Skeena Salmon Conservation Units Habitat Report Cards: Chinook, coho, pink, chum, and river sockeye

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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.
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 risk 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 Skeena 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 history 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.

1 Introduction

1.1 The Skeena River Basin

The Skeena River is located in mid-British Columbia, originating in the Skeena Mountains and flowing south and southwest for 400 km where it joins the Pacific Ocean at Chatham Sound near Prince Rupert. It drains an areas of 54,432 km^2, making it the second largest watershed in British Columbia (SISRP 2008). Important tributaries within the Skeena River basin include the Babine River, the Kispiox River, and the Bulkley River. While the Skeena has long been inhabited by First Nations who have relied on the river and tributaries for subsistence fisheries, it was not until the mid-1800's that there were any non-First Nations influences in the region. As a result of relatively limited exploitation to date and a pristine setting, the Skeena River is known to be one of the most productive river systems in British Columbia. The Skeena River Basin provides extensive spawning and rearing habitat for all five Pacific salmon species (sockeye, coho, Chinook, chum, and pink), steelhead, and at least 30 other freshwater fish species. All five species use the Skeena River Estuary and lower mainstem Skeena River, with four of these species (sockeye, coho, Chinook, and chum) migrating into the upper river and tributaries. The Skeena has so far avoided much of the development pressure that has compromised fish habitats in many other large watersheds throughout the world. However, there are known to be exceptions in specific locations (e.g., from logging, recreational properties, and water extraction) and there are strong concerns about current habitat deterioration that may have harmed fish populations (SISRP 2008). There is also growing awareness that new development proposals for the region could present potential threats to the continued maintenance of healthy Skeena fish habitats and associated populations. Such threats could be exacerbated by the as-yet-unknown effects of potential climate change in the region. As stated in the recent review by the Skeena Independent Science Review Panel "… it is clear that the Skeena watershed is at a critical juncture; it is a productive region, but it is vulnerable to attack" (SISRP 2008).

1.2 Skeena 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 in SISRP 2008).

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/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 (DFO 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 effective in alleviating pressures and 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 captured 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. CU Overview Reports have not yet been undertaken for any salmon species in any regions of northern British Columbia. In CUs where defined benchmarks/thresholds of concern 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 will 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). DFO has completed pilot Habitat Status Reports for six watersheds in southern British Columbia (the Sarita River, Lower Harrison River, Cowichan River, Bedwell River, San Juan and Gordon Rivers and the Somass River watersheds) but similar assessments have not yet been undertaken in any watersheds in northern British Columbia.

1.3.1 Linkage of Pressure-State Habitat Indicators

There is well-documented evidence that human-induced alterations in landscape and 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/river 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 history 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/quality of spawning habitat and by influencing egg viability.

1a – Stream/River Habitats

1b – Lake Habitats

1c – Estuary Habitats

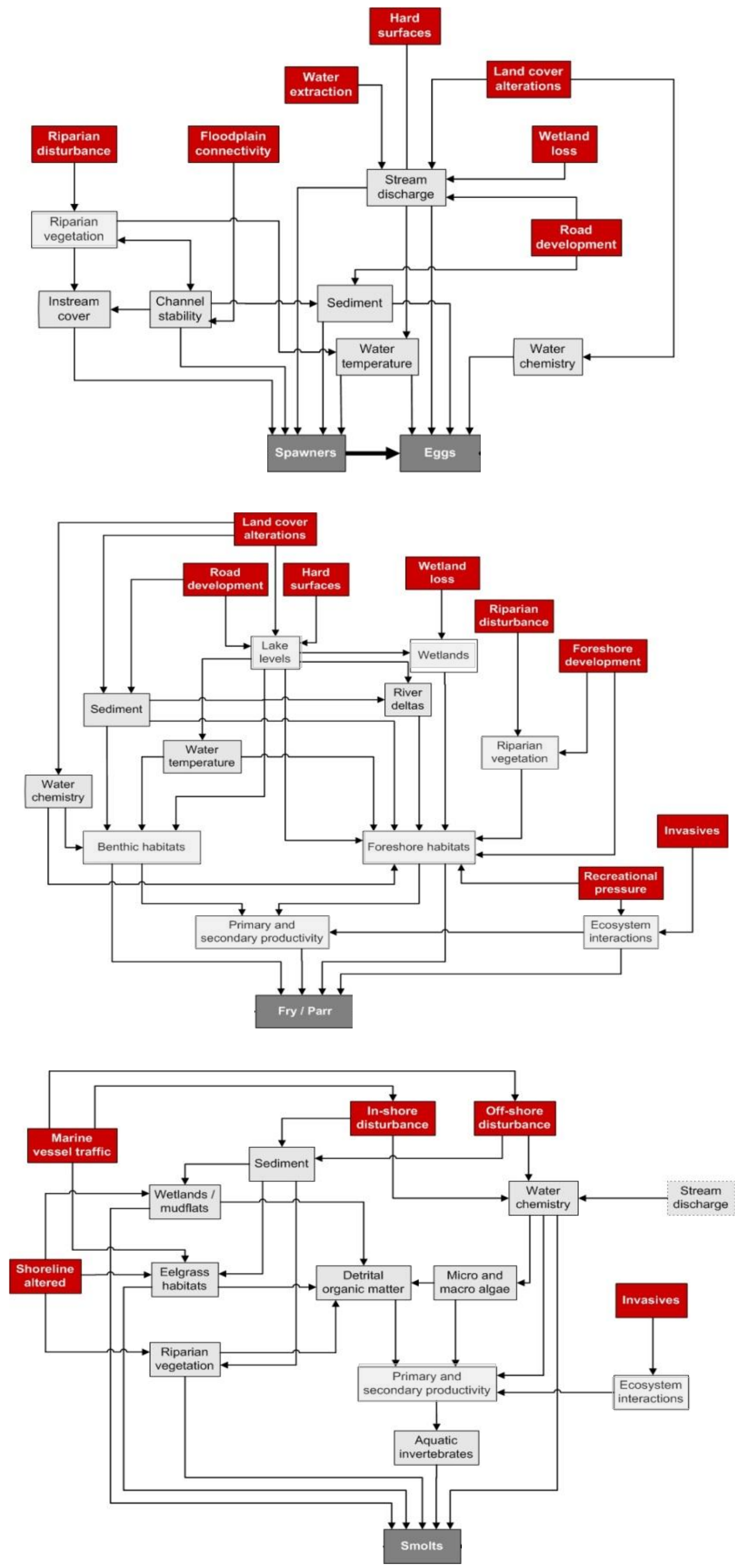

Figure 1 Examples of potential linkages between habitat pressure indicators (red boxes), habitat state indicators (light gray boxes), and salmon life history stages (dark gray boxes) in (a) stream/river , (b) lake, and (c) estuary habitats (modified from Nelitz et al. 2007).

1.4 PSF Project Background

The primary goal of this project (consistent with the first tier of DFO's recommended two-tiered pressure-state habitat monitoring framework) was to undertake a "first cut" evaluation of the extent/intensity of landscape-scale pressures affecting freshwater habitats used by CUs for Chinook, coho, pink, chum and river sockeye salmon. This project is complementary to a previous evaluation of habitats used by Skeena lake sockeye CUs (see Porter et al. 2013b). Together, these two projects encompass all Skeena salmon CUs. Porter et al. 2013b also present information for estuary indicators that are important for all Skeena salmon species, and for indicators that are important for all salmon in the Skeena but cannot be clearly associated with an individual CU.

