obstruction criteria used in the province's current 1:20K FWA-based Fish Habitat Model (Version 2). [**Note**: The delineation of linear salmon habitat was based on a filtering of the province's fish habitat model such that only a subset of stream reaches within the model that were $\leq$ 10% gradient were captured within the GIS and identified as "theoretically" accessible salmon habitat in the Nass for subsequent analyses].

- *The total length of (modelled) salmon accessible stream length will determine the total amount of useable habitat that sockeye could (theoretically) access for spawning and rearing needs. CUs with less accessible habitat would therefore be considered relatively more vulnerable to additional freshwater habitat pressures than CUs with a greater extent of accessible habitat.*

<u>Rearing Period</u>

Rearing Lake Area (ha): total surface area of the CU rearing lake.

- *Given their use of lake habitats, it is possible to estimate the quantity and quality of sockeye salmon rearing habitat in BC from lake size and measures of lake productivity such as photosynthetic rate (PR) (Hume et al. 1996;*

Shortreed et al. 2000). Where lake productivity data is lacking or deficient (as within the Nass system) lake area alone can be considered a reasonable surrogate of habitat productivity since it is a primary driver in productivity relationships (Randall 2003). While annual lake-to-lake differences in productivity per unit area are important (and would be a useful element to add to the analysis in the future as data permits), the extent of the rearing habitat available can also strongly dictate the potential total smolt production from a lake sockeye CU.

B. Other salmon species (river sockeye, Chinook, coho, pink, and chum)

Spawning Period

Total Spawning Length (km): The total length of spawning for the salmon species that is mapped in the province's Fisheries Information Summary System (FISS) and supplemented by local datasets that is located within the CU's defined geographic boundaries. For spawning data for a species represented only by location points (as opposed to mapped linear spawning zones covering that area) each location point was considered to represent 100 m of linear spawning extent (as a default generalized assumption for the purposes of comparative analyses within this project).

- *The total length of identified spawning reaches indicates the scope of opportunities for successful spawning for a CU. CUs with limited spawning reaches would be considered relatively more vulnerable to additional freshwater habitat pressures than CUs with more extensive spawning areas.*

Spawning Length Summer Flow Sensitive – Spawn Timing (km): The total length of the CU's spawning reaches that are considered ***summer*** low flow sensitive based on BC MOE's ecoregional flow sensitivity model and associated mapping. A greater length of flow-sensitive spawning indicates a greater duration of exposure to summer low flow conditions during the spawning period.

- *Flow sensitivity in the province's flow model is characterized by streams with 30-day baseflows in 1 or 2 year frequencies that are ≤20% long term mean annual discharge (MAD) (R. Ptolemy, unpublished). The summer baseflow period is July to October. High water temperature, low levels of dissolved oxygen, and deleterious levels of toxins can all be exacerbated by low stream flow in the summer (Nelitz et al. 2011). Moreover, the quantity, quality and connectivity (e.g. for fish migration) of aquatic habitats are also influenced by the amount of flow. CUs with long stretches of their spawning areas rated as summer flow sensitive would therefore be considered relatively more vulnerable to additional freshwater habitat pressures than CUs with extensive spawning areas that are considered non-sensitive.*

Spawning Length Summer Flow Sensitive (%): The percentage of the CU's spawning reaches that are considered ***summer*** low flow sensitive based on BC MOE's ecoregional flow sensitivity model and associated mapping. A larger percentage of a CU's spawning reaches considered to be summer flow sensitive would increase the likelihood of being consistently exposed to low flow conditions during the spawning period.

- *Flow sensitivity in the province's flow model is characterized by streams with 30-day baseflows in 1 or 2 year frequencies that are ≤20% long term mean annual discharge (MAD) (R. Ptolemy, unpublished). The summer baseflow period is July to October. High water temperature, low levels of dissolved oxygen, and deleterious levels of toxins can all be exacerbated by low stream flow in the summer (Nelitz et al. 2011). Moreover, the quantity, quality and connectivity (e.g. fish migration) of aquatic habitats are also influenced by the amount of flow. CUs with large proportions of their spawning areas rated as summer flow sensitive would therefore be considered relatively more vulnerable to additional freshwater habitat pressures than CUs with most spawning areas that are considered non-sensitive.*

Incubation Period

Spawning Length Winter Flow Sensitive – Incubation Timing (km): The total length of the CU's spawning reaches that are considered ***winter*** low flow sensitive based on BC MOE's ecoregional flow sensitivity model and associated mapping. A greater length of winter flow-sensitive spawning indicates a greater extent of exposure to low flow conditions during the egg incubation period.

- *Flow sensitivity in the province's flow model is characterized by streams with 30-day baseflows in 1 or 2 year frequencies that are ≤20% long term mean annual discharge (MAD) (R. Ptolemy, unpublished). The winter baseflow period is November to March. Low flows in winter can cause freezing or desiccation of incubating salmon eggs and embryos found within spawning channels and can increase mortality risks from concentrated toxins, mechanical destruction (e.g. sedimentation) and predation (NMFS/USFW 2004). CUs with long stretches of their spawning areas rated as winter flow sensitive would therefore be considered relatively more vulnerable to additional freshwater habitat pressures than CUs with extensive spawning areas considered non-sensitive.*

Spawning Length Winter Flow Sensitive – Incubation Timing (%): the percentage of the CU's spawning reaches that are considered ***winter*** low flow sensitive based on BC MOE's ecoregional flow sensitivity model and associated mapping. A larger percentage of a CU's spawning reaches considered to be winter flow sensitive would increase the likelihood of being consistently exposed to low flow conditions during the incubation period.

- *Flow sensitivity in the province's flow model is characterized by streams with 30-day baseflows in 1 or 2 year frequencies that are $\leq$20% long term mean annual discharge (MAD) (R. Ptolemy, unpublished). The winter baseflow period is November to March. Low flows in winter can cause freezing or desiccation of incubating salmon eggs and embryos found within spawning channels and can increase mortality risks from concentrated toxins, mechanical destruction (e.g. sedimentation) and predation (NMFS/USFW 2004). CUs with large proportions of their spawning areas rated as winter flow sensitive would therefore be considered relatively more vulnerable to additional freshwater habitat pressures than CUs with most spawning areas considered non-sensitive.*

Rearing/Migration Period

Accessible Stream Length (km): The total length of stream within a salmon CU's rearing/migration ZOI that is considered accessible to salmon based on gradient/obstruction criteria used in the used in the province's current 1:20K FWA-based Fish Habitat model (Version 2). [Note: The delineation of linear salmon habitat was based on a filtering of the province's fish habitat model such that only a subset of stream reaches within the model that were $\leq$ 10% gradient were captured within the GIS and identified as "theoretically" accessible salmon habitat in the Nass for subsequent analyses].

- *The total length of (modelled) accessible stream length will determine the total amount of useable habitat that a salmon CU could (theoretically) access for spawning and rearing needs. CUs with less accessible habitat would therefore be considered relatively more vulnerable to additional freshwater habitat pressures than CUs with a greater extent of accessible habitat.*

Accessible Stream Length Flow Sensitive – All Seasons (km): The total length of the CU's accessible reaches that are considered flow sensitive based on BC MOE's ecoregional flow sensitivity model and associated mapping.

- *Long stretches of flow sensitive (all seasons) accessible streams indicates a greater potential for CUs to be exposed to low flow conditions at varied points in their life cycle. CUs with long stretches of accessible habitat that are considered flow sensitive would therefore be considered relatively more vulnerable to additional freshwater habitat pressures than CUs with limited extents of accessible habitat considered to be flow sensitive.*

Accessible Stream Length Flow Sensitive – All Seasons (%): The percentage of the CU's accessible stream reaches that are considered flow sensitive based on BC MOE's ecoregional flow sensitivity model and associated mapping.

- *A larger percentage of a CU's accessible stream reaches considered to be flow sensitive (all seasons) would increase the likelihood of a CU being occasionally or consistently exposed to low flow conditions throughout the* *year. CUs with a larger proportion of their accessible habitat considered to be flow sensitive would therefore be considered relatively more vulnerable to additional freshwater habitat pressures than CUs with a smaller proportion of their accessible habitat considered to be flow sensitive.*

Lake Area (km^2) – Coho CUs Only: The total area of FWA-delineated lakes present within each coho CU.

- *Lakes, wetlands, and off-channel ponds can be critically important for coho survival and production as they will move into such areas to avoid swift currents and find more hospitable growing conditions during the overwintering period (Chilibeck et al. 1992). CUs with a smaller total area of available lakes would therefore be considered relatively more vulnerable to additional freshwater habitat pressures than CUs with a greater extent of lakes.*

Wetland Area (km^2) – Coho CUs Only: The total area of FWA-delineated wetlands present within each coho CU.

- *Lakes, wetlands, and off-channel ponds can be critically important for coho survival and production as they will move into such areas to avoid swift currents and find more hospitable growing conditions during the overwintering period (Chilibeck et al. 1992). CUs with a smaller total area of available wetlands would therefore be considered relatively more vulnerable to additional freshwater habitat pressures than CUs with a greater extent of wetlands.*

2.3 Indicator Benchmarks (for Watershed Pressure Indicators)

Where possible, empirical benchmarks for habitat pressure indicators were developed based on existing science (e.g. Stalberg et al. 2009 or other literature/expert sources). A benchmark is defined as a standard (quantified metric) against which habitat risk or condition can be measured or judged, and compared over time and space to determine the risk of adverse effects. For habitat pressure indicators where scientifically defensible empirical benchmarks do not exist or could not be explicitly defined for use in the Nass, benchmarks were developed based on relative rankings from distribution curves developed for indicator values across the full spatial extent of all FWA-defined watersheds in the Nass drainage[1] (an initial approach consistent with recommendations in Stalberg et al. 2009). While acceptable as an interim benchmarking step until regional science/expert-based indicator benchmarks can be further developed, the weakness of a relative ranking approach is that all of the watersheds could in reality be quite healthy or alternatively they could all be at risk in an absolute sense, regardless of their relative ranking. However, this approach at

[1] Note that for the Nass-Skeena Estuary Pink (even) CU (which spans multiple drainages) pressure indicator benchmarks based on relative distributions instead employed risk benchmarks developed for Skeena watersheds as part of earlier PSF analyses (Porter et al., 2014).

least serves to identify the potential worst-case CU habitats and inform selection of priority watersheds for further investigation of the actual level of impact.

Where benchmarks were based on relative distribution of habitat pressure intensities and extents (lower, moderate, higher risk) across all watersheds in the Nass Area (n = 550 1:20K-defined FWA assessment watersheds), we employed two alterative benchmarking approaches, depending on the spread of the habitat indicator data:

1. ***Relative benchmarking approach (type 1) for indicator values with <u>symmetric or moderately skewed distributions</u>*****:** Using the distribution of indicator values across all Nass Area watersheds, any value for the indictor below the 50th percentile was considered relatively **lower risk** (coded green), values in the 50th to 75th percentile were considered relatively **moderate risk** (coded amber), and any value above the 75th percentile was considered relatively **higher risk** (coded red). In other words, the best 50% of watersheds for a given indicator were coded as being at relatively lower risk, and the worst 25% of the watersheds were coded as being at relatively higher risk. All other watersheds were coded as being at relatively moderate risk. See Figure 2 for an interpretative key to use of percentile-based box plots for assigning risk scores.

2. ***Relative benchmarking approach (type 2) for indicator values with a <u>highly skewed distribution</u> (e.g. many 0 values)*****:** 0 values for the indicator were considered relatively low risk (coded green); any value above 0 was considered relatively high risk (coded red). There were two reasons for this approach. First, the severity of the skewness of indicator values made the simple percentiles approach (type 1 above) inappropriate. For example, if that approach was used where 80% of the watersheds had a 0 value for a given indicator, then 50% would be rated as green, 25% would be rated as amber, and 5% would be rated as red despite having identical indicator values. Second, where a particular habitat pressure (e.g. mining development) does not exist in a watershed (i.e. has a 0 value), it is safe to assume that mining development does not represent a local habitat pressure and therefore the watershed would be considered at low risk with respect to this indicator. While a 0 value is clearly low risk, the question then becomes at what point does the presence of a particular pressure become a problem? Instead of using the 50th and 75th percentiles we simply categorized watersheds that had this pressure present as being at relatively high risk (i.e. binary risk classification based on presence/absence of the pressure in the watershed). This approach suffers from the same pitfall as the first in that presence does not necessarily imply a watershed-level problem. However, as described above, the relative benchmarking approach reliably identifies potential problem watersheds and is a useful way to compare and contrast similar habitat pressures across

numerous watersheds and CUs, until such time as more research is conducted to produce empirically based benchmarks for all indicators.

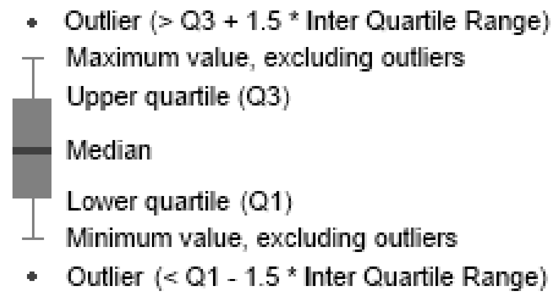

Figure 2 Key to interpreting a "box plot" used for assigning a relative risk score to a habitat pressure indicator value. The plot includes a box indicating the inner 50th percentile of the data (known as the interquartile range, IQR), whiskers showing the robust data range, outliers, and median. The top and bottom of the box are the 25th (Q1) and 75th (Q3) percentiles. The size of the box is called the Interquartile Range (IQR) and is defined as IQR = Q(3) - Q(1). The whiskers extend to the most extreme data points which are not considered outliers. The horizontal line inside the box represents the median (50th percentile, Q2). Data which fall outside the IQR box by a specific amount are considered "outliers". Outliers are values greater than 1.5*IQR outside of the IQR.

2.4 Nass Salmon CU Zones of Influence (ZOIs)

The ZOI concept refers to a specific watershed-boundary-delineated area that is considered to influence habitats used by individual salmon CUs, and in which life-stage-specific habitat vulnerabilities and upstream/upslope habitat pressures for each CU can be assessed and quantified. Various rules were employed for establishing life-stage-specific ZOIs that could be used to bound our comparative analyses of habitat status for the different Nass salmon CUs.

A. Lake Sockeye ZOIs

2.4.1 Rearing Lake ZOI (lake sockeye)

For each Nass lake sockeye CU, we identified the principal rearing lake association as identified within the most current DFO delineations of nursery lakes for the Nass (DFO SELKS_nursery_lakes_01May08) and defined an upstream ZOI simply by delineating the areas of all 1:20K FWA “fundamental” watersheds present upstream of the lake outlet.

2.4.2 Mainstem, Lake and Tributary Spawning ZOIs (lake sockeye)

1. The ZOI for any mainstem/lake outlet or lake spawning sites identified in a CU will be the same as the ZOI that has been defined for the CU rearing lake.

2. The ZOIs for lake inlet/tributary spawners, while embedded within the broader area of each CU’s rearing lake ZOI, are more precisely defined. The individual

1:20K FWA assessment watersheds in which spawning areas are identified and the FWA assessment watersheds directly upstream of these areas represent the ZOI around any tributary spawning areas. The composite of all these FWA watersheds represents the total ZOI area for lake inlet/tributary spawning within a CU.

As our default rule, all spawning mapped within the boundaries of the defined CU rearing lake ZOI will be considered to be associated with that particular lake sockeye CU (although this is not likely to be 100% correct, as spawning activities/CU spatial associations are more dynamic in reality).

2.4.3 Migration Corridor ZOI (lake sockeye)

The migration route and distance for each lake sockeye CU was determined by developing a connected hydrology network that traced a path from the outlet of each CU's nursery lake to the mouth of the Nass River. All 1:20K FWA watersheds that intersected each CU's migration route within a 1 km buffer along the river were used to define a variable-width migration corridor ZOI for each CU, within which watershed stressors were assessed. The width of the ZOI (while variable) is substantially larger than the distances typically used by agencies to directly protect stream riparian zones. The significantly larger ZOI allows us to ensure that that we are also capturing the potential effect of upstream watershed activities along the migration corridor that may have broader, more diffuse impacts than those immediately adjacent to the migration path.

B. Other salmon species (river sockeye, Chinook, coho, pink, and chum)

Various rules were developed within this project for establishing life-history-stage-specific ZOIs that could be used to bound our comparative analyses of habitat status for Chinook, coho, pink, chum and river sockeye salmon CUs. Note that for all species, egg incubation occurs in the same locations as adult spawning (although at a different time of year); therefore, habitat within the spawning ZOIs corresponds to both the spawning and incubation life-history stages (i.e. this can be considered to be a "spawning/incubation ZOI" although for brevity it is labeled simply as "spawning ZOI" throughout). While the habitats used within a CU's spawning ZOI will be identical for these two life-history stages there may be life-history-stage specific differences in vulnerability to the associated habitat pressures. Conversely, while various rearing and migration habitats will be used throughout a CU's broad combined rearing/migration ZOI the exact locations used by either life-history stage (and the degree of overlap between the two) cannot be determined and associated vulnerabilities to habitat pressures cannot be differentiated between these two life-history stages.

Chinook ZOIs

2.4.4 Spawning ZOI (Chinook)

The localized spawning ZOI for each Chinook CU was delineated by capturing the extent of all 1:20K FWA Assessment Watersheds that directly intersect with Nass Chinook CU boundaries (as presented in the most recent GIS layer available from DFO for Nass Chinook CUs (DFO CK_CU_ 01May08)).

2.4.5 Rearing/Migration ZOI (Chinook)

Rearing areas and migration routes for Chinook are diverse and have not been explicitly delineated or differentiated within the Nass Area. A combined rearing/migration ZOI for each Chinook CU was therefore delineated based on the boundaries of the Nass Area subdrainages (as captured within the province's "major watersheds" 1:50K GIS layer) in which CU spawning had been identified, plus any subdrainages intersecting the migration route from the CU-specific spawning areas downstream through the Lower Nass subdrainage and into the Nass estuary (i.e. all Chinook CUs will move out of their respective rearing subdrainages and then join a common path to the sea). [Note that for purposes of refining analyses for this project the Nass Area, as originally delineated within the province's major watershed GIS layer, has been split into three zones (upper, middle and lower Nass)]. Rearing of upriver Chinook CUs may be expected to occur in adjoining watersheds at any point along this migratory route, including in the lower Nass. All 1:20K FWA watersheds embedded within the subdrainage-defined boundary are considered part of the rearing/migration ZOI for our analyses.

Coho ZOIs

2.4.6 Spawning ZOI (Coho)

The localized spawning ZOI for each coho CU was delineated by capturing the extent of all 1:20K FWA Assessment Watersheds that directly intersect with identified coho spawning sites in the Nass, with the specific CU association for each spawning site based on the most current DFO-delineated CU boundaries for Nass coho (DFO CO_CU_01May08).