The project is intended to provide a summary of the regional pressures facing habitats used by Skeena salmon and description of relative habitat risk for the individual Skeena salmon CUs defined for each species (i.e., analogous to a CU Overview Report). Project methodology was based on approaches recently used in the broad-scale evaluation of the status of freshwater habitats used by Skeena lake sockeye CUs (Porter et al. 2013b); an approach which was in turn derived from methods used in assessing habitat status for Lower Thompson coho CU (Beauchamp 2008), Fraser River sockeye CUs (Nelitz et al. 2011) and Southern Chinook CUs (Porter et al. 2013a). Each of these projects developed a varied suite of habitat pressure and habitat quantity/quality (vulnerability) indicators for assessing status of freshwater 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 and expanded upon through use of local datasets developed specific to the Skeena River Basin and provided by the project's Technical Advisory Committee (Skeena TAC). Specific project objectives were to:

1. Develop a synoptic overview of habitat pressures/risk within freshwater habitats used by Chinook, coho, pink, chum and river sockeye CUs across the Skeena River Basin; and

2. Develop map-based CU habitat report cards for each of these Skeena salmon species that:

    a. Summarize the relative extents/intensities of landscape pressures on freshwater habitats used by key life history stages (migration, spawning , incubation, rearing) for each salmon CU in relation to defined indicator benchmarks of concern (i.e., habitat status); and

    b. Summarize the relative vulnerability of habitats used by the different life history stages (migration, spawning, incubation, rearing) for each Skeena salmon CU based on habitat quantity/quality characteristics that relate to inherent sensitivity/resilience to habitat impacts.

This report describes the methods and results of this synoptic regional-scale overview of habitat pressures and vulnerabilities for 11 Chinook, 3 coho, 3 chum, 4 pink, and 2 river sockeye CUs located in British Columbia's Skeena River Basin. The list of Skeena salmon CUs evaluated for this project is provided in Appendix 1.

2 Methods

2.1 Data Processing

All GIS data processing and map production for this project was implemented using ESRI's ArcMap Desktop software, version 10.0. CU habitat report cards for each salmon species were produced using Microsoft Publisher software and R programming language. Appendix 2 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, spreadsheets, and associated metadata files, which are available upon request from the Pacific Salmon Foundation.

2.2 Habitat Indicators

The synoptic overview of habitat status across Skeena salmon CU freshwater habitats used a core set of habitat pressure, habitat quantity, and habitat quality indicators recommended for 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, as well as habitat indicators developed recently for salmon habitat assessments undertaken by Nelitz et al. 2011 and Porter et al. 2013a and 2013b. Report summaries on the status of habitat indicators within the Skeena are based either on novel analyses undertaken for this project by ESSA or alternatively from ongoing Skeena regional projects that maintain derived mapped or modeled information on particular freshwater habitat indicators. The habitat indicators proposed for analysis and reporting by ESSA were reviewed by the project's TAC before final selection and supplemented with local datasets where feasible.

2.2.1 Habitat Pressure Indicators

Descriptions and rationales for indicators used for quantifying habitat pressures on CU-associated watersheds are provided in Section 2.2.1 (current pressures) and Section 2.2.3 (future pressures) of Porter et al. 2013b. The reader may consult those sections in Porter et al. 2013b for further information, as pressure indicators used for the earlier assessment of lake sockeye habitats were identical to those used within the current report analyses for the additional Skeena salmon species. A listing of the habitat pressure indicators used for watershed analyses is provided in **Table 2**.

2.2.2 Vulnerability Indicators (Measures of Habitat Quantity and Quality)

For analyses undertaken in this report, an increasing intensity or extent of habitat pressures is considered representative of increasing risk of adverse effects to salmon habitats. 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. However, it must be noted that the actual "risk" to salmon populations using these habitats will be a combination both of the intensity/extent of habitat pressures and life-history-stage-specific sensitivities/vulnerabilities. Sensitivity/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). CU habitat indicator summaries were therefore augmented where possible with information on the relative vulnerability of CUs to freshwater habitat pressures (where vulnerability was based on CU-specific life history characteristics and broader scale habitat influences). This approach, although fairly crude and based on a limited number of quantifiable vulnerability indicators (measures of habitat quantity and/or quality), is intended to provide an additional filter to identify CUs that may be at highest potential risk from the impacts of habitat degradation. CU habitat risk "status" is therefore defined by the combined ratings of the watershed pressure indicators and the assessed vulnerability indicators. Those CUs considered at greater potential risk (to one or more life history stages) would then warrant more thorough field-based assessment.

Spawning Period

Total Spawning Length (km): The total linear length of spawning habitat for each CU based on GIS depictions of spawning extent as mapped in the province's Fisheries Information Summary System (FISS) and supplemented by more detailed spawn mapping undertaken recently by the Skeena TAC.

- *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 linear 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 linear 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 flow-sensitive spawning indicates a greater duration of exposure to winter 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 $\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 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 linear length of stream within a salmon CU's rearing/migration that is considered accessible to salmonids based on general gradient/obstruction criteria used in the MOE provincial fish passage model. [**Note**: The province's Fish Passage Model uses accessibility criteria based on bull trout, and is not specific to the swimming and passage abilities of different salmon species which will likely have more restricted distributions within a watershed; as such, we have adjusted the default passage model for pink, chum and river sockeye so that modelled accessible habitat is restricted only to streams $\geq 4^{th}$ order (as defined with the Freshwater Atlas (FWA) stream hydrology GIS layer) to better reflect the dominant use of larger streams by these particular species.]

- *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 linear 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 available to 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 1992, Skeena TAC). 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 available to 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 1992, Skeena TAC). 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)

Benchmarks within the WSP reflect DFO's intent to take action to protect or restore habitat on a preventative basis, as required, before salmon population abundance declines in response to degraded habitat (DFO 2005). 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. Where possible, empirical benchmarks of concern used in this project for habitat pressure indicators were defined based on existing science (e.g., Stalberg et al. 2009 or other literature/expert sources). For habitat pressure indicators where scientifically defensible empirical benchmarks do not exist or could not be explicitly defined/resolved through discussions with the Skeena TAC, benchmarks for our analyses 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 Skeena River Basin (an interim approach recommended in Stalberg et al. 2009). While acceptable as an initial benchmarking step until regionally-specific 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 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.

For those indicators of current habitat pressures for which benchmarks were based on the relative distribution of habitat pressure intensities/extents (lower, moderate, higher risk) across all watersheds in the Skeena River Basin (n=1141 1:20K-defined FWA watersheds), we employed two alterative benchmarking approaches for this project, 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 Skeena 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 the 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 or expert-based benchmarks for all habitat indicators.

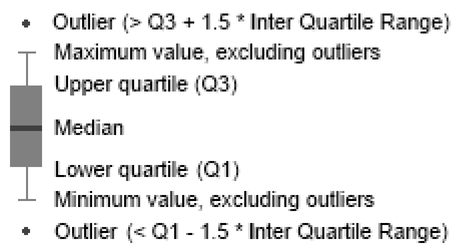

Figure 2 Key to interpreting a "box plot" used for assigning a relative risk score to a habitat pressure indicator value. The plot includes a box indicating the inner 50th percentile of the data (known as the interquartile range, IQR), whiskers showing the robust data range, outliers, and median. The 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 = Q3 - Q1. 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 Skeena Salmon CU Zones of Influence (ZOIs)

The “zone of influence” (ZOI) refers to a specific watershed-boundary-delineated area that is considered to influence habitats used by individual salmon CUs (CUs as defined in Holtby et al. 2007), and in which life-history-stage-specific habitat vulnerabilities and upstream/upslope habitat pressures for each CU can be assessed and quantified. 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.