2.4.7 Rearing/Migration ZOI (Coho)

Rearing areas and migration routes for coho are diverse and widespread and have not been explicitly delineated or differentiated within the Nass Area. A combined rearing/migration ZOI for each coho CU was therefore delineated based on the boundaries of the subdrainages in which CU spawning has been identified, plus any subdrainages intersecting the migration route from the CU-specific spawning areas downstream through the Lower Nass subdrainage and into the Nass estuary. Rearing of upriver coho CUs may be expected to occur at any point along this route, including in the lower Nass. All 1:20K FWA watersheds embedded within the subdrainage-defined boundary are considered part of the rearing/migration ZOI for our analyses.

Pink ZOIs

2.4.8 Spawning ZOI (Pink)[2]

The localized spawning ZOI for each pink salmon CU was delineated by capturing the extent of all 1:20K FWA Assessment Watersheds that directly intersect with identified pink spawning sites (odd or even), with the specific CU association for each spawning site based on the most current DFO-delineated CU boundaries for Nass pink salmon (DFO PKE_CU_01May08 and DFO PKO_CU_01May08). [Note that the boundaries of the Nass-Skeena Estuary Pink (even) CU extend beyond the Nass and into the Skeena drainage. The spawning ZOI for this Pink CU within the Skeena drainage were defined in earlier PSF analyses (Porter et al. 2014)].

2.4.9 Rearing/Migration ZOI (Pink)

As pink salmon spend limited time post-hatch rearing in freshwater, their rearing and migration areas can be considered essentially the same. We therefore captured a combined rearing/migration ZOI for each pink salmon CU based on the boundaries of the subdrainages in which CU spawning has been identified, plus any subdrainages intersecting the migration route from the CU-specific spawning areas downstream through the Lower Nass subdrainage and into the Nass estuary. All 1:20K FWA watersheds embedded within the subdrainage-defined boundary are considered part of the rearing/migration ZOI for our analyses. [Note that the boundaries of the Nass-Skeena Estuary Pink (even) CU extend beyond the Nass and into the Skeena drainage. The rearing/migration ZOI for this Pink CU within the Skeena drainage were defined in earlier PSF analyses (Porter et al. 2014)].

Chum ZOIs

2.4.10Spawning ZOI (Chum)

The localized spawning ZOI for each chum CU was delineated by capturing the extent of all 1:20K FWA Assessment Watersheds that directly intersect with identified chum spawning sites, with the specific CU association for each spawning site based on the most current DFO-delineated CU boundaries for Nass chum (DFO CM_CU_01May08).

2.4.11Rearing/Migration ZOI (Chum)

As chum spend limited time post-hatch rearing in freshwater, their rearing and migration areas can be considered essentially the same. We therefore captured a combined rearing/migration ZOI for each chum CU based on the boundaries of the subdrainages in which chum spawning has been identified, plus any subdrainages intersecting the migration route from the CU-specific spawning areas downstream

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[2] Note that the agency spawning information available for this exercise did not allow us to differentiate between mapped spawning for odd and even Upper Nass Pink CUs, so that pink spawning areas located within the boundaries of these spatially overlapping CUs were considered part of both CUs interchangeably and could not be discriminated on a temporal basis.

through the Lower Nass subdrainage and into the Nass estuary. All 1:20K FWA watersheds embedded within the subdrainage-defined boundary are considered part of the rearing/migration ZOI for our analyses.

River Sockeye [3]

2.4.12 Spawning ZOI (River Sockeye)

The localized spawning ZOI for each river sockeye CU was delineated by capturing the extent of all 1:20K FWA Assessment Watersheds that directly intersect with identified river sockeye spawning sites (that are located outside lake sockeye rearing Lake ZOIs), with the specific CU association for each spawning site based on the most current DFO-delineated CU boundaries for Nass river sockeye (DFO SERIVER_01May08).

2.4.13 Rearing/Migration ZOI (River Sockeye)

Little is known about the freshwater ecology of river sockeye, and rearing areas and migration routes for river sockeye have not been explicitly delineated or differentiated within the Nass Area. A combined rearing/migration ZOI for each river sockeye CU was therefore delineated based on the boundaries of the Nass subdrainages in which CU spawning had been identified, plus any subdrainages intersecting the migration route from the CU-specific spawning areas downstream through the Lower Nass subdrainage and into the Nass estuary. Rearing of river sockeye CUs may be expected to occur in adjoining watersheds at any point along this migratory route, including in the lower Nass. All 1:20K FWA watersheds embedded within the subdrainage-defined boundary are considered part of the rearing/migration ZOI for our analyses.

2.5 Calculation of Cumulative Risk Ratings for Watersheds within Nass CU ZOIs

Reporting out on the large number of habitat indicators presents a challenge in providing a general, overall assessment of habitat risk for Nass salmon CUs. Determining how to best combine and "roll up" information from a suite of selected habitat indicators to allow assessment of overall cumulative impacts and overall habitat status within a salmon CU was identified as a remaining and unresolved challenge in Stalberg et al. (2009). Aggregating information into a single overall "index" score can make interpretation easier but information can be lost and there may be multiple approaches to aggregating indicators without certainty about which is best. Aggregating indicators into a single, composite risk or condition score, however, is an approach taken by a variety of agency programs that currently monitor watersheds in Canada and the US Pacific Northwest (e.g. BC Ministry of Forests, Lands and Natural Resource Operations (FLRNO) Forest and Range Evaluation Program (FREP), United States Environmental Protection Agency's

[3] Note that accurate identification of spawning and rearing/migration areas for river sockeye within the Nass River Basin is problematic and the distribution and ecology of this species is poorly understood.

Environmental Monitoring & Assessment Program (EMAP), United States Department of Agriculture Forest Service's Aquatic and Riparian Effectiveness Monitoring Program (AREMP)). These agency programs use a variety of methods (ranging widely in complexity) to aggregate their habitat data and each approach has strengths and weaknesses (Pickard et al. 2008). Recent habitat indicator analyses for BC salmon CUs (e.g. Cohen Commission analyses of Fraser sockeye CUs (Nelitz et al. 2011) and an indicators mapping project for the Lower Thompson coho CU (Beauchamp 2008) generated cumulative habitat stressor/impact scores based on a simple summation of all the individually scored indictors (i.e. a higher total score equates to higher risk). Habitat assessments undertaken in Porter et al. 2013 employed an alternative approach for rating relative risk (green, amber, and red) for Southern Chinook CU-associated watersheds in which cumulative risk scoring was instead based on an indicator "roll-up" rule set based on the proportion of the indicators that were rated lower, moderate or higher risk. For our analyses we used an approach piloted earlier for the Skeena drainage (Porter et al. 2013b; 2104) where derivations of both approaches (i.e. simple risk score summations and also scoring rollup rule sets) were used for assigning cumulative risk scoring for watersheds in species CU ZOIs, depending on the life-history stage assessed.

2.5.1 Rearing/tributary Spawning ZOIs (Lake Sockeye) and Spawning ZOIs (Other Species)

For watersheds in lake sockeye CU rearing lake and tributary spawning ZOIs as well as other species spawning ZOIs we developed a cumulative risk rule set that was based on a 2-stage roll-up of habitat pressure indicator risk ratings within seven defined "Impact Categories" (similarly to Porter et al. 2013b; 2014). This included a 1st level roll-up of risk ratings *within* each Impact Category, and then 2^{nd} level roll-up of risk ratings *across* all the Impact Categories. Impact Categories were developed for this project to represent process-based classes of nested pressure indicators that would better partition differential impacts across a suite of, in some cases, correlated information. This approach is analogous to that used for categorizing pressure indicators into unique Impact Categories within the province's traditional Watershed Assessment Procedures (MOF 1995a, b). As in PSF's earlier project for the Skeena drainage (Porter et al. 2013b; 2014) seven Impact Categories were used for the cumulative risk analyses with different pressure indicators assigned to each of these Impact Categories. The seven Impact Categories selected for the cumulative risk roll-ups were considered to represent relatively independent processes driving potential change in environmental conditions within salmon habitats. Table 1 provides descriptions of the specific rule sets used for defining "cumulative" habitat risk ratings for watersheds in Nass lake sockeye CU rearing/tributary spawning ZOIs and in other species CUs spawning ZOIs.

Table 1 Habitat pressure indicator and habitat Impact Category "roll-up" rule sets used for developing cumulative habitat risk ratings for watersheds within Nass salmon CU ZOIs (rearing lake and tributary spawning ZOIs for lake sockeye CUs and spawning ZOIs for all other salmon species CUs).

1st-level rollup-up rules (*within* Impact Categories)

Impact Categories	Embedded Habitat Pressure Indicators	Individual Impact Category Roll-up
Hydrologic Processes	ECA, forest disturbance	if ≥ 1 indicator rated red then Impact Category rated red, if 2 Indicators rated green then Impact Category rated green, else Impact Category rated amber
Surface Erosion	road density	if the indicator is rated green then Impact Category rated green, if the indicator is rated amber then Impact Category rated amber, if the indicator is rated red then Impact Category rated red
Fish Passage/Habitat Connectivity	stream crossing density in salmon habitat	if the indicator is rated green then Impact Category rated green, if the indicator is rated amber then Impact Category rated amber, if the indicator is rated red then Impact Category rated red
Vegetation Quality	riparian disturbance, insect defoliation	if ≥ 1 indicator rated red then Impact Category rated red, if 2 indicators rated green then Impact Category rated green, else Impact Category rated amber
Water Quantity	water allocations	if the indicator is rated green then Impact Category rated green, if the indicator is rated amber then Impact Category rated amber, if the indicator is rated red then Impact Category rated red
Water Quality	waste water discharges	if the indicator is rated green then Impact Category rated green, if the indicator is rated amber then Impact Category rated amber, if the indicator is rated red then Impact Category rated red
Human Development Footprint	total land cover alteration, impervious surfaces, linear development, mines	if ≥ 2 indicators rated red then Impact Category rated red, if ≥ 3 indicators rated green then Impact Category rated green, else Impact Category rated amber

2nd level roll-up rule (*across* Impact Categories)

Cumulative Habitat Risk Classification	Number of Impact Categories Rated Green	Number of Impact Categories Rated Red
Green	≥ 5/7	-
Red	-	≥ 3/7
Amber	< 5/7	< 3/7

2.5.2 Migration ZOIs (Lake Sockeye) and Rearing/Migration ZOIs (Other Species)

For scoring of cumulative habitat risk for watersheds within the migration corridor ZOI for lake sockeye CUs and within the rearing/migration ZOI for the other salmon species CUs we employed the same 1st level "within" Impact Category roll-up rule set as was used in Section 2.5.1. However, we used a different approach in these ZOIs for our subsequent 2nd level "across" Impact Categories scoring. Similar to methods used in Nelitz et al. (2011) and Beauchamp (2008), each higher risk (red) categorized Impact Category in a watershed was given a score of 2, each moderate risk (amber) categorized Impact Category was given a score of 1, and each lower risk (green) categorized Impact Category was given a score of 0. For Impact categories with only binary ratings a score of 2 (higher risk) or 0 (lower risk) was given. Cumulative risk scores in each watershed therefore ranged from 0 to 14 (based on possible scoring outcomes across the seven Impact Categories). The individual watershed scores were then summed across all the watersheds compromising the CU's ZOI to determine the total cumulative risk score for a particular CU's migration corridor ZOI (i.e. migration ZOI for lake sockeye, rearing/migration ZOI for all other species). Scoring of the cumulative risks along the migration ZOI using this alternative approach provides a better spatial representation of the changing pressure intensities along the migration route and also better accounts for the more diffuse nature of the corridor impacts (i.e. migrating salmon may not actually be using the migration ZOI-defined watersheds themselves but are instead experiencing the effects as they are manifested and potentially compounded downstream in the receiving mainstem river migration corridor).

2.6 Summary of Habitat Indicator Information

Table 2 provides a summary of the indicators for habitat vulnerability (based on measures of habitat quantity and quality) and habitat pressure that have been included in the Nass Salmon CU Habitat Report Cards, as well as the benchmarking approaches and criteria, supporting data sources, and the literature basis for particular indicator development and habitat risk categorizations.

Table 2 Summary of habitat quantity and quality (i.e. vulnerability), and habitat pressure indicators used for assessing habitats within Nass salmon Conservation Units (CUs) life-stage-specific zones of influence (ZOIs) with indicator rationales, associated data sources, and the habitat indicator benchmark values used for analysis of habitat status.

Indicator Type	Indicator	Units	Scale	Benchmark Type	Benchmarks[4]			Data Sources	Literature support for indicator inclusion
					Green (lower risk)	Amber (moderate risk)	Red (higher risk)		
Habitat Vulnerability Indicators									
Lake Sockeye									
Spawning period	Total spawning length	km	CU spawning ZOI	n/a	No specific CU benchmarks defined – comparisons based on each CU's ranked value relative to the other CUs			Lake sockeye spawning distribution FWA hydrology	Stalberg et al. 2009 (WSP)
	Length of lake shore spawning areas	km	CU spawning ZOI	n/a	No specific CU benchmarks defined – comparisons based on each CU's ranked value relative to the other CUs			Lake sockeye lakeshore spawning zones; FWA hydrology	Stalberg et al. 2009 (WSP)
	Length of lake-influenced (mainstem/lake outlet) spawning areas	km	CU spawning ZOI	n/a	No specific CU benchmarks defined – comparisons based on each CU's ranked value relative to the other CUs			Lake sockeye mainstem/lake outlet spawning zones, FWA hydrology	Nelitz et al. 2011; Arp et al. 2006; Myers et al. 2007; Jones 2010
	Length of tributary/lake inlet spawning areas	km	CU spawning ZOI	n/a	No specific CU benchmarks defined – comparisons based on each CU's ranked value relative to the other CUs			Lake sockeye tributary spawning, FWA hydrology	Nelitz et al. 2011; Arp et al. 2006; Myers et al. 2007; Jones 2010
	Ratio of all lake-influenced spawning to total spawning	0 – 1 scale	CU spawning ZOI	n/a	No specific CU benchmarks defined – comparisons based on each CU's ranked value relative to the other CUs			Lake sockeye spawning distribution, FWA hydrology	Nelitz et al. 2011; Arp et al. 2006; Myers et al. 2007; Jones 2010
	Accessible habitat	km	CU spawning ZOI	n/a	No specific CU benchmarks defined – comparisons based on each CU's ranked value relative to the other CUs			MOE Fish Passage Model (Version 2); FWA hydrology	Stalberg et al. 2009 (WSP), Mount et al. 2011

[4] **Watershed Pressure indicators**: Green = relatively lower risk of degraded fish habitat; Amber = relatively moderate risk of degraded fish habitat; Red = relatively higher risk of degraded fish habitat

Rearing period	Nursery lake area	ha	CU rearing ZOI	n/a	No specific CU benchmarks defined – comparisons based on each CU's ranked value relative to the other CUs	FWA lakes, DFO designated sockeye CU nursery lakes	Nelitz et al. 2011; Randall 2003
Migration period	Migration distance	km	CU migration ZOI	n/a	No specific CU benchmarks defined – comparisons based on each CU's ranked value relative to the other CUs	DFO and Nass TAC designated sockeye CU nursery lakes, FWA hydrology	Nelitz et al. 2011; Crossin et al. 2004
	Flow sensitivity	Distance (km) and % of CU migration route defined as summer low flow sensitive	CU migration ZOI	Science based/expert based (Ptolemy unpubl.)	No specific CU benchmark defined – comparisons based on each CU's ranked value relative to the other CUs	BC MOE ecoregional flow sensitivity mapping (R. Ptolemy, unpubl.)	Richter et al. 1997; R. Ptolemy (unpubl.)
River sockeye, Chinook, coho, pink and chum							
Spawning period	Total spawning length	km	CU spawning ZOI	n/a	No specific CU benchmarks defined – comparisons based on each CU's ranked value relative to the other CUs	Nass salmon species spawning distributions, FWA hydrology	Stalberg et al. 2009 (WSP)
	Flow sensitivity – summer (spawning period)	Length (km) and % of CU spawning reaches defined as summer flow sensitive	CU spawning ZOI	Science based/expert based (Ptolemy unpubl.)	No specific CU benchmarks defined – comparisons based on each CU's ranked value relative to the other CUs	Nass salmon species spawning distributions, FWA hydrology, BC MOE ecoregional flow sensitivity mapping (R. Ptolemy, unpubl.)	Richter et al. 1997; R. Ptolemy (unpubl.)
Incubation period	Flow sensitivity – winter (egg incubation period)	Length (km) and % of CU spawning reaches defined as winter flow sensitive	CU spawning ZOI	Science based/expert based (Ptolemy unpubl.)	No specific CU benchmarks defined – comparisons based on each CU's ranked value relative to the other CUs	Nass salmon species spawning distributions,, FWA hydrology, BC MOE ecoregional flow sensitivity mapping (R. Ptolemy, unpubl.)	Richter et al. 1997; R. Ptolemy (unpubl.)