2.4.1 Chinook CU Zones of Influence (ZOIs)

Spawning ZOI

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 Skeena Chinook CU boundaries (as presented in the most recent GIS layer available for Skeena Chinook CUs (draft – Version 4)).

Rearing/Migration ZOI

Rearing areas and migration routes for Chinook are diverse and have not been explicitly delineated or differentiated within the Skeena Basin. A combined rearing/migration ZOI for each Chinook CU was therefore delineated based on the boundaries of the Skeena subdrainage or suite of subdrainages (subdrainages as captured within the province's "major watershed" 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 Skeena subdrainage and into the Skeena estuary (i.e., all Chinook CUs will move out of their respective rearing subdrainages and then join a common path to the sea). Rearing of upriver Chinook CUs may be expected to occur in adjoining watersheds at any point along this migratory route, including in the lower Skeena (Skeena TAC). All 1:20K FWA watersheds embedded within the subdrainage-defined boundary are considered part of the rearing/migration ZOI for our analyses.

2.4.2 Coho CU Zones of Influence (ZOIs)

Spawning ZOI

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 the Skeena TAC's most recently identified coho spawning reaches, with the specific CU association for each spawning reach based on the most current DFO-delineated CU boundaries for Skeena coho (Version 2).

Rearing/Migration ZOI

Rearing areas and migration routes for coho are diverse and widespread and have not been explicitly delineated or differentiated within the Skeena Basin. A combined rearing/migration ZOI for each coho CU was therefore delineated based on the boundaries of the subdrainage or suite of 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 Skeena subdrainage and into the Skeena estuary. Rearing of upriver coho CUs may be expected to occur at any point along this route, including in the lower Skeena (Skeena TAC). All 1:20K FWA watersheds embedded within the subdrainage-defined boundary are considered part of the rearing/migration ZOI for our analyses.

2.4.3 Pink CU Zones of Influence (ZOIs)

Spawning ZOI

The localized spawning ZOI for each pink salmon CU (with the lower Skeena Pink CU that is joined with the Nass truncated to the boundaries of the Skeena Basin for our analyses), we defined a localized spawning ZOI within DFO-delineated CU boundaries by capturing the areas of all 1:20K FWA Assessment Watersheds that directly intersect with the Skeena TAC's most recently identified pink spawning reaches (odd and even), with the specific CU association for each spawning reach based on the most current DFO-delineated CU boundaries for Skeena pink salmon (Version 2).

Rearing/Migration ZOI

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

2.4.4 Chum CU Zones of Influence (ZOIs)

Spawning ZOI

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 the Skeena TAC's most recently identified chum spawning reaches, with the specific CU association for each spawning reach based on the most current DFO-delineated CU boundaries for Skeena chum (Version 2).

Rearing/Migration ZOI

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 subdrainage or suite of subdrainages in which chum spawning has been identified, plus any subdrainages intersecting the migration route from the CU-specific spawning areas downstream through the Lower Skeena subdrainage and into the Skeena estuary. All 1:20K FWA watersheds embedded within the subdrainage-defined boundary are considered part of the rearing/migration ZOI for our analyses.

2.4.5 River Sockeye CU Zones of Influence (ZOIs)[1]

Spawning ZOI

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 the Skeena TAC's most recently identified river sockeye spawning reaches, with the specific CU association for each spawning reach based on the most current DFO-delineated CU boundaries for Skeena river sockeye (Version 2).

Rearing/Migration ZOI

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

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 Skeena Basin. A combined rearing/migration ZOI for each river sockeye CU was therefore delineated based on the boundaries of the Skeena subdrainage or suite of 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 Skeena subdrainage and into the Skeena 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 Skeena (Skeena TAC). 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 Skeena Salmon CU ZOIs

Reporting out on the large number of habitat indicators presents a challenge in providing a general, overall assessment of habitat risk for Skeena 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 FLRNO’s Forest and Range Evaluation Program (FREP), USEPA’s Environmental Monitoring & Assessment Program (EMAP), USDA 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 recently for southern Chinook CUs (Porter et al. 2013a) and Skeena lake sockeye (Porter et al. 2013b) employed alternative approaches for rating relative risk (green/amber/red) in which cumulative risk scoring was instead based on indicator roll-up rule sets.

Similar to Porter et al. 2013b, for this project we also developed cumulative risk ratings for watersheds within CU spawning and rearing/migration ZOIs using a cumulative risk rule set that was derived from a roll-up of habitat pressure indicator risk ratings within seven defined “Impact Categories” (1st level roll-up: with the rule set used within each Impact Category varying dependent on the number of embedded habitat pressure indicators and the indicator data types), and then a roll-up of risk ratings across the Impact Categories (2nd level roll-up). 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). The Skeena TAC assisted in defining the seven Impact

Categories to be used for the cumulative risk analyses and in assignment of the different pressure indicators to each of the 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 freshwater habitats. **Table 1** provides descriptions of the specific rule sets used for defining cumulative habitat risk ratings for watersheds in Skeena salmon species CU spawning and rearing/migration ZOIs.

Table 1 Habitat pressure indicator and habitat Impact Category roll-up rule sets used for developing cumulative habitat risk ratings for watersheds within Skeena salmon species CU spawning and rearing/migration zones of influence (ZOIs). Note that for our analyses the summer spawning and winter egg incubation life history stages are considered to overlap spatially and are restricted to the defined spawning ZOIs.

1st level roll-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 fish 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, acid-generating mines	if ≥ 1 indicator rated red then Impact Category rated red, else Impact Category rated green
Human Development Footprint	total land cover alteration, impervious surfaces, linear development, mines (general)	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 Classifications for Watersheds in CU Rearing Lake and Tributary Spawning ZOIs	Number of Impact Categories Rated Green	Number of Impact Categories Rated Red
Green	≥ 5/7	-
Red	-	≥ 3/7
Amber	< 5/7	< 3/7

For scoring of cumulative risk within the CU rearing/migration ZOI, we employed the same 1st level "within Impact Category" rule set as used for spawning ZOI watersheds for the roll-up of pressure indicators for assigning risk ratings (green/amber/red) to each of the seven Impact Categories. However, we used a different approach in the CU rearing/migration ZOI 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. Cumulative risk scores in each watershed in the CU rearing/migration ZOI 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 ZOI to determine the total cumulative risk score for a particular CU's rearing/migration ZOI. Scoring of the cumulative risks with the rearing/migration ZOI using this alternative approach provides a better spatial representation of the changing pressure intensities along the species generalized migration route and also better accounts for the more diffuse nature of the impacts (i.e., migrating salmon may not directly use each of the ZOI-defined watersheds themselves but are instead experiencing the downstream effects of impacts (potentially compounded) in the receiving rearing areas and migration corridors).

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 species 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 Skeena 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[2]			Data Sources	Literature support for indicator inclusion
					Green (low risk)	Amber (moderate risk)	Red (high risk)		
Habitat Vulnerability Indicators									
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			Skeena salmon species spawning distributions (provided by Skeena TAC), 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			Skeena salmon species spawning distributions (provided by Skeena TAC), 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			Skeena salmon species spawning distributions (provided by Skeena TAC), FWA hydrology, BC MOE ecoregional flow sensitivity mapping (R. Ptolemy, unpubl.)	Richter et al. 1997; R. Ptolemy (unpubl.)
Rearing /	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, FWA hydrology	Stalberg et al. 2009 (WSP)

[2] **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.

Migration period	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; Skeena TAC
	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; Skeena TAC
Habitat Pressure Indicators									
	Cumulative CU rearing/migration ZOI stressor score Combined stressor rating across pressure Impact Categories and their associated indicators	n/a	CU rearing / migration ZOI	Indicator roll-up decision rule set	Summation of the seven Impact Category ratings within watersheds in the rearing/migration ZOI (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 rearing/migration ZOI therefore ranges from 0 to 14.			Multiple data sources used across the habitat pressure indicators to inform the seven Impact Categories	Roll-up 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,b
Spawning ZOIs	**Hydrologic Processes**								
	Forest disturbance	% of watershed	watershed	Relative ranking (RR1)	< 4.8	> 4.8 to < 19.0	> 19.0	VRI, RESULTS, FTEN	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	VRI, DRA, FTEN, LCC2000-V	MOF 2001; Smith and Redding 2012
	Surface Erosion								
	Road development	km/km²	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 + Culvert passability	# crossings/km of fish accessible stream + % culverts passable (for subset of Skeena watersheds where surveys have occurred)	watershed	Relative ranking (RR1)	< 0.20	≥ 0.20 to < 0.58	≥ 0.58	BC MOE Fish Passage layer, BC MOE Road Crossings, PCIS culvert assessments, local Skeena culvert assessments (Skeena TAC)	Alberti et al. 2007; FPB 2009; FLNRO 2012
	Vegetation Quality								
	Insect and disease defoliation	% forest stands killed	watershed	Relative ranking (RR1)	< 3.3	≥ 3.3 to < 15	≥ 15	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	0	> 0		MOE Wastewater Discharge and Permits database	Stalberg et al. 2009
	Mining development	# of acid-generating mines	watershed	Binary ranking (RR2)	0	> 0		MEM & PR database, Skeena TAC identified acid-generating mines	Kondolf 1997; Nelson et al. 1991; Skeena TAC
	Human Development Footprint								
	Total land cover alteration	% of watershed	watershed	Relative ranking (RR1)	< 6.4	≥ 6.4 to < 22.0	≥ 22.0	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 (WSP)
	Linear development	km/km^2	watershed	Relative ranking (RR1)	< 0.59	≥ 0.59 to < 1.3	≥ 1.3	DRA, FTEN, NTS	WCEL 2011; MOE 2012
	Mining development	# of mines (total of, mineral, placer, aggregate and coal mines)	watershed	Binary ranking (RR2)	0	> 0		MEM & PR database	Nellitz et al. 2011; Kondolf 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 spawning ZOIs Combined stressor rating across seven 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 seven 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,b
Future Habitat Pressure Indicators									
Watersheds/ CU ZOIs	Proposed resource development (future pressures) - Proposed mines (placer, coal, mineral), pipelines, transmission lines, water licenses, port expansion points, wind and water power generation sites	Multiple indicators – various units (#, km^2, %)	CU ZOIs (rearing /migration and spawning)	n/a	No specific CU benchmarks defined. Potential increases in development within CU ZOIs (total change and % change from current levels)			Proposed development GIS layers**:** BC Mineral Placer Tenures, BC Mines, BC Water Licences Proposed, Coal Developed Prospects, Proposed Mining Roads, Natural Gas Facilities, Port Expansion, Proposed BC Advance Exploration Sites, Proposed NOW, Proposed NWBC-Wind, Proposed TLs – mines, Proposed Pipelines, Proposed Transmission Lines, Proposed Wind & Water Power. These GIS layers were provided by Skeena TAC and were compiled from multiple data sources.	Skeena TAC

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

In addition to individual and composite/cumulative indicator risk scoring for individual watersheds within life history stage ZOIs, we also determined the "average" risk scores for the pressure indicators across all watersheds in each salmon species CU's spawning ZOI. 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 rearing lake ZOI boundary, even when only a portion of the FWA watershed was within the CU's ZOI (i.e., where there was any mismatch between the FWA watershed boundaries and the more spatially precise FWA "fundamental" watersheds layer that had been used to more accurately define the full extent of the CU's spawning 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 scores 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 a particular CU spawning ZOI.

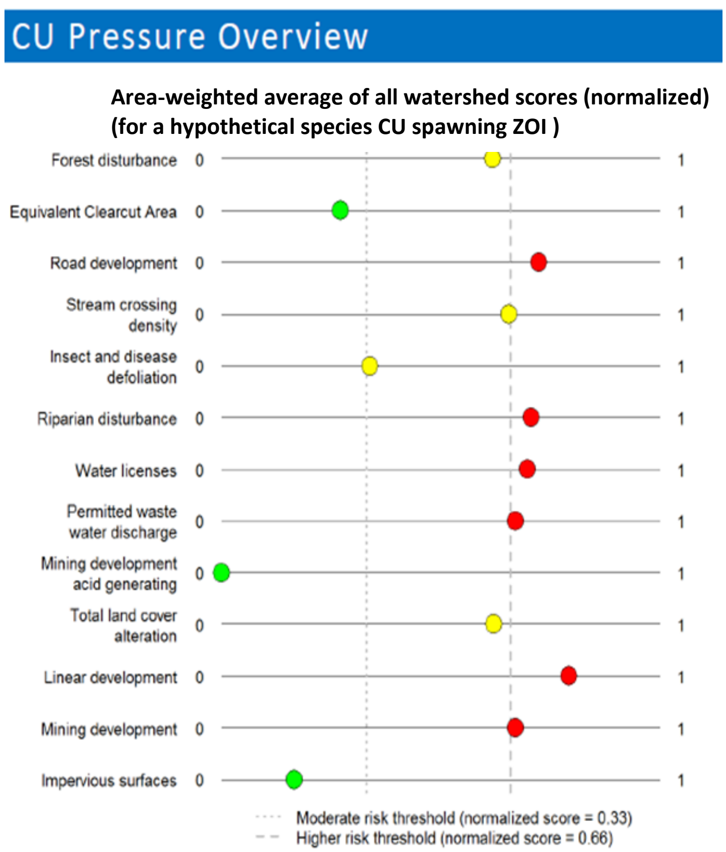

Figure 3 Example "slider" for illustrating the normalized area-weighted average watershed pressure indicator risk scores across a (hypothetical) spawning zone of influence (ZOI) for a Skeena salmon CU.

2.8 Integrated Habitat Pressures and Vulnerabilities Rankings across Skeena Salmon CU Spawning and Rearing/Migration ZOIs

Given a general lack of information for reliable assessment of differences in habitat condition across all spawning, incubation, rearing, and migratory habitats for Skeena salmon, we have instead defined relative species CU habitat status as 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. 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, incubation, and/or rearing/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 sockeye salmon freshwater survival. In the future, with continued work on the effects of landscape habitat pressures and salmon habitat responses/resilience, it may be possible to better define benchmarks of concern for combined pressures/vulnerability scores (i.e., instead of basing thresholds simply on relative CU rankings).

2.8.1 Vulnerability and Cumulative Pressure Indices (for Chinook, Coho, Chum, Pink, and River Sockeye CUs)

<u>CU-Scale Vulnerability Indicators (Habitat Quantity and Quality)</u>

Spawning ZOI (spawning life history stage / summer spawn timing)	Rearing/Migration ZOI
1. Total spawning length (km)	1. Accessible stream length (km) – BC MOE Fish Passage Model
2. Total spawning length (km) in summer flow sensitive areas	2. Total accessible stream length for ZOI within flow sensitive areas (all seasons)
3. % of total spawning length in summer flow sensitive areas	3. % of total accessible stream length for ZOI within flow sensitive areas (all seasons)
Spawning ZOI (egg incubation life history stage / winter incubation timing)	**Coho only:** lake area, wetland area (not used for integrated analyses)
1. Total spawning length (km) in winter flow sensitive areas	
2. % of total spawning length in winter flow sensitive areas	

A subset of these vulnerability indicators (habitat quantity and/or quality) 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 species. 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.