Rearing / Migration period	Accessible habitat	km	CU rearing / migration ZOI	n/a	No specific CU benchmarks defined – comparisons based on each CU's ranked value relative to the other CUs	MOE Fish Passage Model (Version 2), FWA hydrology	Stalberg et al. 2009 (WSP), Mount et al. 2011
	Flow sensitivity (all seasons)	Length (km) and % of CU accessible stream reaches defined as flow sensitive (all seasons)	CU rearing / migration ZOI	Science based/expert based (Ptolemy unpubl.)	No specific CU benchmark defined – comparisons based on each CU's ranked value relative to the other CUs	BC MOE ecoregional flow sensitivity mapping (R. Ptolemy, unpubl.)	Richter et al. 1997; R. Ptolemy (unpubl.)
	Lakes (coho CUs only)	km^2	CU rearing / migration ZOI	n/a	No specific CU benchmarks defined – comparisons based on each CU's ranked value relative to the other CUs	FWA Lakes	Nelitz et all. 2007; Stalberg et al. 2009
	Wetlands (coho CUs only)	km^2	CU rearing / migration ZOI	n/a	No specific CU benchmarks defined – comparisons based on each CU's ranked value relative to the other CUs	FWA Wetlands	Nelitz et all. 2007
Habitat Pressure Indicators[5]							
Migration ZOI *(lake sockeye)* ***Rearing/Migration ZOI*** *(river sockeye, Chinook, coho, chum, & pink)*	Migration obstructions (total) (Lake sockeye CUs only)	# of obstructions	CU migration ZOI	n/a	No specific CU benchmark defined – comparisons based on each CU's ranked value relative to the other CUs	FISS Obstructions layer, FWA Obstructions layers	Wood 2001; Ricker 1987
	Licensed water use permits (total) (Lake sockeye CUs only)	# of water permits	CU migration ZOI	n/a	No specific CU benchmark defined – comparisons based on each CU's ranked value relative to the other CUs	LMB Water License Points of Diversion (POD)	Nelitz et al. 2007; Stalberg et al. 2009; Nelitz et al. 2011
	Cumulative CU migration corridor stressor score Combined stressor rating across pressure Impact Categories and their associated indicators	n/a	CU migration ZOI	Indicator roll-up decision rule set	Summation of the seven Impact Category ratings within watersheds in the migration ZOI (lake sockeye) or rearing/migration ZOI (other salmon species). Score of 2 for each red-rated Impact Category, score of 1 for an amber-rated Impact Category, and score of 0 for a green rated Impact Category. Total potential cumulative risk score for each watershed in the migration ZOI therefore ranges from 0 to 14.	Multiple data sources used across the habitat pressure indicators to inform the 7 Impact Categories	Rollup and summation of individual pressure indicator risk ratings for presentation of a composite score for assessing relative cumulative habitat risk status Nelitz et al. 2011; Nelitz et al. 2007; Porter et al. 2012;

									Beauchamp 2008; Porter et al. 2013a; 2013b; 2014
CU Watersheds	**Hydrologic Processes**								
	Forest disturbance	% of watershed	watershed	Relative ranking (RR1)	0	> 0 to < 10.0	≥ 10.0	Consolidated Cutblocks layer (VRI, RESULTS, FTEN, LANDSAT)	NOAA 1996: Rosenau and Angelo 2009
	Equivalent Clear Cut Area (ECA) (total)	% of watershed	watershed	green/amber (science/expert based - (NOAA 1996: MOF 2001), amber/red (science based - Summit/MOE 2006, FPB 2011)	< 15	≥ 15 to < 20	≥ 20	Consolidated Cutblocks layer (VRI, RESULTS, FTEN, LANDSAT), LCC2000-V	MOF 2001; Smith and Redding 2012
	Surface Erosion								
	Road development	km/km^2	watershed	green/amber (science/expert based – Stalberg et al. 2009); amber/red (science based – MOF 1995a,b & Porter et al. 2012)	< 0.4	≥ 0.4 to < 1.2	≥ 1.2	DRA, FTEN	Stalberg et al. 2009 (WSP), MOF 1995a,b; MOF 2001
	Fish Passage/Habitat Connectivity								
	Stream crossing density	# crossings/km of salmon accessible stream	watershed	Relative ranking (RR1)	0	> 0 to < 0.25	≥ 0.25	BC MOE Fish Habitat Model (Version 2), , FWA hydrology	Alberti et al. 2007; FPB 2009, FLNRO 2012., Mount et al. 2011

[5] Note that for the multi-drainage spanning Nass-Skeena Pink (even) CU habitat pressure indicator benchmarks were based on those developed in earlier PSF analyses for the Skeena drainage (Porter et al. 2014).

	Vegetation Quality								
	Insect and disease defoliation	% forest stands killed	watershed	Binary ranking (RR2)	0	> 0		VRI	Nelitz et al. 2011; Stalberg et al. 2009; EDI 2008; Redding et al. 2008; Rosenau and Angelo 2009
	Riparian disturbance	% of riparian zone	watershed	green/amber (science/expert based – Stalberg et al. 2009); amber/red (science based - Tripp and Bird 2004)	< 5	≥ 5 to < 15	≥ 15	Total Land Cover Alteration (above) restricted to riparian zone, FWA (streams, lakes, wetlands)	Stalberg et al. 2009 (WSP), Tripp and Bird (2004); Nelitz et al. 2007
	Water Quantity								
	Licensed water use permits	# of water licenses	watershed	Binary ranking (RR2)	0	> 0		LMB Water License Points of Diversion	Nelitz et al. 2007; Stalberg et al. 2009; Nelitz et al. 2011
	Water Quality								
	Permitted waste water discharges	# discharges	watershed	Binary ranking (RR2)	0	> 0		MOE Wastewater Discharge and Permits database	Stalberg et al. 2009
	Human Development Footprint								
	Total land cover alteration	% of watershed	watershed	Relative ranking (RR1)	0	> 0 to < 12.0	≥ 12.0	LCC2000-V (agriculture, urban), VRI (forestry, fire, mining, urban), DRA (roads), FTEN (roads, forestry), RESULTS (forestry), NTS (rail), Crown Tenure (Utility Corridors and Right of Ways), Current & Historical Fire Polygons (fire), BTM (mining)	Stalberg et al. 2009
	Linear development	km/km^2	watershed	Relative ranking (RR1)	0	> 0 to < 0.59	≥ 0.59	DRA, FTEN, NTS	WCEL 2011; MOE 2012
	Mining development	# of mines (total of	watershed	Binary ranking (RR2)	0			MEM & PR database	Nellitz et al. 2011; Kondolf

		coal, mineral and aggregate mines)				> 0			1997; Nelson et al. 1991
	Impervious Surface (integration of urban & agricultural/rural development)	% of watershed	watershed	green/amber/red (science/expert based – Paul and Meyer 200; Smith 2005)	< 3	≥ 3 to < 10	≥ 10	LCC2000-V (agriculture, urban), VRI (urban), DRA (roads), FTEN (roads), NTS (rail)	Paul and Meyer 2001; Smith 2005; Rosenau and Angelo 2009, Nelitz et al. 2007)
	Cumulative habitat pressure scoring within CU watersheds Combined stressor rating across 7 Impact Categories and their associated habitat pressure indicators	n/a	watershed	Indicator roll-up decision rule set	Roll up rule set criteria for defining lower relative risk of cumulative impacts (i.e. ≥ 5 Impact Categories rated green)	Roll up rule set criteria for defining a moderate relative risk of cumulative impacts (i.e. < 5 Impact Categories rated green and < 3 Impact Categories rated red)	Roll up rule set criteria for defining higher relative risk of cumulative impacts (i.e. ≥ 3 Impact Categories rated red	Multiple data sources used across the habitat pressure indicators to inform the 7 Impact Categories roll up and summation of individual pressure indicator Impact Category risk ratings for presentation of a composite score for assessing relative cumulative habitat risk status in each watershed	Nelitz et al. 2011; Nelitz et al. 2007; Porter et al. 2012; Beauchamp 2008, Porter et al. 2013a; 213b; 2014
Future Habitat Pressure Indicators									
Nass Area	Proposed resource development (future pressures) - Proposed mines (coal, mineral), water licenses, logging	Multiple indicators – various units (#, km^2)	Whole drainage	n/a	No specific benchmarks defined. Potential increases in development pressures that can be evaluated.			Proposed development GIS layers MEM & PR database (proposed mines), LMB Water License Points of Diversion (proposed), Timber Harvesting Land Base (THLB) layer	n/a

2.7 "Average" Habitat Pressure Indicator Risk Ratings across Watersheds within Nass Salmon CU ZOIs

In addition to individual and cumulative indicator risk scoring for individual watersheds within life stage ZOIs, we also determined the "average" risk scores for the pressure indicators across all watersheds in each salmon CU's rearing lake ZOI (for lake sockeye) or spawning ZOI (for all other species). This was based on the area-weighted averages of all watershed scores within the ZOI, for all FWA watersheds that overlapped the CU's ZOI boundary. Risk scores were calculated and weighted using entire areas of FWA watersheds that overlapped the ZOI boundary, even when only a portion of the FWA watershed was within the CU's ZOI. The area-weighted average risk scores were then normalized to a 0 to 1 scale for each habitat pressure indicator, with a low to moderate risk benchmark (i.e., green to amber transition) set at 0.33 and a moderate to high risk benchmark (i.e., amber to red transition) set at 0.66 on the normalized scale for each indicator. The normalized area weighted indicator averages are presented in each salmon CU habitat report card using a colour coded "slider" (see example in Figure 3 to graphically illustrate the general range of perceived risk from habitat pressures across the ZOI).

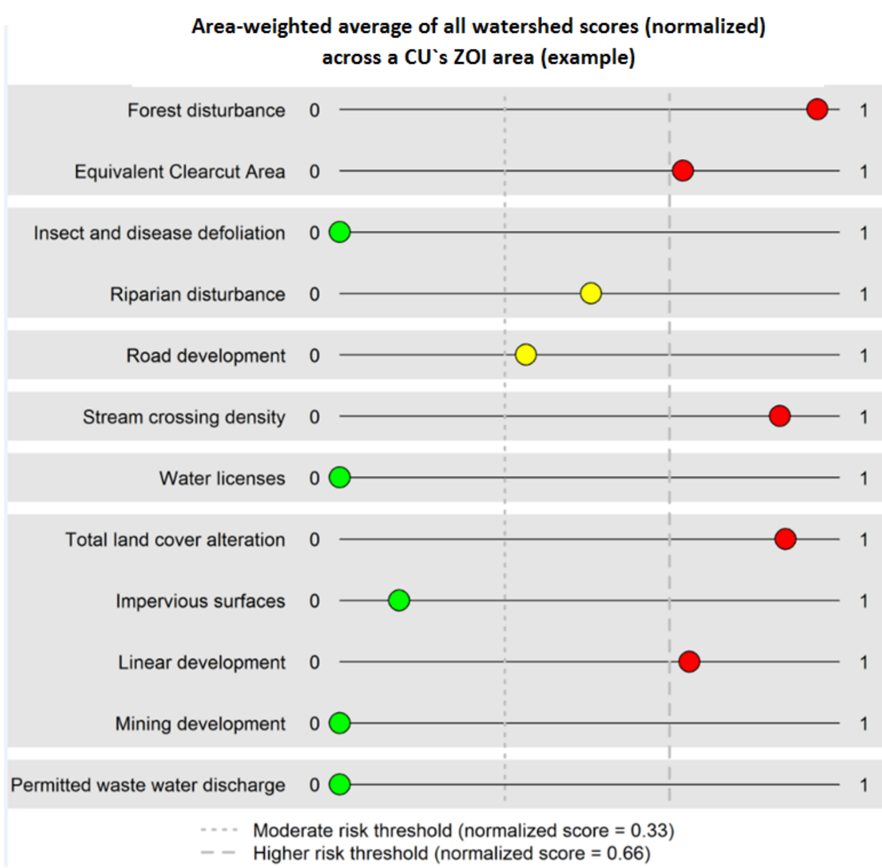

Figure 3 Example "slider" for illustrating the normalized area-weighted average watershed pressure indicator risk scores across the ZOI for a hypothetical CU. The ZOI evaluated for lake sockeye is the rearing lake ZOI, whereas for all other salmon species the ZOI evaluated is the spawning ZOI.

2.8 Integrated Habitat Pressure/Vulnerability Indices for Nass Salmon CU life-history stages

Given a general lack of comprehensive information that could be used to reliably assess differences in habitat condition across all habitats used by Nass salmon CUs we have instead defined relative CU habitat status as a combination of: (1) the cumulative intensity of various human stresses on their habitats, and (2) the intrinsic vulnerability to these habitat impacts (based on quantified measures of habitat quantity and/or quality). In this approach a CU that was considered more highly vulnerable (relatively more sensitive to potential habitat impacts compared to other CUs), while also exposed to relatively high levels of composite human development pressures within its spawning, rearing and/or migratory habitats, would be considered to have a relatively poor habitat status. Conversely, a CU with limited vulnerability (relatively less sensitive) and minimal human development pressure would be considered as having a relatively good habitat status. We stress that these are only relative indices based on CU rankings for these indicators at this time. Even those CUs rated as having *relatively* high habitat pressures and *relatively* high vulnerability may not have any demonstrated actual negative impacts of human stressors on salmon freshwater survival. In the future, with continued work on the effects of landscape habitat pressures and salmon responses/resilience, it may be possible to better define benchmarks of concern for combined pressures/vulnerability scores.

2.8.1 Vulnerability and Cumulative Pressure Indicators

A subset of the vulnerability indicators (habitat quantity and/or quality) listed in Table 3 that were considered most uniquely informative were selected for use in integrated CU vulnerability/cumulative pressures assessment and ranking across the different life-history stages for each salmon species. Note that egg incubation is considered to occur in the same locations as adult spawning, although at different times of year; therefore habitat areas delineated for the spawning ZOIs correspond to both the spawning and incubation life-history stages.

Table 3 Vulnerability and cumulative pressure indicators for species Conservation Unit CU) zones of influence (ZOIs).

Vulnerability Indicators	
Lake Sockeye	**Relationship**
Migration	
1. Total migration distance (km) for the CU	Greater distance = greater vulnerability
2. Length (km) of CU migration route (km) within summer low flow sensitive areas[6]	Greater distance = greater vulnerability
3. % of CU migration route within summer low flow sensitive areas	Greater % = greater vulnerability
Spawning	
1. Total spawning length for CU (km)	Less length = greater vulnerability
2. Length (km) of lake shore spawning in CU	Less length = greater vulnerability
3. Length (km) of tributary/lake inlet spawning in CU	More length = greater vulnerability
4. Length (km) of mainstem/lake outlet spawning in CU	Less length = greater vulnerability
5. Ratio of lake-influenced spawning (i.e. lake and mainstem/lake outlet) to total spawning for the CU	Smaller ratio = greater vulnerability
6. Total length (km) of accessible salmon habitat in CU rearing lake ZOI	Less length = greater vulnerability
Rearing	
1. Area (km^2) of CU nursery/rearing lake	Smaller area = greater vulnerability
River sockeye, Chinook, coho, chum and pink	**Relationship**
Spawning (summer spawn timing)	
1. Total identified spawning length (km) in CU	Less length = greater vulnerability
2. Total spawning length (km) for CU in summer flow sensitive areas	More length = greater vulnerability
3. % of total spawning length for CU in summer flow sensitive areas	Greater % = greater vulnerability
Spawning (winter egg incubation timing)	
1. Total spawning length (km) for CU in winter flow sensitive areas	More length = greater vulnerability
2. % of total spawning length for CU in winter flow sensitive areas	Greater % = greater vulnerability
Rearing/Migration	
1. Salmon accessible stream length[7] in rearing/migration ZOI (km)	Less length = greater vulnerability
2. Total salmon accessible stream length (km) in CU rearing/migration ZOI within flow sensitive areas (all seasons)	More length = greater vulnerability
3. % of total salmon accessible stream length within CU rearing/migration ZOI within flow sensitive areas (all seasons)	Greater percentage = greater vulnerability
Coho only: lake area within CU, wetland area within CU (not used for integrated pressure/vulnerability analyses)	Smaller area = greater vulnerability

[6] Seasonal flow sensitivities based on BC MOE Flow Sensitivity Mapping (R. Ptolemy, unpublished)
[7] Accessible salmon habitat based on < 10% reach gradient filtering of BC MOE Fish Habitat Model (Version 2)

Cumulative Pressure Indicators	
Lake Sockeye	**Relationship**
Migration	
1. Total # of water licenses within CU migration corridor	Greater # of licenses = greater cumulative pressure
2. Total # of identified FISS/FWA obstructions along the CU migration corridor	Greater # of obstructions = greater cumulative pressure
3. Cumulative migration corridor pressure score for the CU based on an area-weighted total of the individual watershed risk scores (as described in Section 2.5.2) along the length of the migration corridor[8]	Higher score = greater cumulative pressure
Spawning	
1. % of all watersheds in tributary spawning ZOI classified as either moderate or higher (amber, red) for cumulative habitat risk	Greater % of "at risk"[9] watersheds = greater cumulative pressure
Rearing	
1. Sum[10] total across the individual habitat pressure indicator normalized risk scores for a CU's rearing lake ZOI (based on the area-weighted averages (normalized) rearing lake ZOI individual watershed risk classifications for each indicators – as described in Section 2.7)	Higher combined total score = greater cumulative pressure.
River sockeye, Chinook, coho, chum and pink	
Spawning	
1. % of CU spawning ZOI watersheds (also includes area of egg incubation) that are classified as either moderate or higher (amber, red) for cumulative habitat risk	Greater % of "at risk" watersheds = greater cumulative pressure
Rearing/Migration	
1. Cumulative CU migration/rearing ZOI pressure score based on an area-weighted total of the individual watershed risk scores (as described in Section 2.5.2) within the CU rearing/migration ZOI[7]	Higher score = greater cumulative pressure

[8] An area-weighted total for the migration corridor ZOI (lake sockeye) or rearing/migration ZOI (all other salmon species) was generated by multiplying the cumulative risk scores for individual watersheds by the percentage of the total ZOI area that is represented by watersheds with that particular cumulative risk score [e.g. Area-weighted total score for CU migration corridor pressures = (7*0.21) + (3*0.23) + (13*0.18) + (9*0.18) + (2*0.14) + (1*0.06) = 6.46 (where whole numbers in this example calculation represent cumulative risk scores for individual watersheds and fractional values represent the proportion of the total area for all watersheds in the ZOI that are represented by watersheds having that particular cumulative pressure score (numbers hypothetical)]. A higher total area-weighted cumulative risk score across all ZOI watersheds = greater cumulative pressure (highest possible score =14).

[9] All watersheds in which spawning is occurring are considered of critical importance and no differentiation is between moderate or higher risk classifications used within this integrated cumulative pressure indicator

[10] The sum of the individual (normalized) pressure indicator scores represents the total cumulative pressure index score for the CU rearing lake. A CU's cumulative pressure index score ranges from 0 to 12, based on the normalized 0-1 risk scoring within each of the twelve individual habitat pressure indicators evaluated.

2.8.2 Rule Sets for Integrated Vulnerability/Cumulative Pressures Indices

2.8.2.1 Vulnerability (Lake Sockeye)

1. **Migration:** Use either of the two vulnerability indicators 1) total CU migration distance or 2) length of CU migration length within summer low flow sensitive areas (actual distance flow sensitive being considered more relevant for quantifying potential impacts to the CU than the % of total distance). Consider both vulnerability indicators to be equally weighted and plot the lowest (worst) ranking between the two indicators (i.e. ranked as relatively the more vulnerable compared to other lake sockeye CUs) as the particular CU's migration vulnerability ranking point (e.g. if ranked 12th for total migration distance and 28th for distance that is summer flow sensitive, plot the 28th rank to represent the relative migration corridor vulnerability index score for the CU). This approach is intended to identify the most serious habitat vulnerability for a particular CU relative to other lake sockeye CUs in the Nass.

2. **Spawning:** Use either of the two vulnerability indicators 1) total CU spawning length or 2) the ratio of CU lake-influenced spawning to total CU spawning length. Consider both indicators to be equally weighted and plot the lowest (worst) ranking between the two indicators (i.e. ranked as relatively the more vulnerable compared to other lake sockeye CUs) as the particular CU's spawning vulnerability ranking point.

3. **Rearing:** Plot the ranked score for the one rearing vulnerability indicator (CU lake size) as the particular CU's ranking point (i.e. CUs with smaller rearing lakes will be considered relatively more vulnerable to impacts than lake sockeye CUs with larger lakes).

2.8.2.2 Cumulative Pressures (Lake Sockeye)

1. **Migration:** Use any of the three migration corridor pressure indicators 1) total # of water licenses, total # of obstructions, 3) cumulative pressure score. Consider all equally weighted and plot the lowest (worst) ranking across the three indicators (i.e., ranked as relatively the highest pressures compared to other CUs) as this CU's ranking point (e.g. if ranked 12th for # of water licenses, 15th for # of migration obstructions and 18th for cumulative migration corridor pressure scoring, plot the 18th rank to represent the relative cumulative pressure index score for the CU). This approach is intended to identify the most serious cumulative habitat pressure in the migration corridor for a particular CU relative to other CUs in the Nass.

2. **Spawning:** Plot the ranked score for the one spawning pressure indicator (% of CU tributary spawning ZOI watersheds "at risk") as the particular CU's ranking point (i.e. CUs with a greater % of spawning watersheds with red or amber

cumulative risk classifications will have higher relative rankings for the spawning cumulative risk index).

3. **Rearing:** Plot the ranked total score for the (normalized) suite of rearing lake ZOI pressures as the particular CU's ranking point for the cumulative pressure index (i.e. CUs with a higher total score for this integrated metric will have higher relative rankings for the rearing cumulative risk index).

2.8.2.3 Vulnerability (river sockeye, Chinook, coho, chum and pink)

1. **Spawning (summer spawning):** Use either of the two vulnerability indicators 1) total CU spawning length or 2) % of CU spawning length in summer flow sensitive areas. Consider both selected vulnerability indicators equally weighted and plot the lowest (worst) ranking between the two indicators (i.e. ranked as relatively more vulnerable compared to other salmon CUs for the species) as the particular CU's summer spawning vulnerability ranking point.

2. **Spawning (winter egg incubation):** Use the single vulnerability indicator % of spawning length in winter flow sensitive areas. Plot the ranking for this indicator to represent the relative spawning ZOI (winter egg incubation timing) vulnerability index score for the CU.

3. **Rearing/Migration:** Use either of the two vulnerability indicators 1) total CU salmon accessible stream length or 2) % of salmon accessible stream length in flow sensitive areas (all seasons). Consider both selected vulnerability indicators equally weighted and plot the lowest (worst) ranking between the two indicators as the particular CU's rearing/migration vulnerability ranking point.

2.8.2.4 Cumulative Pressures (river sockeye, Chinook, coho, chum and pink)

1. **Spawning (for both summer spawn and winter egg incubation timing):** Use the single cumulative pressure indicator: % of spawning ZOI watersheds considered "at risk". Plot the ranked score for this indicator as the particular CU's spawning cumulative risk ranking point (i.e., CUs with a greater % of watersheds with red or amber cumulative risk classifications will have higher relative pressure rankings for the spawning areas cumulative risk index).

2. **Rearing/Migration:** Use the single cumulative pressure indicator: area-weighted total of migration/rearing watershed risk scores. Plot the ranked score for this cumulative pressure index as the particular CU's migration/rearing cumulative risk ranking point.

Figure 4 provides some examples of the outputs of such integrated vulnerability/cumulative pressures analyses, showing (for hypothetical CUs) their ranked index score relative to other CUs along the two axes of habitat vulnerability and cumulative habitat pressure (together providing a broad relative assessment of a CU's habitat status in relation to its use by different salmon life-history stages).

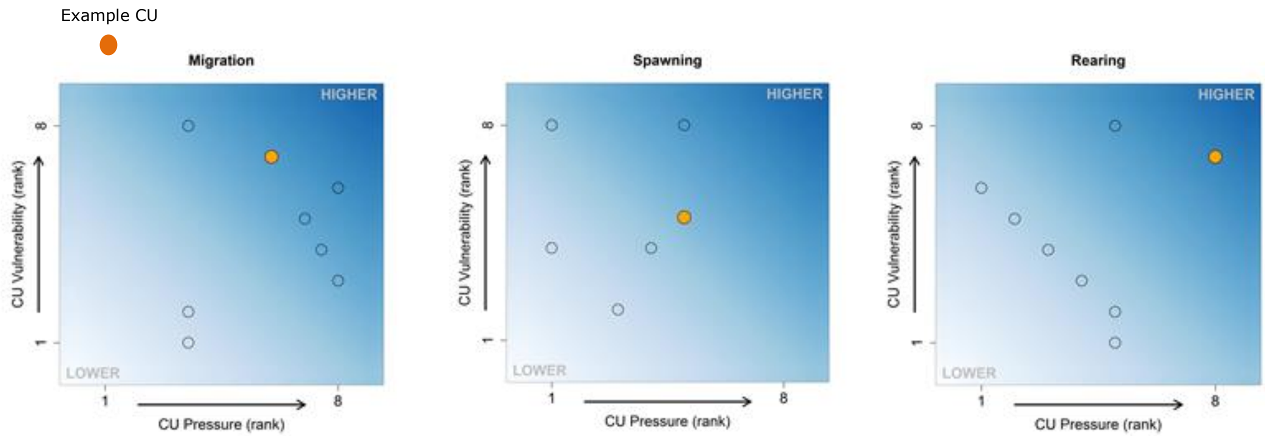

Figure 4 Example output from integrated life-history stage specific habitat vulnerability and cumulative habitat pressures analysis for defining relative rankings of habitat "status" across CUs (orange circle represents a hypothetical ranking for an example CU). CUs in the upper right hand quadrant would have both the highest habitat-based vulnerability while also experiencing the highest cumulative habitat pressures on that life-history stage to other CUs.

3 Results

3.1 Nass CU Habitat Report Cards

Summaries report cards of habitat indicator information within defined CU life-history stage specific ZOIs have been developed for 22 Nass CUs including eight lake sockeye, two river sockeye, two Chinook, three coho, three chum, and four pink CUs. These report cards provide an overview of indicators for current and potential future habitat pressures, as well as habitat vulnerabilities to these pressures (i.e. indicators of habitat quantity and quality).. Current habitat pressure indicators within delineated CU ZOI watersheds are rated for their relative risk (higher, moderate, or lower) of degrading fish habitat, while vulnerability indicators are rated for their relative (ranked) sensitivity to those potential habitat disturbances. Summary information is presented for each CU in graphical and map-based presentation formats. Results of these comparative habitat analyses are presented in habitat report cards for each of the Nass salmon CUs. Nass CU habitat report cards for lake sockeye, river sockeye, Chinook, coho, chum, and pink salmon, as well as a guidance document on how to interpret the various Nass report card elements, can be viewed and downloaded at the PSF's Skeena Salmon Program website: www.skeenasalmonprogram.ca.

These report cards provide a considerable amount of information, describing the habitat pressures and risks affecting each Nass salmon CU. The CU report cards are based on similar approaches used by Nelitz et al. 2011 and Porter et al. 2013a; 2013b; 2014 to visualize a suite of information related to the status of habitats used by salmon CUs. The report cards represent an attempt to concisely identify and quantify major pressures that could act on freshwater habitats used by Nass salmon CUs and that could contribute to the overall productivity of a CU. An example report card "walk through" illustrating how a user would assess CU-specific freshwater habitat information is provided in Section 3.1 of the Porter et al. 2013b Skeena habitat report and the reader may consult that report section text (downloadable from PSF's website) for additional guidance as it conforms generally with the structure of the Nass CU habitat report cards.

3.2 Habitat Pressure Indicators

3.2.1 Lake Sockeye

A broad overview of habitat pressures within and across Nass lake sockeye CU ZOIs is provided by identifying:

1) the percentage of watersheds within each CU's rearing lake ZOI that were rated as higher, moderate, or lower risk (i.e. red/amber/green) for *cumulative* habitat pressures (see Table 4) based on pressure indicator roll-up rules,
2) the percentage of watersheds within each rearing lake ZOI that were rated as higher, moderate, or lower risk (i.e. red/amber/green) for each of the

individual habitat pressure indicators evaluated (see Table 5 5, Table 6, and Table 7),

3) the percentage of watersheds within each CU's tributary spawning ZOI (where applicable) that were rated as higher, moderate, or lower risk (i.e., red/amber/green) for *cumulative* habitat pressures (see Table 8) based on pressure indicator roll-up rules,
4) the percentage of watersheds within each rearing lake CU that were rated as higher, moderate, or lower risk (i.e., red/amber/green) for each of the *individual* habitat pressure indicators evaluated (see Table 9, Table 10 and Table 11), and
5) the *cumulative* risk scores (total and area-weighted total) for each CU's migration corridor ZOI (see Table 12) based on pressure indicator roll-up rules, as well as the total number of obstructions and permitted water licenses along the migration corridor.

Lake Sockeye Rearing: Watershed habitats located within Nass lake sockeye CU rearing lake ZOIs were generally rated at lower or at most moderate risk for cumulative habitat impacts. Only the Bowser and Oweegee CUs had watersheds within their rearing ZOI rated as higher risk. However while this higher risk rating represented only 6% of the watersheds (1 of 18) for the Bowser CU and only 8% of watersheds for the Meziadin CU (1 of 13) it represented 100% of the habitat for the much smaller rearing lake ZOI of the Owegee CU (a single watershed rated higher risk) (see Table 4). Similarly, evaluation of individual habitat pressure indicators for Nass lake sockeye CU rearing lake ZOIs (Table 5, Table 6, and Table 7) indicates that habitat for many would be considered relatively undisturbed, with the majority of CUs presenting a high percentage of lower (green) risk ratings across most of the pressure indicators evaluated for this project. Lake sockeye CUs showing some higher (red) risk ratings for various individual habitat pressures within some or all of their rearing lake ZOI watersheds were Bowser, Clements, Fred Wright, Meziadin, and Owegee. Pressure indicators that generated higher individual risk ratings across rearing ZOIs for these lake sockeye CUs included Land cover altered, Forest Disturbed, Mines, Linear development, Stream crossing density, Permitted water licenses, Riparian disturbance and ECA. Bowser, Meziadin and Oweegee CUs were most affected across these habitat pressures, but Clements and Fred Wright CUs also had some individual higher risk ratings.

Lake Sockeye Tributary Spawning: For lake sockeye CUs with identified areas of tributary spawning (4 CUs) the spawning ZOIs would also be rated as in relatively good shape, with many of the CUs having all or most of their ZOI watersheds rated as being at lower risk or at most moderate risk from cumulative habitat pressures (Table 8). Exceptions to this include the Owegee CU with its single spawning ZOI watershed rated as higher risk and the Meziadin CU with 8% (1 of 13) of its tributary spawning ZOI watersheds rated higher risk for habitat pressures. Evaluation of individual habitat pressure indicators in the subset of CUs with tributary spawning ZOIs (Table 9, Table 10, and

Table 11) indicates, similarly, that many of the associated watersheds are relatively undisturbed, generating lower risk ratings across most of the habitat pressure indicators. CUs showing some higher risk ratings for various individual habitat pressures across watersheds within their tributary spawning ZOIs were Fred Wright, Meziadin and Oweegee. Pressure indicators that generated higher individual risk ratings across spawning ZOIs for these CUs included Land cover altered, Forest disturbed, Mines, Linear development, Stream crossing density, Riparian disturbance, and ECA.

Lake Sockeye Migration: The area-weighted total cumulative risk scoring for lake sockeye CU migration corridor ZOIs (Table 12) suggests that the CUs experiencing the greatest amount of overall habitat pressure along the migration route include Kwinageese (score = 5.68), Fred Wright (score = 5.66), Meziadin (score = 5.61), and Owegee (score = 5.60). The lowest cumulative risk scores for migration were shown by Leverson (score = 0.0), Clements (score = 4.06), and Damdochax (score = 4.07). Calculated migration distance was longest for Oweegee and shortest for Leverson. The total number of identified mainstem obstructions/obstacles that migrating Nass lake sockeye CUs could experience during migration was generally quite low and varied from as few as 0 (for Leverson) to as many as 10 (Meziadin). There were no permitted water licenses along the CU migration corridors for Leverson or Clements, while migration corridors for the other lake sockeye CUs had either 18 or 19 permitted water licenses along their routes.

Table 4 The percentage of watersheds in the **rearing lake "zone of influence" (ZOI)** for each Nass lake sockeye Conservation Unit (CU) that are rated as being at relatively higher, moderate, or lower risk from **"cumulative" habitat impacts**. Cumulative risk is based on a composite risk scoring roll-up rule set using the identified individual risk status for seven habitat pressure Impact Categories: Hydrological processes, Vegetation quality, Surface erosion, Fish passage/habitat connectivity, Water quantity, Human development footprint, and Water quality.

CU_NAME	CU_ID	ZOI area (km2)	Watersheds in ZOI (# of)	Higher-risk Watersheds (%)	Moderate-risk Watersheds (%)	Lower Risk Watersheds (%)
Bowser	420	1297.8	18	6%	6%	89%
Clements	418	6.0	1	0%	100%	0%
Damdochax	421	114.5	3	0%	0%	100%
Fred Wright	422	201.9	4	0%	100%	0%
Kwinageese	423	13.4	1	0%	100%	0%
Leverson	419	20.1	1	0%	0%	100%
Meziadin	424	670.6	13	8%	31%	62%
Oweegee	425	55.0	1	100%	0%	0%

Table 5 The percentage of watersheds in the **rearing lake "zone of influence" (ZOI)** for each Nass lake sockeye Conservation Unit (CU) that were identified as relatively **higher risk** (red rating) for each of the **individual habitat pressure indicators** evaluated.

CU_NAME	CU_ID	Watersheds in ZOI (# of)	Land Cover Altered (%)	Forest Disturbed (%)	Impervious surface (%)	Mines (#)	Linear development (km/km²)	Road density (km/km²)	Stream crossing density (#/km)	Permitted water licenses (#)	Riparian disturbance (%)	Waste water discharge sites (#)	ECA (%)	Forest stands defoliated (%)
Bowser	420	18	6%	6%	0%	11%	6%	0%	17%	6%	0%	0%	6%	0%
Clements	418	1	0%	0%	0%	100%	0%	0%	100%	0%	0%	0%	0%	0%
Damdochax	421	3	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fred Wright	422	4	0%	0%	0%	0%	50%	0%	25%	0%	0%	0%	0%	0%
Kwinageese	423	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Leverson	419	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Meziadin	424	13	23%	23%	0%	8%	31%	0%	31%	8%	8%	0%	0%	0%
Oweegee	425	1	100%	100%	0%	0%	100%	0%	100%	0%	0%	0%	100%	0%

Table 6 The percentage of watersheds in the rearing lake "zone of influence" (ZOI) for each Nass lake sockeye Conservation Unit (CU) that were identified as relatively moderate risk (amber rating) for each of the individual habitat pressure indicators evaluated.

CU_NAME	CU_ID	Watersheds in ZOI (# of)	Land Cover Altered (%)	Forest Disturbed (%)	Impervious surface (%)	Mines (#)	Linear development (km/km²)	Road density (km/km²)	Stream crossing density (#/km)	Permitted water licenses (#)	Riparian disturbance (%)	Waste water discharge sites (#)	ECA (%)	Forest stands defoliated (%)
Bowser	420	18	44%	6%	0%	0%	44%	6%	22%	0%	6%	0%	0%	0%
Clements	418	1	100%	100%	0%	0%	100%	0%	0%	0%	100%	0%	0%	0%
Damdochax	421	3	33%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fred Wright	422	4	100%	100%	0%	0%	50%	50%	75%	0%	50%	0%	0%	0%
Kwinageese	423	1	100%	100%	0%	0%	100%	0%	100%	0%	0%	0%	0%	0%
Leverson	419	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Meziadin	424	13	46%	23%	0%	0%	31%	31%	23%	0%	23%	0%	15%	0%
Oweegee	425	1	0%	0%	0%	0%	0%	100%	0%	0%	100%	0%	0%	0%

Table 7 The percentage of watersheds in the rearing lake "zone of influence" (ZOI) for each Nass lake sockeye Conservation Unit (CU) that were identified as relatively lower risk (green rating) for each of the individual habitat pressure indicators evaluated.

CU_NAME	CU_ID	Watersheds in ZOI (# of)	Land Cover Altered (%)	Forest Disturbed (%)	Impervious surface (%)	Mines (#)	Linear development (km/km²)	Road density (km/km²)	Stream crossing density (#/km)	Permitted water licenses (#)	Riparian disturbance (%)	Waste water discharge sites (#)	ECA (%)	Forest stands defoliated (%)
Bowser	420	18	50%	89%	100%	89%	50%	94%	61%	94%	94%	100%	94%	100%
Clements	418	1	0%	0%	100%	0%	0%	100%	0%	100%	0%	100%	100%	100%
Damdochax	421	3	67%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Fred Wright	422	4	0%	0%	100%	100%	0%	50%	0%	100%	50%	100%	100%	100%
Kwinageese	423	1	0%	0%	100%	100%	0%	100%	0%	100%	100%	100%	100%	100%
Leverson	419	1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Meziadin	424	13	31%	54%	100%	92%	38%	69%	46%	92%	69%	100%	85%	100%
Oweegee	425	1	0%	0%	100%	100%	0%	0%	0%	100%	0%	100%	0%	100%

Table 8 The percentage of watersheds in the tributary spawning "zone of influence" (ZOI) for each Nass lake sockeye Conservation Unit (CU) in which tributary spawning occurs that are rated as being at relatively higher, moderate, or lower risk from "cumulative" habitat impacts. Cumulative risk is based on a composite risk scoring roll-up rule set using the identified individual risk status for seven habitat pressure Impact Categories: Hydrological processes, Vegetation quality, Surface erosion, Fish passage/habitat connectivity, Water quantity, Human development footprint, and Water quality.

CU_NAME	CU_ID	ZOI area (km2)	Watersheds in ZOI (# of)	Higher-risk Watersheds (%)	Moderate-risk Watersheds (%)	Lower Risk Watersheds (%)
Bowser	420	0	0	n/a	n/a	n/a
Clements	418	0	0	n/a	n/a	n/a
Damdochax	421	68.8	2	0%	0%	100%
Fred Wright	422	201.9	4	0%	100%	0%
Kwinageese	423	0	0	n/a	n/a	n/a
Leverson	419	0	0	n/a	n/a	n/a
Meziadin	424	670.6	13	8%	31%	62%
Oweegee	425	55.0	1	100%	0%	0%

Table 9 The percentage of watersheds in the tributary spawning "zone of influence" (ZOI) for each Nass lake sockeye Conservation Unit (CU) in which tributary spawning occurs that were identified as relatively higher risk (red rating) for each of the individual habitat pressure indicators evaluated.