CU-Scale Cumulative Pressure Indicators

- **Spawning ZOI:** % of watersheds within the spawning ZOI (also includes area of egg incubation) that are classified as either moderate or high (amber, red) for cumulative risk.
- **Rearing/Migration ZOI**: Area-weighted total of all scored cumulative risk classifications for watersheds within a CU's rearing/migration ZOI (see Section 2.5 for a description of cumulative risk scoring approach for each watershed in the rearing/migration ZOI). An area-weighted total for the rearing/migration ZOI was generated by multiplying the cumulative risk scores for individual watersheds by the percentage of the total rearing/migration ZOI area that is represented by watersheds with that particular cumulative risk score [e.g., area-weighted total score for CU rearing/migration 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 rearing/migration that are represented by watersheds having that particular cumulative pressure score (numbers hypothetical))]. A higher area-weighted total cumulative risk score across all rearing/migration ZOI watersheds = greater cumulative pressure (highest possible score = 14).

Rule Sets for Intregrated Vulnerability/Cumulative Pressures Assessment and Ranking

Vulnerability:

1. **Spawning ZOI (summer spawn timing):** Use vulnerability indicators (a) total spawning length and (b) % of 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 the more vulnerable compared to other salmon CUs for the species) as the particular CU's ranking point (e.g., if ranked 6th for total spawning length and 3rd for % of spawning that is summer flow sensitive, plot the 6th rank to represent the relative spawning ZOI (summer timing) vulnerability index score for the CU). This approach is intended to identify the most serious habitat vulnerability for a particular CU relative to other salmon CUs for the species in the Skeena.

2. **Spawning ZOI (winter egg incubation timing):** Use 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 ZOI:** Use vulnerability indicators (a) total accessible stream length and (b) % of 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 (i.e., ranked as relatively the more vulnerable compared to other salmon CUs) as the particular CU's ranking point (e.g., if ranked 1st for total accessible stream length migration distance and 2nd for % that is flow sensitive, plot the 2nd rank to represent the relative rearing/migration ZOI

vulnerability index score for the CU). This approach is intended to identify the most serious migration habitat vulnerability for a particular CU relative to other salmon CUs for the species in the Skeena.

Cumulative Pressures:

1. **Spawning ZOI (for both summer spawn and winter egg incubation timing)**: Plot the ranked score for this cumulative pressure indicator as the CU's 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 ZOI**: Plot the ranked score for this cumulative pressure index as the CU's ranking point (i.e., CUs with a higher area-weighted total cumulative risk score will have higher relative pressure rankings for the rearing/migration ZOI cumulative risk index).

Figure 4 (summer spawn timing) and **Figure 5** (winter egg incubation timing) provide examples of the outputs of these analyses within the spawning ZOI, showing (for a hypothetical CU) the ranked index scores relative to other Skeena salmon CUs along the two axes of habitat vulnerability and cumulative habitat pressure (together providing a broad relative assessment of a CU's spawning area habitat status). **Figure 6** provides an example of the relative ranking for a hypothetical CU within the rearing/migration ZOI.

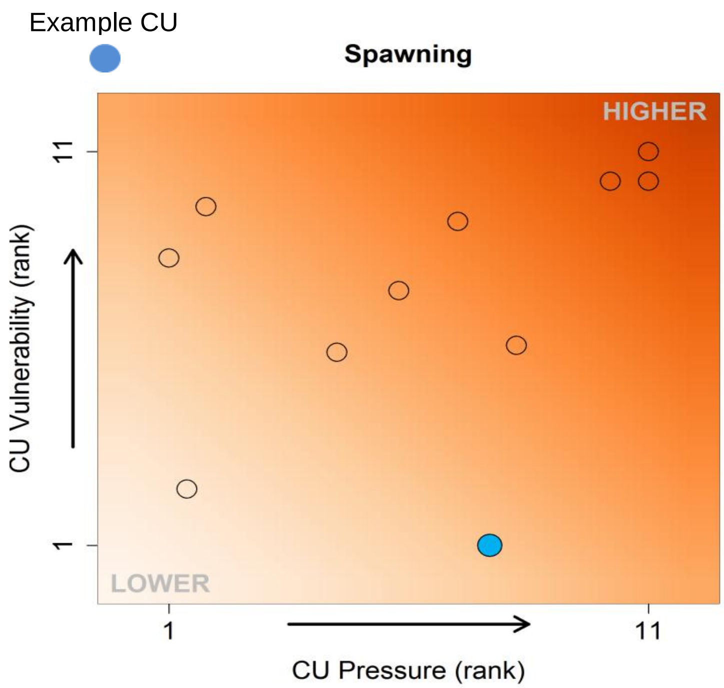

Figure 4 Example output from integrated CU habitat vulnerability and cumulative habitat pressures analysis for defining the relative ranking of habitat "status" across the spawning ZOI (summer spawn timing) for Skeena salmon CUs (blue circle represents a hypothetical ranking for an example CU). CUs in the upper right hand quadrant would have both the highest vulnerability (summer period) and are experiencing the highest cumulative habitat pressures in spawning areas relative to other CUs.

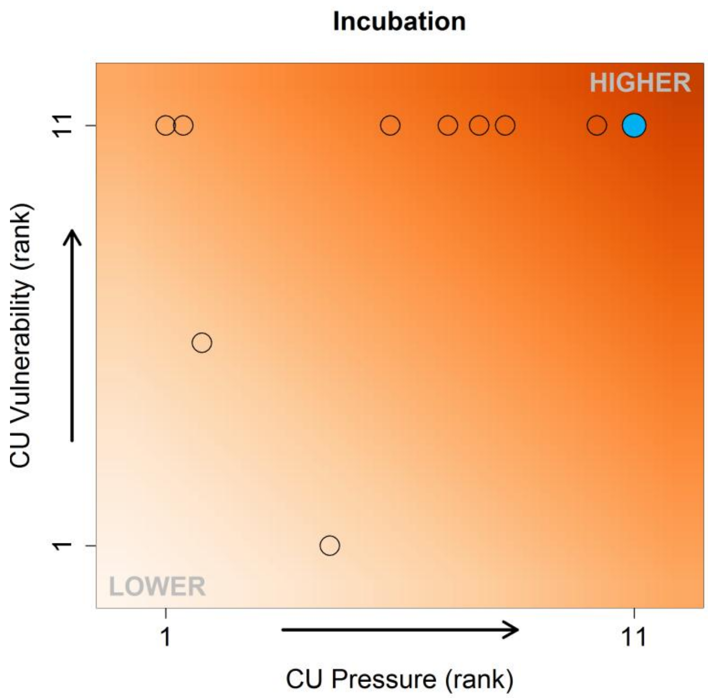

Figure 5 Example output from integrated CU habitat vulnerability and cumulative habitat pressures analysis for defining the relative ranking of habitat "status" across the spawning ZOI (winter incubation timing) for Skeena salmon CUs (blue circle represents a hypothetical ranking for an example CU). The spawning ZOI represents the area where egg incubation occurs during the winter.