CU_NAME	CU_ID	Watersheds (# of)	Land Cover Altered (%)	Forest Disturbed (%)	Impervious surface (%)	Mines (#)	Linear development (km/km²)	Road density (km/km²)	Stream crossing density (#/km)	Permitted water licenses (#)	Riparian disturbance (%)	Waste water discharge sites (#)	ECA (%)	Forest stands defoliated (%)
Bowser	420	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Clements	418	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Damdochax	421	2	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fred Wright	422	4	0%	0%	0%	0%	50%	0%	25%	0%	0%	0%	0%	0%
Kwinageese	423	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Leverson	419	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Meziadin	424	13	23%	23%	0%	8%	31%	0%	31%	8%	8%	0%	0%	0%
Oweegee	425	1	100%	100%	0%	0%	100%	0%	100%	0%	0%	0%	100%	0%

Table 10 The percentage of watersheds in the tributary spawning "zone of influence" (ZOI) for each Nass lake sockeye Conservation Unit (CU) in which tributary spawning occurs that were identified as relatively moderate risk (amber rating) for each of the individual habitat pressure indicators evaluated.

CU_NAME	CU_INDEX	Watersheds (# of)	Land Cover Altered (%)	Forest Disturbed (%)	Impervious surface (%)	Mines (#)	Linear development (km/km^2)	Road density (km/km^2)	Stream crossing density (#/km)	Permitted water licenses (#)	Riparian disturbance (%)	Waste water discharge sites (#)	ECA (%)	Forest stands defoliated (%)
Bowser	420	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Clements	418	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Damdochax	421	2	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fred Wright	422	4	100%	100%	0%	0%	50%	50%	75%	0%	50%	0%	0%	0%
Kwinageese	423	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Leverson	419	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Meziadin	424	13	46%	23%	0%	0%	31%	31%	23%	0%	23%	0%	15%	0%
Oweegee	425	1	0%	0%	0%	0%	0%	100%	0%	0%	100%	0%	0%	0%

Table 11 The percentage of watersheds in the tributary spawning "zone of influence" (ZOI) for each Nass lake sockeye Conservation Unit (CU) in which tributary spawning occurs that were identified as relatively lower risk (green rating) for each of the individual habitat pressure indicators evaluated.

CU_NAME	CU_INDEX	Watersheds (# of)	Land Cover Altered (%)	Forest Disturbed (%)	Impervious surface (%)	Mines (#)	Linear development (km/km^2)	Road density (km/km^2)	Stream crossing density (#/km)	Permitted water licenses (#)	Riparian disturbance (%)	Waste water discharge sites (#)	ECA (%)	F Forest stands defoliated (%)
Bowser	420	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Clements	418	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Damdochax	421	2	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Fred Wright	422	4	0%	0%	100%	100%	0%	50%	0%	100%	50%	100%	100%	100%
Kwinageese	423	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Leverson	419	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Meziadin	424	13	31%	54%	100%	92%	38%	69%	46%	92%	69%	100%	85%	100%
Oweegee	425	1	0%	0%	100%	100%	0%	0%	0%	100%	0%	100%	0%	100%

Table 12 Total cumulative risk scoring elements for habitat in the migration corridor "zone of influence" (ZOI) for each Nass lake sockeye Conservation Unit (CU). Cumulative risk across the migration corridor ZOI is based on a summation of watershed scores for each of the seven habitat pressure Impact Categories: Hydrological processes, Vegetation quality, Surface erosion, Fish passage/habitat connectivity, Water quantity, Human development footprint, and Water quality. A higher-risk Impact Category is scored as 2, a moderate-risk Impact Category is scored as 1, and a lower risk Impact Category in scored as 0. Additional cumulative impact summaries are the total number of identified obstructions and the total number of permitted water licenses located in the migration corridor ZOI.

CU_NAME	CU_ID	ZOI area (km^2)	Watersheds in ZOI (# of)	Migration distance (km)	Total cumulative risk score across migration ZOI watersheds	Area-weighted total cumulative risk score across migration ZOI watersheds	Total obstructions (#)	Total permitted water licenses (#)
Bowser	420	5215.0	97	261.58	507	4.84	7	19
Clements	418	206.7	5	17.47	20	4.06	0	0
Damdochax	421	4968.4	102	320.21	441	4.07	7	18
Fred Wright	422	3843.9	78	264.49	462	5.66	8	18
Kwinageese	423	3830.2	77	273.02	459	5.68	8	18
Leverson	419	24.0	1	1.82	0	0	3	0
Meziadin	424	3602.4	72	197.34	411	5.61	10	19
Oweegee	425	4545.0	91	299.93	537	5.60	8	19

3.2.2 River Sockeye, Chinook, Coho, Chum, and Pink

A broad overview of habitat pressures within and across CU ZOIs for river sockeye, Chinook, coho, chum, and pink is provided by identifying:

1. the percentage of watersheds within each CU's spawning ZOI that were rated as higher, moderate, or lower risk (i.e., red/amber/green) for *cumulative* habitat pressures (see Table 13) based on pressure indicator roll-up rules;

2. the percentage of watersheds within each CU's spawning ZOI that were rated as higher, moderate, or lower risk (i.e., red/amber/green) for each of the *individual* habitat pressure indicators evaluated (see Table 14, Table 15, and Table 16); and

3. the *cumulative* risk scores (total and area-weighted total) for each CU's rearing/migration ZOI (see Table 17) based on pressure indicator roll-up rules.

Spawning (Chinook, chum, coho, pink and river sockeye): Our assessment indicated that many habitats associated with spawning for these species are experiencing some impacts, with all but one CU (Chum – Portland Inlet) having at least one watershed within their spawning ZOIs rated as being at higher risk from cumulative habitat pressures (Table 4).

On a percentage basis the *worst* rated CUs for *cumulative habitat pressures* across the different species CUs were:

- **Chinook** – Upper Nass CU with 44% of the 80 watersheds in the spawning ZOI rated higher risk and 33% rated moderate risk;
- **chum** – Lower Nass CU with 35% of the 17 watersheds in the spawning ZOI rated higher risk and 47% rated moderate risk;
- **coho** – Lower Nass CU with 33% of the 30 watersheds in the spawning ZOI rated higher risk and 50% rated moderate; Upper Nass CU with 37% of the 43 watersheds in the spawning ZOI rated higher risk and 40% rated moderate risk;
- **pink** – Upper Nass CUs (both odd and even, which cannot be differentiated within this habitat analysis) with 60% of the 5 watersheds in the spawning ZOI rated higher risk and other 40% rated moderate risk;
- **river sockeye** - Upper Nass River CU with 62% of the 13 watersheds in the spawning ZOI rated higher risk and 23% rated moderate risk, Lower Nass-Portland CU with 50% of the 10 watersheds in the spawning ZOI rated higher risk and other 50% rated moderate risk.

The *best* rated CUs for **cumulative habitat pressures** across the different salmon species were:

- **Chinook** – Portland Sound-Observatory Inlet-Lower Nass CU with only 13% of the 69 watersheds within its spawning ZOI rated higher risk while 43% were rated lower risk
- **chum –** Portland Inlet CU with none of its 11 spawning ZOI watersheds rated higher risk and 64% of them rated lower risk; Portland Canal-Observatory CU with only 4% of its 27 spawning ZOI watersheds rated higher risk and 56% of them rated lower risk
- **coho –** Portland Sound-Observatory Inlet-Portland Canal CU with only 3% of the 40 watersheds within its spawning ZOI rated higher risk while 55% were rated lower risk
- **pink –** Nass Portland Observatory CU with only 13% of the 76 watersheds within its spawning ZOI rated higher risk while 45% were rated lower risk
- **river sockeye –** Both the Lower Nass-Portland and Upper Nass River CUs seem generally comparable with higher or moderate risk ratings for most of their spawning ZOI watersheds. The Upper Nass slightly better with 15% of its 13 spawning ZOI watersheds rated lower risk, whereas the lower Nass CU had no spawning ZOI watersheds rated lower risk.

Species CUs with notably higher percentages of watersheds in their spawning ZOIs with higher risk ratings (Table 5) for *individual habitat pressures* include:

- **Chinook** – Upper Nass CU (Land cover altered, Forest disturbance, Linear development, Stream crossing density, Forest stands defoliated)
- **chum** – Lower Nass CU (Land cover altered, Forest disturbed, Linear development, Stream crossing density, Forest stands defoliated; Portland Canal-Observatory (Mines, Stream crossing density, Forest stands defoliated)
- **coho** – Lower Nass CU (Land cover altered, Forest disturbed, Linear development, Stream crossing density, Forest stands defoliated); Upper Nass CU (Land cover altered, Forest disturbed, Linear development, Stream crossing density, Forest stands defoliated)
- **pink –** Upper Nass CU (odd and even) **-** Land cover altered, Forest disturbed, Linear development, Forest stands defoliated
- **river sockeye –** Lower Nass-Portland CU **(**Land cover altered, Forest disturbed, Mines, Linear development, Road density, Stream crossing density, Permitted water licenses, Forest stands defoliated); Upper Nass River CU (Land cover altered, Forest disturbed, Linear development, Riparian disturbance, Forest stands defoliated)

Species CUs with relatively high percentages of watersheds in their spawning ZOIs with lower risk ratings (Table 7) across *individual pressure* indicators include:

- **Chinook** – Portland Sound-Observatory Inlet-Lower Nass
- **chum** – Portland Canal-Observatory
- **coho** – Portland Sound-Observatory Inlet-Portland Canal
- **pink** – Nass-Skeena Estuary (even); Nass-Portland Observatory (odd)
- **river sockeye** – Lower Nass-Portland

Rearing/migration (Chinook, chum, coho, pink and river sockeye): The area-weighted total cumulative risk scoring for CU rearing/migration (Table 17) suggests that the species CUs experiencing the greatest relative amount of overall habitat pressure within their combined rearing/migration ZOIs were Chinook – Portland Sound-Observatory Inlet-Lower Nass CU and Upper Nass CU (both with scores = 2.76); chum – lower Nass (score = 4.04); coho – lower Nass (score = 4.04); pink – Upper Nass (even and odd) (score = 4.74); river sockeye – Upper Nass River (score = 2.89).

Table 13 The percentage of watersheds in the spawning "zone of influence" (ZOI)11 for each Nass salmon Conservation Unit (CU) that are rated as being at relatively higher, moderate, or lower risk from "cumulative" habitat impacts. Cumulative risk is based on a composite risk scoring roll-up rule set using the identified individual risk status for seven habitat pressure Impact Categories: Hydrological Processes, Vegetation Quality, Surface Erosion, Fish Passage/Habitat Connectivity, Water Quantity, Human Development Footprint, and Water Quality. Habitat pressures in the spawning ZOI will act on both summer spawning and winter egg incubation life history stages.

Species	CU Name	ZOI area (km^2)	Watersheds in spawning ZOI (# of)	Higher-risk Watersheds (%)	Moderate-risk Watersheds (%)	Lower-risk Watersheds (%)
Chinook	Portland Sound-Observatory Inlet-Lower Nass	3716.7	69	13%	43%	43%
Chinook	Upper Nass	4211.4	80	44%	33%	24%
Chum	Portland Inlet	764.0	11	0%	36%	64%
Chum	Lower Nass	879.4	17	35%	47%	18%
Chum	Portland Canal-Observatory	1355.0	27	4%	41%	56%
Coho	Lower Nass	1645.8	30	33%	50%	17%
Coho	Upper Nass	2640.6	43	37%	40%	23%
Coho	Portland Sound-Observatory Inlet-Portland Canal	2271.2	40	3%	43%	55%
Pink (even)	Nass-Skeena Estuary	8914.4	184	31%	40%	29%
Pink (even)	Upper Nass	397.7	5	60%	40%	0%
Pink (odd)	Nass-Portland-Observatory	4057.0	76	13%	42%	45%
Pink (odd)	Upper Nass	397.7	5	60%	40%	0%
Sockeye-River	Lower Nass-Portland	466.2	10	50%	50%	0%
Sockeye-River	Upper Nass River	738.0	13	62%	23%	15%

[11] Note that for the Nass-Skeena Estuary Pink (even) CU the spawning ZOI also includes areas of the Skeena drainage

Table 14 The percentage of watersheds in the spawning "zone of influence" (ZOI) for each Nass salmon Conservation Unit (CU) that were identified as relatively higher risk (red rating) for each of the individual habitat pressure indicators evaluated. Habitat pressures in the spawning ZOI will act on both summer spawning and winter egg incubation life history stages.

Species	CU Name	Watersheds in spawning ZOI (# of)	Land cover altered (%)	Forest disturbed (%)	Impervious surface (%)	Mines (total #)	Linear development (km/km²)	Road density (km/km²)	Stream crossing density (#/km)	Permitted water licenses (#)	Riparian disturbance (%)	Waste water discharge sites (#)	ECA (%)	Forest stands defoliated (%)
Chinook	Portland Sound-Observatory Inlet-Lower Nass	69	13%	14%	0%	12%	13%	6%	13%	6%	10%	0%	0%	67%
Chinook	Upper Nass	80	43%	48%	0%	0%	53%	14%	34%	5%	25%	0%	0%	79%
Chum	Portland Inlet	11	0%	9%	0%	0%	9%	0%	9%	9%	0%	0%	0%	45%
Chum	Lower Nass	17	29%	29%	0%	6%	41%	6%	35%	18%	12%	0%	0%	100%
Chum	Portland Canal-Observatory	27	0%	0%	0%	41%	0%	0%	30%	7%	0%	0%	0%	52%
Coho	Lower Nass	30	30%	33%	0%	3%	37%	13%	27%	17%	17%	0%	0%	97%
Coho	Upper Nass	43	40%	42%	0%	0%	42%	7%	35%	2%	19%	0%	0%	81%
Coho	Portland Sound-Observatory Inlet-Portland Canal	40	0%	0%	0%	28%	3%	0%	18%	10%	0%	0%	0%	58%
Pink (even)	Nass-Skeena Estuary	184	11%	10%	0%	8%	29%	8%	20%	49%	5%	42%	4%	60%
Pink (even)	Upper Nass	5	60%	80%	0%	0%	80%	20%	20%	0%	20%	0%	0%	100%
Pink (odd)	Nass-Portland-Observatory	76	14%	16%	0%	12%	14%	4%	17%	12%	9%	0%	0%	70%
Pink (odd)	Upper Nass	5	60%	80%	0%	0%	80%	20%	20%	0%	20%	0%	0%	100%
Sockeye-River	Lower Nass-Portland	10	50%	50%	0%	30%	60%	40%	60%	30%	20%	0%	0%	100%
Sockeye-River	Upper Nass River	13	69%	69%	0%	0%	69%	23%	23%	0%	38%	0%	0%	92%

Table 15 The percentage of watersheds in the spawning "zone of influence" (ZOI) for each Nass salmon Conservation Unit (CU) that were identified as relatively moderate risk (amber rating) for each of the individual habitat pressure indicators evaluated. Habitat pressures in the spawning ZOI will act on both summer spawning and winter egg incubation life history stages.

Species	CU Name	Watersheds in spawning ZOI (# of)	Land cover altered (%)	Forest disturbed (%)	Impervious surface (%)	Mines (total #)	Linear development (km/km²)	Road density (km/km²)	Stream crossing density (#/km)	Permitted water licenses (#)	Riparian disturbance (%)	Waste water discharge sites (#)	ECA (%)	Forest stands defoliated (%)
Chinook	Portland Sound-Observatory Inlet-Lower Nass	69	54%	39%	4%	0%	48%	12%	32%	0%	12%	0%	0%	0%
Chinook	Upper Nass	80	38%	23%	3%	0%	25%	43%	31%	0%	30%	0%	0%	0%
Chum	Portland Inlet	11	45%	36%	0%	0%	27%	9%	27%	0%	36%	0%	0%	0%
Chum	Lower Nass	17	71%	59%	0%	0%	53%	53%	47%	0%	29%	0%	0%	0%
Chum	Portland Canal-Observatory	27	52%	26%	0%	0%	44%	0%	7%	0%	4%	0%	0%	0%
Coho	Lower Nass	30	67%	53%	7%	0%	53%	33%	50%	0%	20%	0%	0%	0%
Coho	Upper Nass	43	44%	28%	5%	0%	35%	42%	37%	0%	30%	0%	0%	0%
Coho	Portland Sound-Observatory Inlet-Portland Canal	40	58%	38%	0%	0%	48%	3%	18%	0%	18%	0%	0%	0%
Pink (even)	Nass-Skeena Estuary	184	59%	60%	3%	0%	42%	27%	16%	0%	10%	0%	2%	0%
Pink (even)	Upper Nass	5	40%	20%	0%	0%	20%	80%	80%	0%	80%	0%	0%	0%
Pink (odd)	Nass-Portland-Observatory	76	55%	38%	1%	0%	46%	14%	25%	0%	14%	0%	0%	0%
Pink (odd)	Upper Nass	5	40%	20%	0%	0%	20%	80%	80%	0%	80%	0%	0%	0%
Sockeye-River	Lower Nass-Portland	10	50%	40%	20%	0%	40%	20%	40%	0%	40%	0%	0%	0%
Sockeye-River	Upper Nass River	13	23%	15%	15%	0%	15%	54%	54%	0%	31%	0%	0%	0%

Table 16 The percentage of watersheds in the spawning "zone of influence" (ZOI) for each Nass salmon Conservation Unit (CU) that were identified as relatively lower risk (green rating) for each of the individual habitat pressure indicators evaluated. Habitat pressures in the spawning ZOI will act on both summer spawning and winter egg incubation life history stages.

Species	CU Name	Watersheds in spawning ZOI (# of)	Land cover altered (%)	Forest disturbed (%)	Impervious surface (%)	Mines (total #)	Linear development (km/km²)	Road density (km/km²)	Stream crossing density (#/km)	Permitted water licenses (#)	Riparian disturbance (%)	Waste water discharge sites (#)	ECA (%)	Forest stands defoliated (%)
Chinook	Portland Sound-Observatory Inlet-Lower Nass	69	33%	46%	96%	88%	39%	83%	55%	94%	78%	100%	100%	33%
Chinook	Upper Nass	80	20%	30%	98%	100%	23%	44%	35%	95%	45%	100%	100%	21%
Chum	Portland Inlet	11	55%	55%	100%	100%	64%	91%	64%	91%	64%	100%	100%	55%
Chum	Lower Nass	17	0%	12%	100%	94%	6%	41%	18%	82%	59%	100%	100%	0%
Chum	Portland Canal-Observatory	27	48%	74%	100%	59%	56%	100%	63%	93%	96%	100%	100%	48%
Coho	Lower Nass	30	3%	13%	93%	97%	10%	53%	23%	83%	63%	100%	100%	3%
Coho	Upper Nass	43	16%	30%	95%	100%	23%	51%	28%	98%	51%	100%	100%	19%
Coho	Portland Sound-Observatory Inlet-Portland Canal	40	43%	63%	100%	73%	50%	98%	65%	90%	83%	100%	100%	43%
Pink (even)	Nass-Skeena Estuary	184	30%	30%	97%	92%	29%	65%	64%	51%	85%	58%	94%	40%
Pink (even)	Upper Nass	5	0%	0%	100%	100%	0%	0%	0%	100%	0%	100%	100%	0%
Pink (odd)	Nass-Portland-Observatory	76	30%	46%	99%	88%	39%	82%	58%	88%	76%	100%	100%	30%
Pink (odd)	Upper Nass	5	0%	0%	100%	100%	0%	0%	0%	100%	0%	100%	100%	0%
Sockeye-River	Lower Nass-Portland	10	0%	10%	80%	70%	0%	40%	0%	70%	40%	100%	100%	0%
Sockeye-River	Upper Nass River	13	8%	15%	85%	100%	15%	23%	23%	100%	31%	100%	100%	8%

Table 17 Total cumulative risk scoring for habitat in the rearing/migration "zone of influence" (ZOI)12 for each Nass salmon Conservation Unit (CU). Cumulative risk across the rearing/migration ZOI is based on a summation of watershed scores for each of the seven habitat pressure Impact Categories: Hydrological Processes, Vegetation Quality, Surface Erosion, Fish Passage/Habitat Connectivity, Water Quantity, Human Development Footprint, and Water Quality. A higher-risk Impact Category is scored as 2, a moderate-risk Impact Category is scored as 1, and a lower risk Impact Category in scored as 0. Maximum cumulative risk score for an individual watershed = 14. Maximum area-weighted total cumulative risk score for a CU is also 14.

Species	CU Name	ZOI area (km^2)	Watersheds in ZOI (# of)	Total cumulative risk score across rearing/migration ZOI watersheds	Area-weighted total cumulative risk score across rearing/migration ZOI watersheds
Chinook	Portland Sound-Observatory Inlet-Lower Nass	10043.0	213	778	2.76
Chinook	Upper Nass	19318.1	383	1277	2.76
Chum	Portland Inlet	9975.5	207	755	2.79
Chum	Lower Nass	4356.8	85	428	4.04
Chum	Portland Canal-Observatory	9602.1	201	750	2.88
Coho	Lower Nass	4356.8	85	428	4.04
Coho	Upper Nass	18700.9	370	1258	2.83
Coho	Portland Sound-Observatory Inlet-Portland Canal	9975.5	207	755	2.79
Pink (even)	Nass-Skeena Estuary	24742.2	537	2375	3.63
Pink (even)	Upper Nass	8049.9	160	893	4.74
Pink (odd)	Nass-Portland-Observatory	10715.6	222	803	2.67
Pink (odd)	Upper Nass	7994.6	160	893	4.74
Sockeye-River	Lower Nass-Portland	9763.5	202	750	2.83
Sockeye-River	Upper Nass River	17456.5	348	1203	2.89

[12] Note that for the Nass-Skeena Estuary Pink (even) CU the rearing/migration ZOI also includes areas of the Skeena drainage

3.3 Integrated Cumulative Habitat Pressures/Vulnerability

Figure 5 present for the different Nass salmon species (lake sockeye, river sockeye, Chinook, coho, chum, and pink respectively) the integrated assessments of relative CU habitat status for different life-history stages, based on a combination of: (1) the intrinsic habitat vulnerability to potential impacts (based on quantified measures of habitat quantity and/or quality), and (2) the cumulative intensity of various human stresses on those habitats. CUs in the lower left corner of each figure would be considered to have good relative habitat status for that particular life history stage, experiencing both relatively lower cumulative habitat pressures and relatively lower vulnerability to the impacts of those pressures. Conversely, CUs located in the upper right of each figure would be considered to have poor relative habitat status for that life-history stage, experiencing both relatively higher cumulative habitat pressures and relatively higher vulnerability to the impacts of those pressures (e.g. Clements and Leverson lake sockeye CUs for migration in Figure 5 below). Conversely, CUs located in the upper right of each figure would be considered to have relatively poor relative habitat status, experiencing higher cumulative habitat pressures and higher vulnerability to the impacts of those pressures (e.g. Owegee lake sockeye CU for spawning in Figure 5 below).

Note that the integrated pressure/vulnerability analyses presented here are fairly crude, relying on a small set of quantifiable indicators (for example lake size was the only metric of CU rearing lake vulnerability currently available for use across all lake sockeye CUs for this comparison) and are intended only as a first cut visualization of the potential differences in *relative CU habitat status* based on our derived measures of habitat pressures and vulnerabilities across CUs, so should not be taken to infer actual CU habitat condition (assessment of which would require extensive field-based investigation).

Nass Lake Sockeye CUs

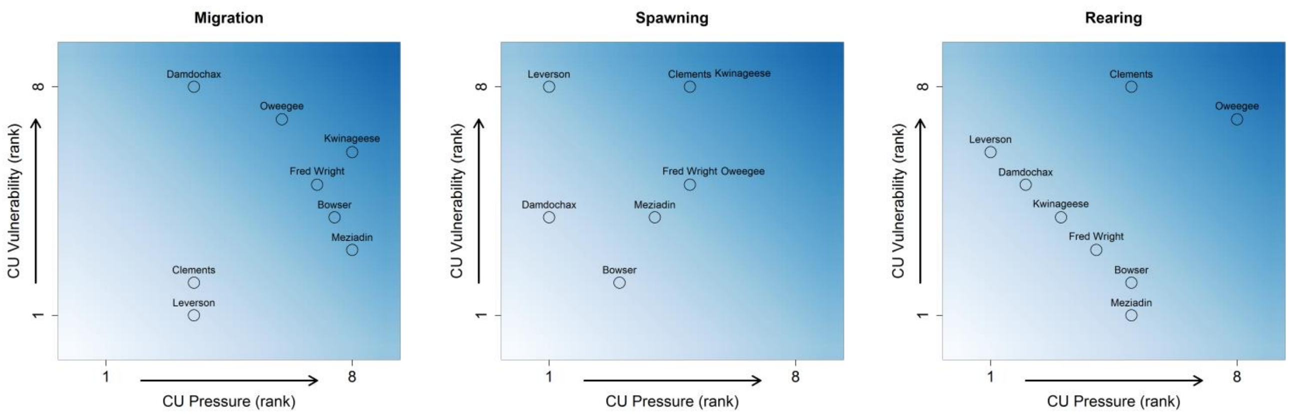

Figure 5 Integrated cumulative habitat pressure CU rankings vs. habitat vulnerability CU rankings for the different life-history stage (migration, spawning and rearing) zones of influence (ZOIs) across the Nass lake sockeye CUs. Colour intensification indicates general increasing CU rankings along either and both of the two figure axes (lower to higher relative rankings).

Nass River Sockeye CUs

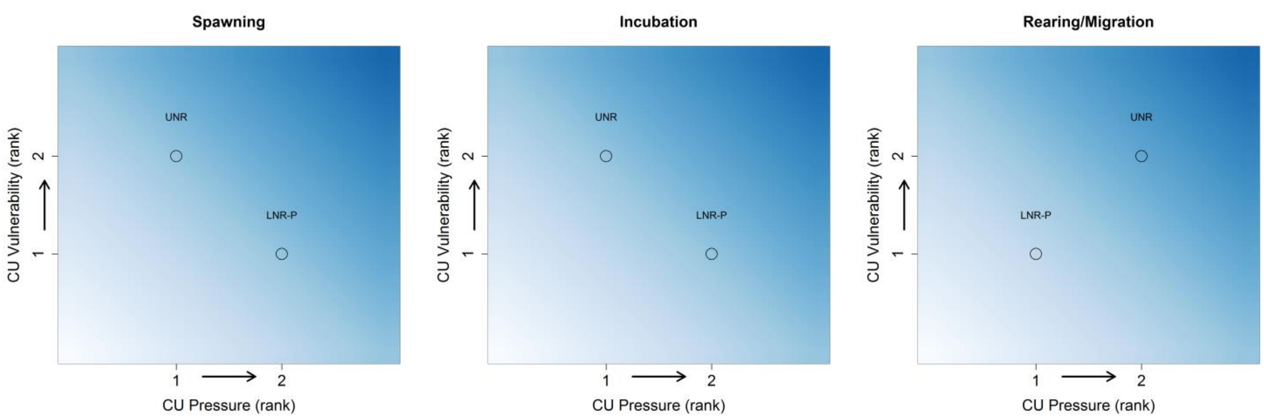

Figure 6 Integrated cumulative habitat pressure CU rankings vs. habitat vulnerability CU rankings for the different life history stages (spawning, incubation, rearing/migration) across Nass river sockeye CUs. Colour intensification indicates general increasing CU rankings along the axes (lower to higher relative rankings). The ranking position of the two Nass river sockeye CUs relative to each other is identified in the figure by the code: Upper Nass River = UNR, Lower Nass River-Portland = LNR-P.

Nass Chinook CUs

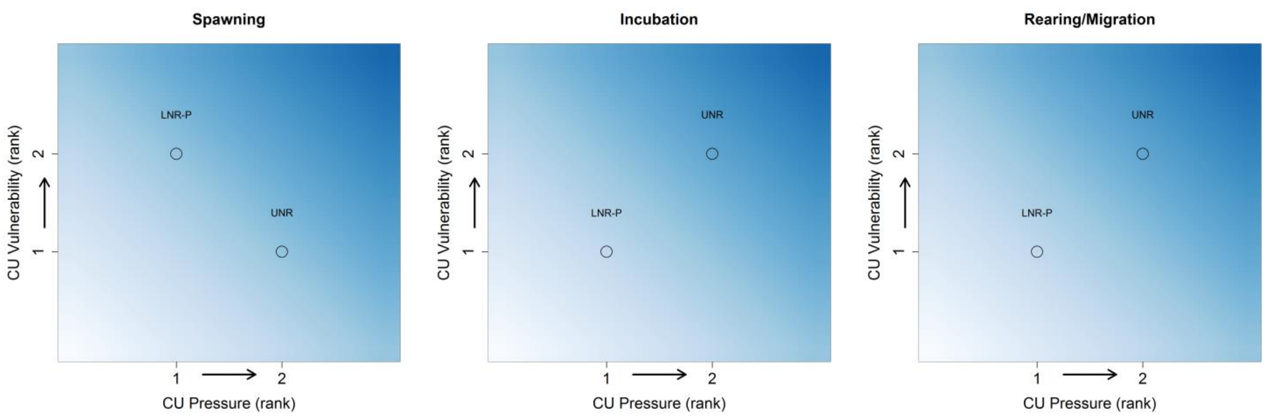

Figure 7 Integrated cumulative habitat pressure CU rankings vs. habitat vulnerability CU rankings for the different life history stages (spawning, incubation, rearing/migration) across Nass Chinook CUs. Colour intensification indicates general increasing CU rankings along the axes (lower to higher relative rankings). The ranking position of the two Nass Chinook CUs relative to each other is identified in the figure by the code: Upper Nass River = UNR, Portland Sound-Observatory Inlet-Lower Nass = LNR-P.

Nass Coho CUs

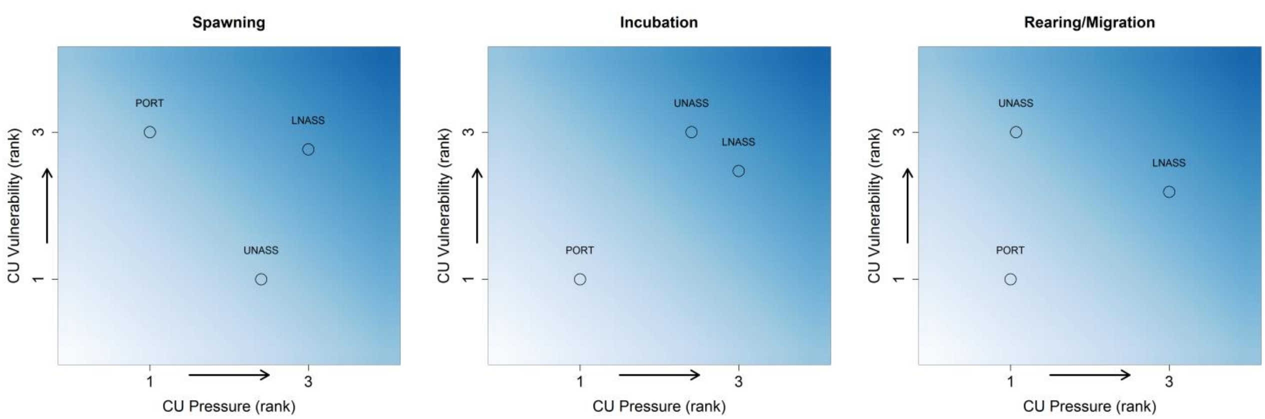

Figure 8 Integrated cumulative habitat pressure CU rankings vs. habitat vulnerability CU rankings for the different life history stages (spawning, incubation, rearing/migration) across Nass coho CUs. Colour intensification indicates general increasing CU rankings along the axes (lower to higher relative rankings). The ranking position of the three Nass coho CUs relative to each other is identified in the figure by the code: Upper Nass River = UNASS, Lower Nass River = LNASS, Portland Sound-Observatory Inlet-Portland Canal = PORT.

Nass Chum CUs

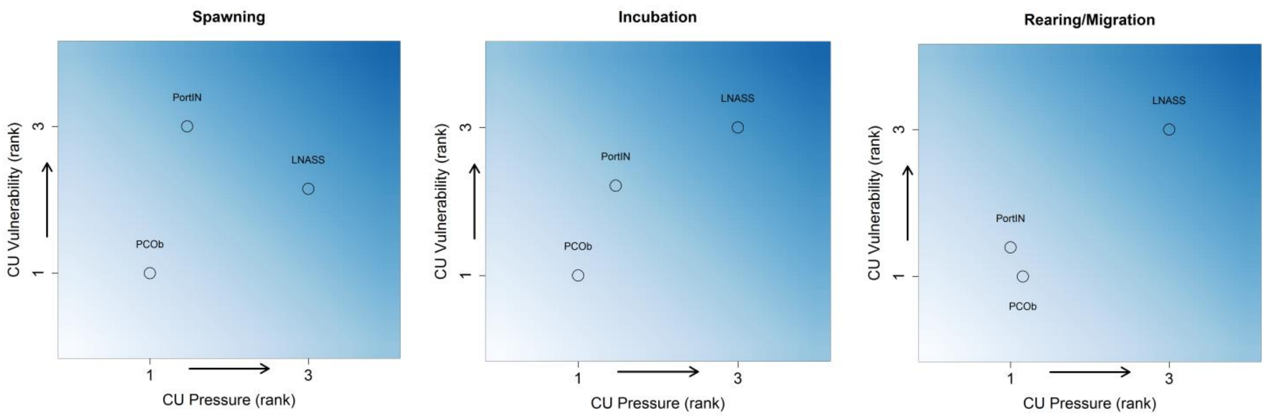

Figure 9 Integrated cumulative habitat pressure CU rankings vs. habitat vulnerability CU rankings for the different life history stages (spawning, incubation, rearing/migration) across Nass chum CUs. Colour intensification indicates general increasing CU rankings along the axes (lower to higher relative rankings). The ranking position of the three Nass chum CUs relative to each other is identified in the figure by the code: Portland Inlet = PortIn, Lower Nass = LNASS, Portland Canal-Observatory = PCOb.

Nass Pink CUs

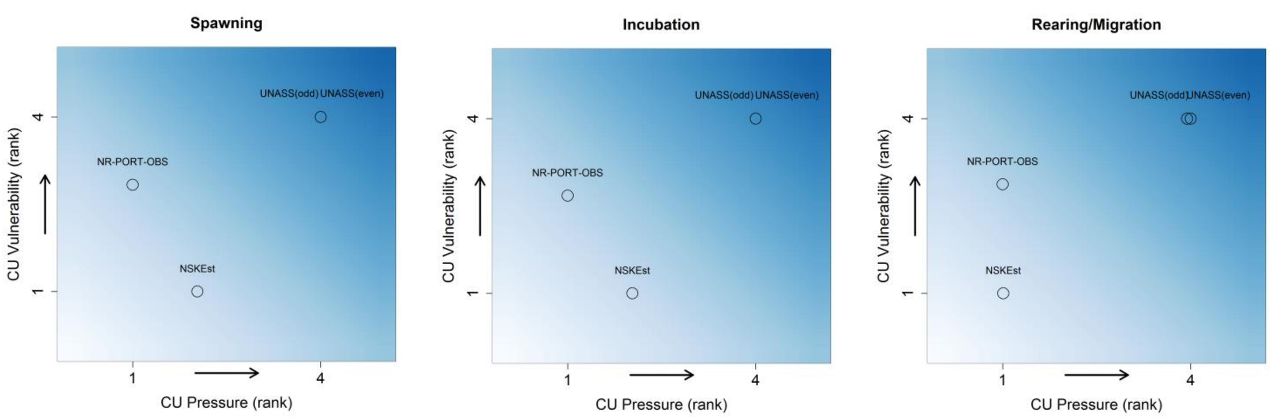

Figure 10 Integrated cumulative habitat pressure CU rankings vs. habitat vulnerability CU rankings for the different life history stages (spawning, incubation, rearing/migration) across Nass pink CUs. Colour intensification indicates general increasing CU rankings along the axes (lower to higher relative rankings). The ranking position of the four river pink CUs relative to each other is identified in the figure by the code: Upper Nass (even) = UNASS (even), Upper Nass (odd) = UNASS (odd), Nass-Portland-Observatory (odd) = NR-PORT-OBS, Nass-Skeena Estuary (even) = NSkEST.

3.4 Habitat Pressures (Future)

Locations of varied proposed development activities (i.e., coal and mineral mines, water licenses, timber harvest land base, power tenures, pipelines, transmission lines) in the Nass and Skeena basins[13] that could have potential future effects on salmon CU habitats were identified and mapped/quantified (i.e., total number, length, or area of activities) (see Figure 11).