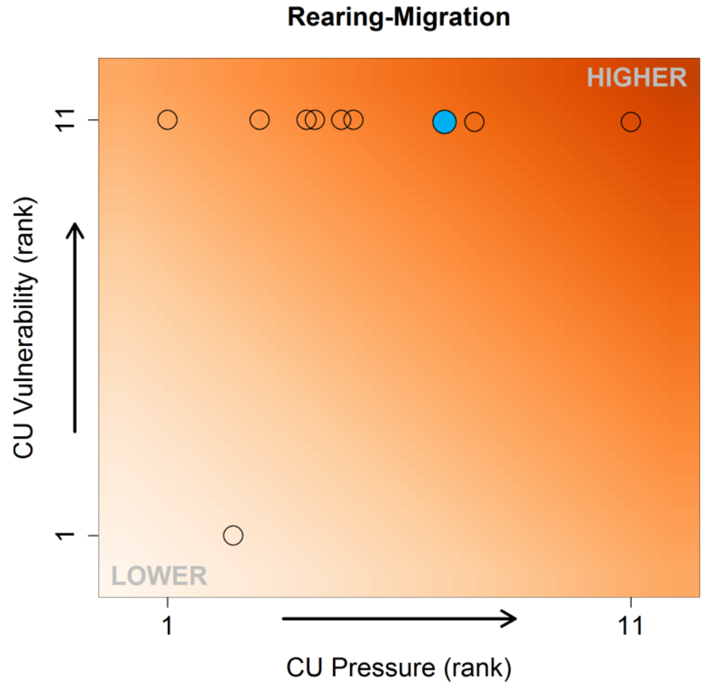

Figure 6 Example output from integrated CU habitat vulnerability and cumulative habitat pressures analysis for defining the relative ranking of habitat "status" across the rearing/migration ZOI for Skeena salmon CUs (blue circle represents a hypothetical ranking for an example CU).

2.9 Skeena Estuary and Skeena River Basin Indicators

A Skeena estuary report card (summarizing information for estuary habitat indicators that are important for all Skeena salmon CUs), and a Skeena River Basin report card (summarizing information for habitat indicators that are important for salmon in the Skeena but cannot be clearly associated with an individual CU) were developed by Porter et al. 2013b. No additional indicators at the broad estuary or basin-wide scales were assessed within the current project so the reader is directed to the Porter et al. 2013b report for description of methods that were used for developing Skeena Estuary and whole Skeena Basin habitat indicators.

3 Results

3.1 Skeena Salmon CU Habitat Report Cards

Summaries of habitat information within defined life-history-stage-specific ZOIs have been developed for all Skeena salmon CUs. These report cards provide an overview of indicators for current and potential future habitat pressures, and habitat vulnerabilities to these pressures (i.e., indicators of habitat quantity and quality) for the 11 Chinook, three coho, three chum, four pink, and two river sockeye CUs evaluated for the Skeena River Basin. Report cards for Skeena lake sockeye CUs were developed for an earlier PSF project (Porter et al 2013b). 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. Assembled habitat information is presented for each salmon CU in graphical and map-based presentation formats. Results of these comparative habitat analyses are presented in habitat report cards for each of the Skeena salmon CUs. Skeena CU habitat report cards for Chinook, coho, pink, chum, lake sockeye and river sockeye (as well as a summary document providing guidance on how to interpret the various report card elements) can be viewed and/or downloaded at the Pacific Foundation (PSF) Skeena Salmon Program website: www.skeenasalmonprogram.ca. A Skeena Estuary report card (summarizing information for estuary habitat indicators that are important for all Skeena salmon CUs), and a Skeena River Basin report card (summarizing information for habitat indicators that are important for salmon in the Skeena but cannot be clearly associated with an individual CU) both developed by Porter et al. 2013b are also available at the PSF website and the reader should view and/or download these in conjunction with the CU-specific Skeena report cards presented here.

These habitat report cards provide a considerable amount of detail, describing the current and potential future habitat pressures/risks affecting each Skeena salmon CU. The CU habitat report cards are based on similar approaches used by Nelitz et al. 2011 and Porter et al. 2013a and 2013b to capture a suite of information related to the status of habitats used by salmon CUs. The report cards represent an attempt to concisely identify/quantify major pressures that could act on freshwater habitats used by salmon CUs and that could contribute to the overall performance 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 Porter et al. 2013b and the reader may consult that report section text for additional guidance.

3.2 Habitat Pressure Indicators (Current)

3.2.1 Watersheds/CU ZOIs

A broad overview of habitat pressures within and across Skeena salmon CU ZOIs 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 3**) 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 4**, **Table 5**, and **Table 6**); and

3. the cumulative risk scores (total and area-weighted total) for each CU's rearing/migration ZOI (see **Table 7**) based on pressure indicator roll-up rules.

Assessment of our defined measure of cumulative habitat risk across Skeena salmon CUs suggests that many habitats associated with spawning are experiencing impacts, with most CUs having some or even a majority of the watersheds compromising their spawning ZOIs rated as being at higher (red) or moderate (amber) risk from cumulative habitat pressures (**Table 3**). On a percentage basis the ***worst*** rated CUs for ***cumulative pressures*** across the different species were **Chinook** – Upper Bulkley CU with 77% of the 30 watersheds in the spawning ZOI rated higher (red) risk and 23% rated moderate (amber) risk, Kalum (late) CU with 60% of 15 watersheds in the spawning ZOI rated higher (red) risk and 33% rated moderate (amber) risk, and Lakelse CU with 55% of the 11 watersheds in the spawning ZOI rated higher (red) risk and

45% rated moderate (amber) risk; **chum** – Middle Skeena CU with 55% of the 29 watersheds in the spawning ZOI rated higher (red) risk and 41% rated moderate (amber) risk; **coho** – Middle Skeena CU with 45% of the 230 watersheds in the spawning ZOI rated higher (red) risk and 38% rated moderate (amber) risk; **pink** – Middle-Upper Skeena (even and odd) CUs with 52% of the 114 watersheds in the spawning ZOIs rated higher (red) risk and 44% rated moderate (amber) risk; **river sockeye** - Skeena River CU with 50% of the 36 watersheds in the spawning ZOI rated higher (red) risk and 25% rated moderate (amber) risk. While all salmon CUs demonstrated at least some level of higher and moderate cumulative habitat risk ratings across their spawning ZOI watersheds, spawning habitats for some CUs appeared to be generally at lower risk. The ***best*** rated CUs for cumulative habitat pressures across the different salmon species were **Chinook** – Sicintine CU with 84% of 37 spawning ZOI watersheds rated lower (green) risk, Upper Skeena CU with 81% of 98 spawning ZOI watersheds rated lower (green) risk, and Ecstall CU with 77% of 22 spawning ZOI watersheds rated lower (green) risk; **chum** – Lower Skeena CU with 51% of the 67 watersheds in the spawning ZOI rated lower (green) risk; **pink** – Lower Skeena (odd) with 43% of the 89 watersheds in the spawning ZOI rated lower (green) risk; **river sockeye** – Skeena River-High Interior CU with 75% of the 8 watersheds in the spawning ZOI rated lower (green) risk.

CUs with notably high percentages of watersheds in their spawning ZOIs with higher risk (**Table 4**) or moderate risk (**Table 5**) ratings for ***individual pressures*** include **Chinook** – Kalum (late) CU (land cover alteration, forest disturbance, linear development, road density, stream crossing density, riparian disturbance, forest stand defoliation), Upper Bulkley CU (land cover alteration, forest disturbance, linear development, road density, stream crossing density, permitted water licenses, riparian disturbance, ECA, forest stand defoliation); **chum** – Middle Skeena CU (land cover alteration, linear development, riparian disturbance), Upper Skeena CU (land cover alteration, linear development, road density, stream crossing density, permitted wastewater discharges, riparian disturbance, forest stand defoliation); **pink** – Middle-Upper Skeena (odd and even) CUs (land cover alteration, road density).

Table 6 highlights the CUs with high percentages of watersheds in their spawning ZOIs that have lower (green) risk ratings for ***individual pressure*** indicators. CUs with predominantly lower individual pressure risk ratings (i.e., in the best shape) across their spawning ZOI watersheds include **Chinook** – Ecstall CU, Scinitine CU, Lower Skeena CU, and Upper Skeena CU; **chum** – Lower Skeena CU; **coho** – Upper Skeena CU; **river sockeye** – Skeena River High Interior CU.

The area-weighted total cumulative risk scoring for CU rearing/migration (**Table 7**) suggests that the CUs experiencing the greatest relative amount of overall habitat pressure within the combined rearing/migration ZOIs include **Chinook** – Upper Bulkley CU (score = 5.26), Mid Skeena Large Lakes CU (score = 4.22), and Mid Skeena Main Tributaries CU (score = 4.02); **chum** – Middle Skeena CU (score = 5.35); **coho** – Middle Skeena CU (score = 5.35); **pink** – Middle-Upper Skeena CU (odd and even) (score = 4.25); **river sockeye** – Skeena River CU (score = 5.34).

Table 3 The percentage of watersheds in the **spawning** "zone of influence" (ZOI) for each Skeena 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	Watersheds in spawning ZOI (# of)	Higher-risk Watersheds (%)	Moderate-risk Watersheds (%)	Lower-risk Watersheds (%)
Chinook	Ecstall	22	9%	14%	77%
Chinook	Zymoetz	39	18%	38%	44%
Chinook	Lower Skeena	90	17%	29%	54%
Chinook	Kalum (early)	27	22%	44%	33%
Chinook	Kalum (late)	15	60%	33%	7%
Chinook	Lakelse	11	55%	45%	0%
Chinook	Sicintine	37	0%	16%	84%
Chinook	Mid Skeena Large Lakes	156	40%	37%	23%
Chinook	Mid Skeena Main Tributaries	173	41%	31%	28%
Chinook	Upper Bulkley	30	77%	23%	0%
Chinook	Upper Skeena	98	5%	14%	81%
Chum	Lower Skeena	67	22%	27%	51%
Chum	Middle Skeena	29	55%	41%	3%
Chum	Upper Skeena	1	0%	100%	0%
Coho	Lower Skeena	150	24%	34%	42%
Coho	Middle Skeena	230	45%	38%	17%
Coho	Upper Skeena	78	3%	12%	86%
Pink	Nass-Skeena Estuary (even)	86	26%	33%	42%
Pink	Middle-Upper Skeena (even)	114	52%	44%	4%
Pink	Lower Skeena (odd)	89	25%	33%	43%
Pink	Middle-Upper Skeena (odd)	114	52%	44%	4%
Sockeye-River	Skeena River	36	50%	25%	25%
Sockeye-River	Skeena River-High Interior	8	0%	25%	75%

Table 4 The percentage of watersheds in the **spawning** "zone of influence" (ZOI) for each Skeena 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	Land cover altered (%)	Forest disturbed (%)	Impervious surface (%)	Mines (total #)	Acid generating 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 (%)
Chinook	Ecstall	5%	5%	0%	0%	0%	23%	9%	14%	14%	5%	0%	0%	0%
Chinook	Zymoetz	21%	23%	0%	5%	3%	23%	18%	54%	5%	21%	5%	13%	0%
Chinook	Lower Skeena	16%	13%	1%	13%	1%	29%	18%	27%	17%	18%	4%	8%	0%
Chinook	Kalum (early)	19%	19%	0%	15%	0%	22%	26%	41%	11%	22%	0%	15%	4%
Chinook	Kalum (late)	60%	40%	7%	40%	0%	60%	60%	73%	47%	67%	13%	13%	0%
Chinook	Lakelse	45%	45%	0%	9%	0%	55%	45%	36%	36%	55%	9%	18%	0%
Chinook	Sicintine	0%	0%	0%	0%	0%	11%	11%	8%	0%	0%	0%	0%	0%
Chinook	Mid Skeena Large Lakes	42%	47%	0%	4%	1%	37%	40%	28%	8%	44%	4%	36%	64%
Chinook	Mid Skeena MainTributaries	37%	34%	0%	14%	1%	43%	42%	36%	27%	35%	4%	10%	13%
Chinook	Upper Bulkley	60%	53%	0%	17%	3%	77%	77%	63%	63%	60%	13%	53%	97%
Chinook	Upper Skeena	6%	6%	0%	5%	0%	8%	2%	3%	2%	8%	0%	6%	22%
Chum	Lower Skeena	21%	18%	1%	15%	1%	37%	25%	30%	18%	19%	6%	7%	0%
Chum	Middle Skeena	52%	48%	0%	17%	0%	59%	62%	45%	38%	52%	7%	14%	3%
Chum	Upper Skeena	0%	0%	0%	0%	0%	100%	0%	0%	100%	0%	0%	0%	100%
Coho	Lower Skeena	20%	21%	0%	15%	1%	30%	23%	37%	17%	24%	5%	9%	0%
Coho	Middle Skeena	44%	43%	0%	11%	2%	42%	44%	38%	25%	42%	6%	23%	37%
Coho	Upper Skeena	4%	4%	0%	3%	0%	6%	5%	5%	1%	5%	0%	4%	12%
Pink	Nass-Skeena Estuary (even)	23%	19%	1%	17%	1%	38%	27%	31%	24%	24%	8%	8%	0%
Pink	Middle-Upper Skeena (even)	52%	49%	0%	16%	1%	49%	53%	37%	31%	48%	8%	24%	31%
Pink	Lower Skeena (odd)	22%	18%	1%	17%	1%	38%	26%	30%	24%	24%	8%	8%	0%
Pink	Middle-Upper Skeena (odd)	52%	49%	0%	16%	1%	49%	53%	37%	31%	48%	8%	24%	31%
Sockeye -River	Skeena River	50%	44%	0%	14%	3%	42%	44%	28%	28%	42%	0%	17%	31%
Sockeye -River	Skeena River-High Interior	0%	0%	0%	0%	0%	13%	0%	0%	13%	0%	0%	0%	13%