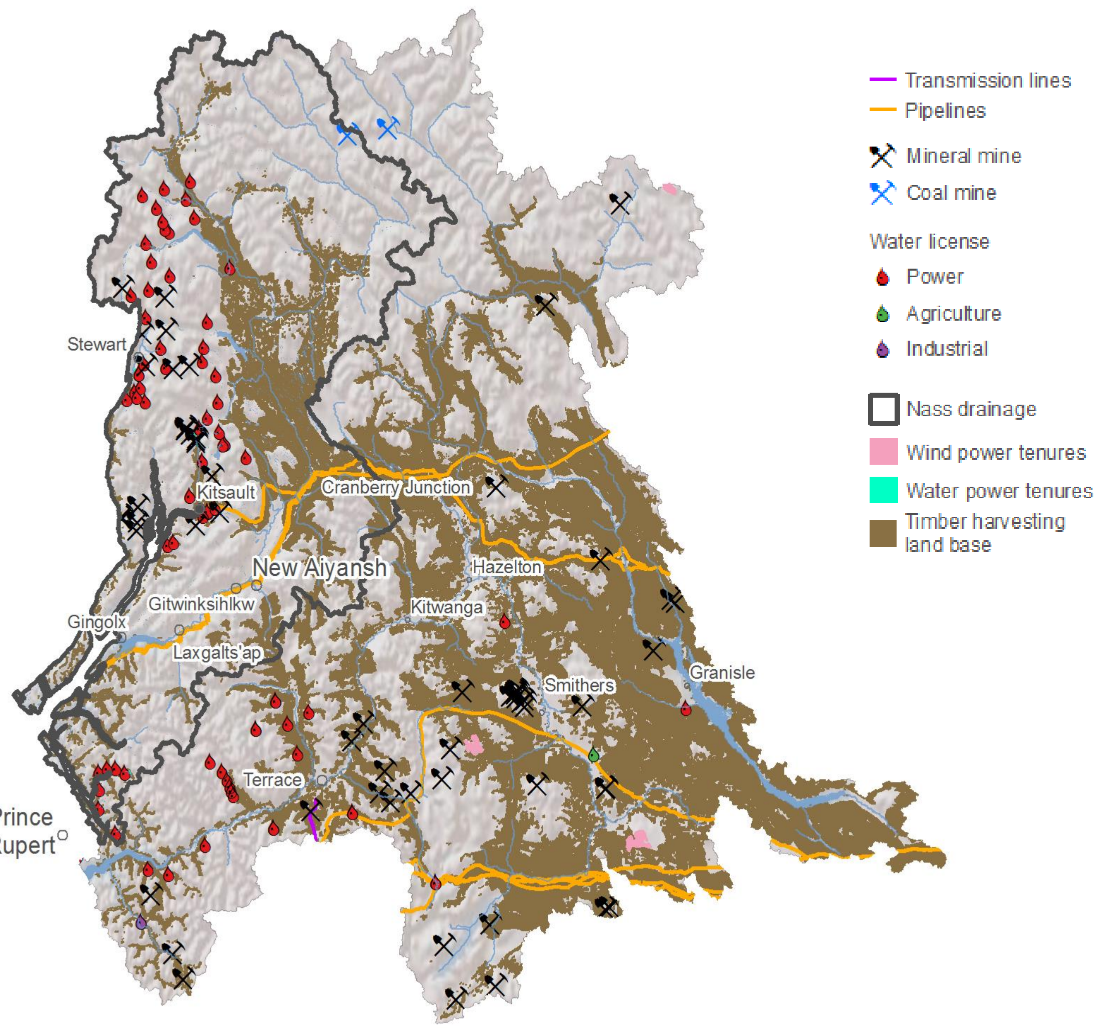

Figure 11 Proposed future development activities (as of 2016) identified for the Nass and Skeena basins.

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[13] Future habitat impacts in the Skeena basin could be of relevance to the Nass-Skeena Estuary Pink (even) CU as the spatial extent of this CU includes areas of both the Nass and Skeena drainages.

4 Summary and Recommendations

Freshwater habitats are known to contribute to the overall diversity and resilience of salmon (Bisson et al. 2009; Healey 2009). Thus protecting freshwater habitats is important to the conservation of Nass Area salmon CUs. There are significant information gaps, however, which hinder the ability to effectively manage habitats for Nass salmon CUs and the human activities that can potentially impact them. To improve our understanding about habitat status across Nass salmon CUs, monitoring of habitat pressure and state indicators needs to be undertaken in a consistent manner on a regular basis across Nass rivers, streams, and nursery lakes.

Traditionally, habitat evaluations tend to focus on a particular area or issue (i.e. linkage to a specific habitat variable or stressor activity) in a particular location. While localized assessments of habitat conditions are invaluable they are not generally amenable to broad synoptic overviews of relative habitat condition across CU watersheds. Broad scale habitat evaluations of landscape-level habitat pressures, such as was developed for this project, can provide useful supporting information and a framework for more general comparisons of the status and trends of habitats used by salmon CUs, if methodologies are repeated. Expanded, well-designed field-based monitoring of key habitat state indicators within representative Nass Area watersheds will however remain critical for improving the quality of information available for any future reporting efforts and to allow reliable inferences as to the implied status of habitats used by salmon CUs across the Nass drainage.

To improve understanding about the effects of human stressors on freshwater habitats, there is a need to develop more precise estimates of the consequences of increasing habitat pressures. A key part of this is developing more defensible pressure indicator benchmarks. For most landscape pressures the general mechanisms of effects on freshwater habitats are known, but estimates of the significance of a given pressure level are crude, especially when individual pressures occur in combination with other types of pressure (natural or anthropogenic). Attempts to consistently define habitat pressure benchmarks have arguably had limited success (e.g. determining reliable ECA thresholds), but their delineation is a key requirement for more defensible decision making at landscape scales. For analyses undertaken for this project many of the habitat indicator benchmarks of concern were based simply on the distribution and associated relative ranking of pressure indicator values across the Nass drainage, rather than hard science/expert based benchmarks. While benchmarking based on relative ranking (with statistically defined breakpoints) represents a viable interim approach, there are major shortcomings (e.g. the analyses must be redone if the distribution of watersheds within CU ZOIs is revised; it is uncertain whether watersheds categorized as lower risk are truly not at risk of adverse effects at these indicator values, or conversely whether watersheds rated as higher risk are actually at significant risk). There is a need for both broad provincial and Nass regionally-focused exercises to identify "hard" values for benchmarks of concern for habitat pressure indicators, relying on either further evaluation of the science and/or expert–based opinion exercises/workshops. Such undertakings are not trivial (see Lanigan et al. 2012 for an example of expert-opinion workshops being used for defining regional habitat benchmarks for the Pacific Northwest), but if integrated across different regional and provincial agencies would help improve monitoring of cumulative effects on salmon habitats and that of other biota.

To improve our understanding of the salmon population-level effects of changes to freshwater habitats, there is a corresponding need for more precise estimates of the biological consequences (e.g. effects on fish growth, survival, productivity, etc.) as a function of changes in habitat state/condition. Once available, this information could be used to model the "environmental envelope" (e.g. Pearson et al. 2002; Hirzel and Arlettaz 2003) required for persistence of salmon in freshwater habitats so that future issues in the Nass might be better anticipated and avoided. Given the importance and extent of legislation and policies designed to govern land and water use, this gap is critical to fill. Without this information managers cannot ensure that policies are achieving their intended objectives of protecting freshwater habitats sufficiently to maintain healthy populations of salmon.

To improve transparency in science and related decision making, scientists, managers, and the public need information that is more accessible. There is a wide audience interested in the status of Nass Area salmon and their habitats. For improved access to information, better communication tools are needed to relay the status of salmon and their habitats. The CU habitat report cards developed for this project provide an example of condensing large quantities of information into a digestible summary to help inform local First Nations s, agencies and interested stakeholders on salmon habitat issues. The report cards themselves can be downloaded from the PSF's Skeena Salmon Program website (www.skeenasalmonprogram.ca), as will the core Nass derived habitat datasets assembled and analyzed for this project.

4.1 Future Improvements to Nass CU Habitat Report Cards

The habitat pressure indicators used for this report represent a broad suite of information that has been derived using currently available provincial and federal agency datasets and GIS layers/models. Local data provided by regional First Nations fisheries departments have greatly improved the quality and relevance of the current data compilation and analyses that have been undertaken (particularly in regards to improved mapping of species spawning distributions).

In addition, there are known data quality deficiencies with many of the datasets used to inform this project (e.g. accurate road densities, actual extent of historical logging, level of riparian disturbance) that may result in under-representation of the true extent of habitat degradation across the multiple watersheds within the Nass Area.

There are also deficiencies and data gaps in some of the biological information needed to better inform assessments of vulnerability to habitat pressures (e.g. lake productivity estimates, more comprehensive spawn mapping). Furthermore, many of the indicators used are captured for this analysis at a very crude level of resolution - simple presence/absence (0/1) categorizations (i.e., mines, wastewater discharges, water licenses). This is because more detailed information on the actual extent of impact footprint, potential contaminant discharges or actual water use at a site etc. may be uncertain or unknown. Any particular site could have the potential for causing habitat degradation but appropriate numerical scaling of this risk is difficult. One mine could, for example, be more damaging than a larger number of mines, depending on a range of underlying factors difficult to evaluate broadly; a single permitted wastewater discharge point may cause no real impact if well managed or could be highly damaging to habitat. Evaluating this requires much better information on what is happening at a site (i.e. contaminants released, water volumes used (rather than what has been permitted or allocated) and obtaining this requires better gauging and field-based monitoring, and tracking of both compliance issues and associated habitat state, something not broadly available at this time to support development of these CU report cards. Developing new or expanded field surveys across Nass Area CUs for key measures of actual habitat condition (e.g. water quality, fish passage, lake productivity, etc.) would be a key element to improve understanding of habitat/population interactions and increase the quality and relevance of any future CU habitat report cards.

Time series information for most habitat pressure indicators in the Nass Area is also generally lacking and was not something incorporated within the current Nass salmon CU habitat report cards. However, as advances are made both in the capture of remote-sensed information through satellite imagery and in improved data inventory systems, with associated development of supporting map-based products by provincial agencies (e.g. as part of planned support for the province's Cumulative Effects Framework currently in development), it should become increasingly more feasible in the future to undertake effective tracking of the changing status of various habitat pressure indicators at a variety of spatial resolutions across the Nass drainage.

The approaches taken in this project for aggregating habitat pressure indicators into cumulative risk scores for watersheds in CU life-stage-specific ZOIs (migration, spawning, rearing,) were similar to those used for scoring suites of indicators in other recent salmon habitat projects (e.g. Nelitz et al. 2011, Porter et al. 2013a; 2013b; 2014). These approaches to indicator aggregation/scoring should, however, be considered only a broad first-cut attempt at quantifying cumulative effects across suites of indicators in the Nass region. Further workshops should be undertaken, employing expert-based assessments of habitat impacts in selected watersheds in order to better calibrate and adjust "roll-up" rule sets for assessing cumulative risk based on aggregated indicator information. An example of this approach is the US

Forest Service's Aquatic and Riparian Effectiveness Monitoring Program, where a series of regional workshops were undertaken to develop regionally-specific habitat indicator weighting factors and roll-up rule sets to inform assessments of overall watershed condition (Lanigan et al. 2012). Continuing efforts in this regard will likely be part of the province's further development of their Cumulative Effects Framework (as part of the development of monitoring needs for the Framework's Aquatic Value) and it would be beneficial for Nations and stakeholders in the Nass region to engage and contribute to the thinking around such exercises.

Habitat risk across Nass salmon CUs was defined within this report based solely on the relative intensity/magnitude of habitat pressures. While it was presumed that this would reflect the potential threat of degradation of salmon habitats, actual risk to salmon populations is also dependent on CU-specific vulnerabilities/sensitivities to these habitat impacts. Vulnerability indicators for salmon are not identified specifically in Stalberg et al. 2009, but we identified a suite of potential indicators of lake sockeye CU life stage habitat vulnerabilities (measures of CU-associated habitat quantity and quality) as part of this report (building on the vulnerability indicators for sockeye salmon CUs used recently in the Cohen Commission analyses for examining sockeye response to freshwater impacts (Nelitz et al. 2011)). The assembled information on relative vulnerabilities was used in our analyses to assess the relative (ranked) habitat status for each CU and life history stage (based on an integration of cumulative habitat pressures and habitat vulnerabilities). However this is admittedly only a crude starting point for such discussions. Further work is needed through engagement with regional First Nations and provincial and federal agencies to identify additional vulnerability indicators that might be used to more fully capture and compare the potential vulnerabilities of Nass salmon CUs to habitat impacts and to determine how to incorporate them into expanded and improved CU habitat risk scoring approaches.

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Appendices

Appendix 1. List of twenty-two Nass salmon Conservation Units (CUs) evaluated for this project.

Species	CU name
Sockeye	Bowser (lake)
	Damdochax (lake)
	Fred Wright (lake)
	Kinageese (lake)
	Meziadin (lake)
	Oweegee (lake)
	Clements (lake)
	Leverson (lake)
	Lower Nass-Portland (river)
	Upper Nass River (river)
Chinook	Portland Sound-Observatory Inlet-Lower Nass
	Upper Nass
Coho	Lower Nass
	Upper Nass
	Portland Sound-Observatory Inlet-Portland Canal
Chum	Portland Inlet
	Lower Nass
	Portland Canal-Observatory
Pink	Upper Nass (even)
	Nass-Skeena Estuary (even)
	Nass-Portland-Observatory (odd)
	Upper Nass (odd)

Appendix 2. List of databases and GIS layers used or created for this project and the associated processing steps undertaken for development and quantification of habitat indicators.

Pressure Indicators[14]						
Spatial Scale	**Indicator**	**Input Data**	**Input Attributes/Features Used**	**Processing**	**Outputs**	**Notes**
Watersheds / CU ZOIs	Forest Disturbance	Provincial Consolidated Cutblocks layer (combination of VRI, LANDSAT, RESULTS, and FTEN)	Forestry land cover polygons – created as part of the total land cover alteration indicator. See total land cover alteration indicator for details.	Forestry polygons were overlaid with the watersheds layer, and total forested area per watershed was calculated.	Watershed layer identifying the percent of watershed logged for each watershed.	See total land cover alteration.
	Equivalent clear-cut area - ECA	VRI, LANDSAT, DRA, FTEN, RESULTS, LCC2000-V, NTS, Crown Tenure (Utility Corridors and Right of Ways)	VRI – PROJ_HEIGHT_1 Urban land cover polygons – Forestry land cover polygons – Road polygon features – Rail polygon features – Utility/ROW corridor land cover polygons – created as part of the total land cover alteration indicator. See total land cover alteration indicator for details.	All urban, road, rail and utility polygons were merged and dissolved into one single 'alienated' layer and overlaid with the watersheds layer. Forestry polygons were combined (union process) with the alienated layer. The growth recovery of each forested/alienated polygon was calculated using the following equation: $ECA = A \cdot C\,(1 - R/100)$ where A is the original polygon area, C is the proportion of the opening covered by functional regeneration (determined from Table A2.1, MOF 2001), and R is the recovery factor determined by the VRI projected height and Table A2.2	Watershed layer identifying the percentage ECA for each watershed.	See total land cover alteration.

[14] Note that for the pressure indicators worked up for Skeena watersheds that were included in the Nass-Skeena Estuary Pink (even) workup the datasets and processing steps used are provided in the earlier PSF reports for the Skeena drainage (Porter et al. 2013b; 2014).

				(MOF 2001). For developed polygons, there is no functional regeneration or recovery factor, so for these polygons C will be equal to 1 and R will be equal to 0. Forestry polygons from RESULTS and FTEN have no tree height attribute, so these polygons were assumed to have a height of 0 m. All ECA values were summed for each watershed and divided by the total watershed area to give an ECA percentage.		
	Insect and disease defoliation	VRI	DEAD_STAND_VOLUME_125 DEAD_STAND_VOLUME_175 DEAD_STAND_VOLUME_225 LIVE_STAND_VOLUME_125 LIVE_STAND_VOLUME_175 LIVE_STAND_VOLUME_225	VRI were overlaid (identity process) with the watersheds layer. VRI polygons' dead and live stand volumes were summarized by watershed, using the maximum value in the 3 dead/live volume utility levels for each stand. Percentage of stand killed was calculated as (sum of dead stand volume) / (sum of dead stand volume + sum of live stand volume).	Watershed layer identifying the percentage of stand killed by insect and disease for each watershed.	Note: Conversion of live standing volume to dead volume in the VRI follow predictions made using the provincial MPB model and the 2010 aerial overview surveys.
	Riparian disturbance[151]	Total Land Cover Alteration (below) restricted to riparian zone, FWA (streams, lakes, wetlands), MTS Consulting (2011)	Total land cover alteration input features – See total land cover alteration indicator for details. Streams – FTRCD 'GA24850000' – River/Stream - Definite 'GA24850140' – River/Stream – Indefinite 'GA24850150' – River/Stream – Intermittent *'GA08800110' – Ditch *'GA0395000' – Canal Rivers – FTRCD 'GA24850000' – River/Stream - Definite	A layer representing the riparian zone (30 m buffer around streams and water bodies) for the study area was created. Stream Features were buffered by 30 m (*only ditch and canal features that intersected the streams were buffered, i.e., isolated ditches and canals were not buffered). An overlay (identity process) was performed using the buffered stream features and the watershed layer. The resulting layer was dissolved by watershed ID. Lake and wetland features were merged into one layer and buffered by 30 m (*Lakes and wetlands isolated from the stream network were not	Watershed layer identifying the total altered riparian zone for each watershed.	See total land cover alteration notes.

[15] Indicator based on a modified version of the output and methodology developed by MTS Consulting, Victoria, BC, December 2011.

			Lakes – <u>WTRBDTP</u> *'L' – Lake Wetlands – <u>WTRBDTP</u> *'W' – Wetland ** See processing notes*	buffered). Buffer features resulting from 'islands' or 'donuts' in the water bodies were removed. Prior to buffering lakes and wetlands, all features in those layers coincident with stream arcs FTRCD WA24111170 (isolated water bodies) were selected and extracted. The extracted isolated water bodies were overlaid with the stream network. Those features intersecting the streams were selected and added to the water body layer for buffering (this was done in case a water body had erroneously been tagged as 'isolated'). An overlay (identity process) was performed using the buffered water body features and the watershed layer. The resulting layer was dissolved by watershed ID. River features were buffered by 30 m. As with water bodies, buffer features created around 'islands' or 'donuts' in the river polygon layer were removed. An overlay (identity process) was performed using the buffered river features and the watershed layer. The resulting layer was dissolved by watershed ID. The buffer layers for streams, water bodies and rivers were merged into one layer and dissolved by watershed ID. The resulting layer was overlaid (identity process) with the total land cover alteration layer. Riparian disturbance was summarized by area (hectares) and percentage of total riparian area per watershed.		

	Road development	DRA, FTEN	DRA all roads FTEN road segments	Roads were clipped using the watershed layer. FTEN road segments that don't appear in the DRA were extracted from FTEN by applying a 30 m buffer to DRA roads and selecting all FTEN roads outside of this buffer. The extracted FTEN roads were merged with the original DRA roads to produce a single comprehensive road layer. The road data was overlaid (identity process) with the watersheds. Road length was summarized by watershed and divided by watershed area to calculate road density per watershed (km/km2).	Watershed layer identifying road density for each watershed.	DRA and FTEN roads contain representations of the same roads but do not have identical geometries. The process of buffering the DRA to identify additional FTEN roads that don't appear in the DRA was a solution to produce a single road layer without duplicated roads. The resulting road layer is not, however, a topologically correct road network and shouldn't be used as one.
	Stream crossing density	BC MOE Fish Habitat layer, BC MOE Road Crossings	FishHabitat – <u>FISH_HABITAT</u> 'FISH HABITAT – INFERRED' 'FISH HABITAT – OBSERVED' '<NULL>' RoadStreamCrossings – <u>FISH_HABITAT</u> FISH HABITAT – INFERRED FISH HABITAT – OBSERVED <NULL>	Fish habitat arcs and stream crossing points were overlaid with the watersheds layer. Inferred and observed fish habitat was merged into a single 'fish habitat' group. A total number of fish habitat crossings per total length of habitat was calculated for each watershed.	Watershed layer identifying the total number of stream crossings per kilometer of fish habitat.	Note the fish habitat and stream crossings are based on modeled data. For more information on the accessible stream length input data contact Craig Mount at the BC Ministry of Environment.
	Number of water licenses (watersheds)	LMB Water License Points of Diversion	<u>LIC_STATUS</u> 'CURRENT' <u>PURPOSE</u>	POD data were clipped using watersheds. Only current licenses were used. The clipped point data were overlaid with watersheds (identity process). The total number of POD locations	Watershed layer identifying the total number of licenses	

			used for classification	was summarized by watershed. Licenses were also categorized into the following classes: power, domestic, agriculture, industrial, or storage.	within each watershed.	
	Total land cover alteration	LCC2000-V (agriculture, urban), VRI (forestry, fire, mining, urban), DRA (roads), FTEN (roads, forestry), LANDSAT (forestry), RESULTS (forestry), NTS (rail), Crown Tenure (Utility Corridors and Right of Ways), Current & Historical Fire Polygons (fire), BTM (mining)	LCC2000v – COVTYPE 120, 121, 122: agriculture 34: urban VRI – BCLCS_LEVEL_5 'RZ', 'RN', 'UR', 'AP': urban 'BU': fire 'GP', 'TZ', 'MI': mining EARLIEST_NONLOGGING_DIST_TYPE 'B*': fire Consolidated Cutblocks DISTURBANCE START DATE All polygons with a harvest date within last 60 years: forestry H_FIRE_PLY – FIRE_YEAR >= 1993: fire C_FIRE_PLY – All features: fire BTM - PLU_LABEL 'MINE': mining FTEN road segments – All features: roads DRA – All features: roads NMBRFLNS	Agriculture land cover was extracted from the LCC2000-V. Urban land cover was extracted from the LCC2000-V and merged with urban polygons extracted from the VRI. Forestry polygons were extracted from the Consolidated Cutblocks layer. Areas where logging had occurred greater than 60 years ago were not considered. The linear road features from the road development indicator were buffered by their corresponding road width, calculated as (number of lanes) * (8 m for freeways/highways or 5 m for everything else). Where the number of lanes attribute was not known (i.e., FTEN roads), the road was assumed to be 1 lane. Rail linear features were buffered by 4 m per track. Agriculture, urban, forestry, road, and rail polygons were merged with the crown tenure utility corridor/ROW polygons, fire (burnt areas) polygons, and mining area polygons. The resulting land cover layer was planarized; where different land cover class polygons overlapped, the following priority order was used to determine the land cover class of the overlapping area (highest priority first): road, rail, utility, forestry, urban, mine, fire, agriculture.	Watershed layer identifying the total altered land area for each watershed.	Users of these data should bear in mind that both VRI and LCC200-V have areas of no data. A 60 year cut off was used in selecting logged areas as after 60 years of forest regeneration there is negligible impact on the watershed from that logged area. Average road widths approximated from Transportation Association of Canada's Geometric Design Guide for Canadian Roads)

			ROAD_CLASS TA_CROWN_TENURES_SVW – All current utility tenures: utility NTS – ENTITYNAME "RAILWAY": rail	The final land cover class layer was overlaid with the watersheds. Total altered land area for any watershed is a sum of all land cover polygons in that watershed.		
	Impervious surfaces	LCC2000-V (agriculture, urban), VRI (urban), DRA (roads), FTEN (roads), NTS (rail)	Urban land cover polygons – Road polygon features – Rail polygon features – Agriculture land cover polygons – created as part of the total land cover alteration indicator. See total land cover alteration indicator for details.	Urban, road, rail, and agriculture polygons were combined (union process) and overlaid with the watersheds layer. An impervious surface coefficient (ISC) attribute was added to each polygon, representing the proportional area of that land cover that can be considered impervious. ISC values were calculated using the average ISC for land cover categories defined by Prisloe et al. 2003, for medium population density areas (>= 500 but < 1800 people per square mile). The following ISC values were applied to the area of each polygon: urban 0.19878, agriculture 0.0719, roads 1.0, rail 1.0. All ISC adjusted polygon areas were then summed to give the total impervious surface area for each watershed.	Watershed layer identifying the percent of watershed area covered by impervious surface for each watershed.	
	Linear development	DRA, FTEN, NTS	Linear road features – created as part of the road development indicator. See road development indicator for details. NTS – Pipelines, power lines, and rail features.	Roads, pipelines, power lines, and railway lines were combined into one linear feature layer. The linear features were overlaid with the watersheds layer and the sum of line length was calculated for each watershed. This length was then divided by the total watershed area to give a linear feature density (km/km^{2}) for each watershed.	Watershed layer identifying the density of linear development for each watershed.	
	Mining development - total # of mines	MEM & PR database	Mineral and coal mines from MINFILE – STATUS_D 'Developed Prospect', 'Past Producer', Producer COMMODIT_D	Developed prospects, past producing, and producing mineral and coal mines were extracted from MINFILE and combined with aggregate mines. Placer mine tenure polygons were converted to point features (center point),	Watershed layer identifying the total number of mines for each watershed.	

			'Coal' Aggregate mines from AGGINV04 and North Coast Aggregate Potential gravel pits. Placer mines from MTA_ACQ_TE_polygon – TNRTPDSCRP 'Placer'	with one point per unique placer mine. These mine point locations were then overlaid with the watersheds layer and the total number of mines calculated for each watershed.		
	Permitted waste water discharges	MOE Wastewater Discharge and Permits database	DischargeT 'effluent' Status 'Active'	Active waste water discharge locations (converted to spatial point features) were overlaid with the watersheds layer. The total number of discharge locations was summarized by watershed.	Watershed layer identifying the total number of discharge locations for each watershed.	
	Obstructions along migration route	FISS Obstructions layer, FWA Obstructions layers, CU Migration routes (see migration distance vulnerability indicator for details)	All FISS and FWA obstruction points.	FWA and FISS obstruction points were joined to the CU migration routes using the FWA watershed codes. Obstructions lying on the migration routes were selected. The total number of obstructions alone each migration route was calculated.	Table of CU migration routes and total number of obstructions along each route.	Although the FISS obstructions layer is based on the 1:50K Watershed Atlas, each point has the corresponding 1:20K FWA watershed code attributes associated with it.
Vulnerability Indicators						
Life Stage	**Indicator**	**Input Data**	**Input Attributes/Features Used**	**Processing**	**Outputs**	**Notes**
Rearing period (lake sockeye)	Area of nursery lake	DFO sockeye CUs	HECTARES	None required.	Table of CUs with nursery lake area for each CU.	
Spawning period (lake sockeye)	Salmon accessible habitat	MOE Fish Habitat Model (Version 2)	FishHabitat – FISH_HABITAT 'FISH HABITAT – INFERRED' (≤ 10% gradient) 'FISH HABITAT – OBSERVED' (≤ 10% gradient)	Salmon habitat arcs were overlaid with the CU boundaries. The sum of inferred and observed habitat length was calculated for each CU.	Table identifying the total length of accessible stream for each CU.	Note the salmon habitat data are based on modeled data. For more information on the accessible stream length input data

						contact Craig Mount at the BC Ministry of Environment.
	Total spawning length (mainstem, tributary & lake)	Sockeye spawning distribution (derived from FISS, regional FNs data)	SPECIES_NAME 'Sockeye' ACTIVITY 'spawning'	Spawning zones were overlaid with the CU lake ZOIs, and total length of spawning (mainstem, tributary and lake inlet, and lake shore) was calculated for each CU.	Table identifying the total length of spawning for each CU.	
	Tributary/lake inlet spawning length	Sockeye spawning distribution (derived from FISS, regional FNs data)	SPECIES_NAME 'Sockeye' ACTIVITY 'spawning'	Spawning zones were overlaid with the CU lake ZOIs, and total length of spawning (tributary and lake inlet spawning only) was calculated for each CU.	Table identifying the total length of tributary and lake inlet spawning for each CU.	
	Mainstem/lake outlet spawning length	Sockeye spawning distribution (derived from FISS, regional FNs data)	SPECIES_NAME 'Sockeye' ACTIVITY 'spawning'	Spawning zones were overlaid with the CU lake ZOIs, and total length of spawning (mainstem and lake outlet/influenced spawning only) was calculated for each CU.	Table identifying the total length of mainstem spawning for each CU.	
	Length of lake shore spawning areas	Sockeye spawning distribution (derived from FISS, regional FNs data)	SPECIES_NAME 'Sockeye' ACTIVITY 'spawning'	Lake spawning zones represented by polygons were converted to polylines to represent the lake shore length used for spawning. Spawning zones were overlaid with the CU lake ZOIs, and total length of spawning (lake shore spawning only) was calculated for each CU.	Table identifying the total length of lake shore spawning for each CU.	
	Ratio of lake-influenced spawning to total spawning	Sockeye spawning distribution (derived from FISS, regional FNs data)	Mainstem/lake outlet spawning and total spawning values – see indicator descriptions for details.	Mainstem/lake outlet spawning length was divided by total spawning length to get the ratio of lake-influenced spawning to total spawning for each CU lake ZOI.	Table of ratio values for each CU.	
Migration period (lake sockeye)	Migration distance	DFO designated nursery lakes, FWA stream network	FWA streams – CWB_WS_CD LOCL_WS_CD STREAM_ORD	Using the FWA watershed codes, the route downstream from each CU lake could be selected from the stream network. The following selection logic was used:	Table of migration route length for each CU.	The FWA stream network is not without errors, and using the

			EDGE_TYPE	For a point on the stream network immediately downstream of the lake:
				
				if LOCL_WS_CD & CWB_WS_CD are the same:
				("CWB_WS_CD" LIKE 'aaa-bbbbbb-cccccc-000000%' AND
				"LOCL_WS_CD" LIKE 'aaa-bbbbbb-cccccc-000000%' OR
				"CWB_WS_CD" LIKE 'aaa-bbbbbb-000000%' AND
				"LOCL_WS_CD" < 'aaa-bbbbbb-cccccc' OR
				"CWB_WS_CD" LIKE 'aaa-000000%' AND
				"LOCL_WS_CD" < 'aaa-bbbbbb') AND
				"LOCL_WS_CD" <> '' AND "STREAM_ORD" >= n AND "EDGE_TYPE" IN (1000,1050,1200,1250)
				
				if LOCL_WS_CD & CWB_WS_CD are different:
				("CWB_WS_CD" LIKE 'aaa-bbbbbb-cccccc-000000%' AND
				"LOCL_WS_CD" < 'aaa-bbbbbb-cccccc-[dddddd+1]' OR
				"CWB_WS_CD" LIKE 'aaa-bbbbbb-000000%' AND
				"LOCL_WS_CD" < 'aaa-bbbbbb-cccccc' OR
				"CWB_WS_CD" LIKE 'aaa-000000%' AND
				"LOCL_WS_CD" < 'aaa-bbbbbb') AND
				"LOCL_WS_CD" <> '' AND "STREAM_ORD" >= n AND "EDGE_TYPE" IN (1000,1050,1200,1250)
				
				The resulting stream segments were dissolved into a single line for each CU, and total line length was calculated.
						watershed codes to extract the downstream path resulted in a number of small gaps in the route which needed to be manually filled. Some additional stream segments joining on to the main route were also selected when using this logic (where wide rivers are represented by a complex route of constructor lines and secondary channels). These additional segments were manually removed from the migration routes.

	Migration route – length	BC MOE ecoregional flow	Flow sensitivity polygons	Flow sensitivity data were overlaid with the CU migration route lines. The sum of line length	Table of summer flow sensitive migration	

	summer flow sensitive	sensitivity mapping (R. Ptolemy, unpubl.), FWA	Migration route lines – see migration distance indicator for details.	within only the summer flow sensitive regions for each migration route was calculated.	length for each CU.	
	Migration route - % summer flow sensitive	BC MOE ecoregional flow sensitivity mapping (R. Ptolemy, unpubl.), FWA	Flow sensitivity polygons Migration route lines – see migration distance indicator for details.	Flow sensitivity data were overlaid with the CU migration route lines. The sum of line length within only the summer flow sensitive regions for each migration route was calculated as a percentage of the total migration route length.	Table of summer flow sensitive migration as a percentage of total migration length for each CU.	
Spawning period (river sockeye, Chinook, coho, chum, and pink)	Total spawning length	Spawning distributions for CUs of Chinook, coho, pink, chum, and river sockeye (derived from FISS, regional FNs data)	<u>SPECIES_NAME</u> 'Chinook, coho, pink, chum, or river sockeye' <u>ACTIVITY</u> 'spawning'	Spawning zones were overlaid with the CU spawning ZOIs, and total length of spawning was calculated for each CU.	Table identifying the total length of spawning for each CU.	
	Total spawning length – summer flow sensitive (km)	Total length of spawning reaches for each CU that are considered to be summer low flow sensitive	<u>SPECIES_NAME</u> 'Chinook, coho, pink, chum, or river sockeye' <u>ACTIVITY</u> 'spawning –total summer flow sensitive'	Spawning reaches were overlaid with the summer flow sensitive polygons and total length of summer flow sensitive spawning was calculated for each CU.	Table identifying the total length of summer flow sensitive spawning reaches for each CU.	
	Total spawning length – summer flow sensitive (%)	Percentage of spawning reaches for each CU that are considered to be summer low flow sensitive	<u>SPECIES_NAME</u> 'Chinook, coho, pink, chum, or river sockeye' <u>ACTIVITY</u> 'spawning –% summer flow sensitive'	Spawning reaches were overlaid with the summer flow sensitive polygons and % of summer flow sensitive spawning was calculated for each CU.	Table identifying the % of summer flow sensitive spawning reaches for each CU.	
Incubation period (river sockeye, Chinook, coho, chum, and pink)	Total spawning length – winter flow sensitive (km)	Total length of spawning reaches for each CU that are considered to be winter low flow sensitive	<u>SPECIES_NAME</u> 'Chinook, coho, pink, chum, or river sockeye' <u>ACTIVITY</u> 'spawning –total winter flow sensitive'	Spawning reaches were overlaid with the winter flow sensitive polygons and total length of winter flow sensitive spawning was calculated for each CU.	Table identifying the total length of winter flow sensitive spawning reaches for each CU.	
	Total spawning length – winter flow sensitive	Percentage of spawning reaches for each CU that	<u>SPECIES_NAME</u> 'Chinook, coho,pink, chum, or river sockeye'	Spawning reaches were overlaid with the winter flow sensitive polygons and % of summer flow sensitive spawning was calculated for each CU.	Table identifying the % of winter flow sensitive spawning reaches for	

	(%)	are considered to be winter low flow sensitive	ACTIVITY 'spawning –% winter flow sensitive'		each CU.	
Rearing/Migration periods (river sockeye, Chinook, coho, chum, and pink)	Accessible habitat length	MOE Fish Habitat Model (Version 2)	FishHabitat – FISH_HABITAT 'FISH HABITAT – INFERRED' 'FISH HABITAT – OBSERVED'	Fish habitat arcs were overlaid with the CU rearing/migration ZOIs. The sum of inferred and observed habitat length was calculated for each CU. For chum, pink and river sockeye salmon areas of modelled accessible habitat were restricted to FWA Assessment watersheds >= 4order to better reflect use by these species of only larger order streams	Table identifying the total length of accessible stream for each CU.	Note the fish habitat data are based on modeled data for all fish species. For more information on the accessible stream length input data contact Craig Mount at the BC Ministry of Environment.
	Accessible habitat –flow sensitive length (all seasons)	BC MOE ecoregional flow sensitivity mapping (R. Ptolemy, unpubl.), FWA	FishHabitat – FISH_HABITAT 'FISH HABITAT – INFERRED' 'FISH HABITAT – OBSERVED' Flow sensitivity polygons	Flow sensitivity data were overlaid with the CU Rearing/Migration ZOI accessible streams. The sum of accessible stream length that was considered flow sensitive within each CU rearing/migration ZOI was calculated.	Table of flow sensitive accessible stream length within the rearing/migration ZOI for each CU.	
	Accessible habitat –% flow sensitive (all seasons)	BC MOE ecoregional flow sensitivity mapping (R. Ptolemy, unpubl.), FWA	FishHabitat – FISH_HABITAT 'FISH HABITAT – INFERRED' 'FISH HABITAT – OBSERVED' Flow sensitivity polygons	Flow sensitivity data were overlaid with the CU Rearing/Migration ZOI accessible streams. The % of total accessible stream length that was considered flow sensitive within each CU rearing/migration ZOI was calculated.	Table of flow sensitive stream length as a percentage of the total accessible stream length within the rearing/migration ZOI for each CU.	
	Lake area (coho CUs only)	FWA lakes	FWA lakes 'lake area'	The total area of delineated lakes in each coho CU rearing/migration ZOI was calculated.	Table of total lake area for each coho CU.	
	Wetland area (coho CUs only)	FWA wetlands	FWA wetlands 'Wetland area'	The total area of delineated wetlands in each coho CU rearing/migration ZOI was calculated.	Table of total wetland area for each coho CU.	

Potential Future Pressures						
Spatial Scale	**Indicator**	**Input Data**	**Input Attributes/Features Used**	**Processing**	**Outputs**	**Notes**
Nass drainage	Proposed resource development activities within Nass drainage (also includes the Skeena drainage for the Nass-Skeena Estuary Pink (even) CU)	MEM & PR database; LMB Water License Points of Diversion (proposed); Proposed Pipelines;, Proposed Transmission Lines; Proposed Wind & Water Power tenures; THLB layer	Mining – STATUS_D 'DEVELOPED PROSPECT' Water License Points of Diversion – LIC_STATUS 'ACTIVE_APPL', 'PENDING' Proposed Wind and Water Power tenures TEN_PURPOSE 'WATERPOWER', 'WINDPOWER' TEN_STAGE – "APPLICATION"	Proposed resource developments were summarized for the Nass drainage as a whole: *Proposed mines* – locations and total number of proposed mineral and/or coal mines *Proposed linear development* – location and total length of proposed transmission lines and/or pipelines *Proposed water licenses* – locations and total number of proposed POD licenses *Proposed power tenures* – locations and total area represented by proposed wind power and water power tenure *Proposed forestry* – locations and total areas of proposed future logging	Summary table of proposed developments across the drainage