Table 5 The percentage of watersheds in the **spawning** "zone of influence" (ZOI) for each Skeena 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	Land cover altered (%)	Forest disturbed (%)	Impervious surface (%)	Mines (total #)	Acid generating 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 (%)
Chinook	Ecstall	14%	18%	0%	0%	0%	9%	18%	5%	0%	27%	0%	0%	0%
Chinook	Zymoetz	33%	41%	3%	0%	0%	31%	44%	13%	0%	36%	0%	10%	23%
Chinook	Lower Skeena	29%	31%	4%	0%	0%	22%	21%	19%	0%	28%	0%	1%	19%
Chinook	Kalum (early)	52%	52%	0%	0%	0%	37%	41%	26%	0%	41%	0%	11%	15%
Chinook	Kalum (late)	33%	53%	13%	0%	0%	27%	40%	27%	0%	20%	0%	13%	53%
Chinook	Lakelse	45%	45%	9%	0%	0%	36%	55%	64%	0%	36%	0%	9%	36%
Chinook	Sicintine	16%	11%	0%	0%	0%	11%	14%	3%	0%	11%	0%	0%	35%
Chinook	Mid Skeena Large Lakes	33%	29%	1%	0%	0%	35%	36%	41%	0%	23%	0%	12%	26%
Chinook	Mid Skeena MainTributaries	35%	34%	8%	0%	0%	29%	31%	34%	0%	31%	0%	12%	34%
Chinook	Upper Bulkley	33%	37%	10%	0%	0%	20%	23%	33%	0%	27%	0%	10%	3%
Chinook	Upper Skeena	8%	6%	0%	0%	0%	23%	15%	21%	0%	6%	0%	0%	38%
Chum	Lower Skeena	27%	28%	3%	0%	0%	18%	18%	16%	0%	31%	0%	3%	22%
Chum	Middle Skeena	45%	41%	0%	0%	0%	38%	34%	41%	0%	21%	0%	24%	28%
Chum	Upper Skeena	100%	100%	0%	0%	0%	0%	100%	100%	0%	100%	0%	0%	0%
Coho	Lower Skeena	37%	38%	4%	0%	0%	26%	33%	23%	0%	34%	0%	7%	26%
Coho	Middle Skeena	37%	33%	4%	0%	0%	37%	37%	40%	0%	31%	0%	16%	33%
Coho	Upper Skeena	8%	4%	0%	0%	0%	22%	12%	17%	0%	5%	0%	0%	37%
Pink	Nass-Skeena Estuary (even)	33%	36%	7%	0%	0%	24%	29%	28%	0%	33%	0%	5%	24%
Pink	Middle-Upper Skeena (even)	40%	39%	6%	0%	0%	40%	39%	53%	0%	36%	0%	14%	35%
Pink	Lower Skeena (odd)	33%	36%	7%	0%	0%	24%	28%	28%	0%	33%	0%	4%	24%
Pink	Middle-Upper Skeena (odd)	40%	39%	6%	0%	0%	40%	39%	53%	0%	36%	0%	14%	35%
Sockeye -River	Skeena River	25%	31%	8%	0%	0%	31%	25%	47%	0%	31%	0%	11%	28%
Sockeye -River	Skeena River-High Interior	25%	25%	0%	0%	0%	13%	25%	25%	0%	13%	0%	0%	38%

Table 6 The percentage of watersheds in the **spawning** "zone of influence" (ZOI) for each Skeena 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	Land cover altered (%)	Forest disturbed (%)	Impervious surface (%)	Mines (total #)	Acid generating 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 (%)
Chinook	Ecstall	82%	77%	100%	100%	100%	68%	73%	82%	86%	68%	100%	100%	100%
Chinook	Zymoetz	46%	36%	97%	95%	97%	46%	38%	33%	95%	44%	95%	77%	77%
Chinook	Lower Skeena	56%	56%	94%	87%	99%	49%	61%	54%	83%	54%	96%	91%	81%
Chinook	Kalum (early)	30%	30%	100%	85%	100%	41%	33%	33%	89%	37%	100%	74%	81%
Chinook	Kalum (late)	7%	7%	80%	60%	100%	13%	0%	0%	53%	13%	87%	73%	47%
Chinook	Lakelse	9%	9%	91%	91%	100%	9%	0%	0%	64%	9%	91%	73%	64%
Chinook	Sicintine	84%	89%	100%	100%	100%	78%	76%	89%	100%	89%	100%	100%	65%
Chinook	Mid Skeena Large Lakes	25%	24%	99%	96%	99%	28%	24%	31%	92%	33%	96%	53%	10%
Chinook	Mid Skeena MainTributaries	28%	33%	92%	86%	99%	27%	28%	31%	73%	34%	96%	79%	53%
Chinook	Upper Bulkley	7%	10%	90%	83%	97%	3%	0%	3%	37%	13%	87%	37%	0%
Chinook	Upper Skeena	86%	88%	100%	95%	100%	68%	83%	76%	98%	86%	100%	94%	40%
Chum	Lower Skeena	52%	54%	96%	85%	99%	45%	57%	54%	82%	49%	94%	90%	78%
Chum	Middle Skeena	3%	10%	100%	83%	100%	3%	3%	14%	62%	28%	93%	62%	69%
Chum	Upper Skeena	0%	0%	100%	100%	100%	0%	0%	0%	0%	0%	100%	100%	0%
Coho	Lower Skeena	43%	41%	96%	85%	99%	44%	43%	39%	83%	42%	95%	85%	74%
Coho	Middle Skeena	19%	23%	96%	89%	98%	21%	18%	22%	75%	27%	94%	61%	30%
Coho	Upper Skeena	88%	92%	100%	97%	100%	72%	83%	78%	99%	90%	100%	96%	51%
Pink	Nass-Skeena Estuary (even)	44%	45%	92%	83%	99%	37%	44%	41%	76%	43%	92%	87%	76%
Pink	Middle-Upper Skeena (even)	8%	11%	94%	84%	99%	11%	8%	11%	69%	16%	92%	62%	34%
Pink	Lower Skeena (odd)	45%	46%	92%	83%	99%	38%	46%	42%	76%	44%	92%	88%	76%
Pink	Middle-Upper Skeena (odd)	8%	11%	94%	84%	99%	11%	8%	11%	69%	16%	92%	62%	34%
Sockeye -River	Skeena River	25%	25%	92%	86%	97%	28%	31%	25%	72%	28%	100%	72%	42%
Sockeye -River	Skeena River-High Interior	75%	75%	100%	100%	100%	75%	75%	75%	88%	88%	100%	100%	50%

Table 7 Total **cumulative risk** scoring elements for habitat in the **rearing/migration** "zone of influence" (ZOI) for each Skeena 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	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	Ecstall	152	426	2.79
Chinook	Zymoetz	221	663	3.16
Chinook	Lower Skeena	162	426	2.62
Chinook	Kalum (early)	198	651	3.34
Chinook	Kalum (late)	198	651	3.34
Chinook	Lakelse	163	497	3.10
Chinook	Sicintine	611	2077	3.42
Chinook	Mid Skeena Large Lakes	946	3984	4.22
Chinook	Mid Skeena Main Tributaries	714	2852	4.02
Chinook	Upper Bulkley	462	2427	5.26
Chinook	Upper Skeena	472	1003	2.18
Chum	Lower Skeena	288	959	3.53
Chum	Middle Skeena	736	3950	5.35
Chum	Upper Skeena	472	1003	2.18
Coho	Lower Skeena	288	959	3.53
Coho	Middle Skeena	736	3950	5.35
Coho	Upper Skeena	472	1003	2.18
Pink	Nass-Skeena Estuary (even)	288	959	3.53
Pink	Middle-Upper Skeena (even)	1005	4264	4.25
Pink	Lower Skeena (odd)	288	959	3.53
Pink	Middle-Upper Skeena (odd)	1005	4264	4.25
Sockeye-River	Skeena River	782	4175	5.34
Sockeye-River	Skeena River-High Interior	472	1003	2.18

3.3 Integrated Cumulative Habitat Pressures/Vulnerability

Figure 7 present for the different salmon species[3] (Chinook, coho, chum, pink (even), pink (odd), and river sockeye respectively) the integrated assessments of relative CU habitat status for spawning, incubation, and rearing/migration 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. So for example, as indicated in **Figure 7**, habitat status for all three life history stages of the Upper Bulkley Chinook CU would be considered poorest, as for each of the spawning, incubation and rearing/migration life history stages the Upper Bulkley CU displays the worst combined rankings for cumulative habitat pressures and vulnerability.

[3] Note that we have separated odd and even CUs of pink salmon for our integrated analyses, with the thinking that odd-year vs. even-year pink CUs could be experiencing sharply contrasting levels of habitat pressure intensities or contrasting vulnerabilities to those habitat pressures in their alternating years within Skeena watersheds that might make any comparisons more difficult across year types.

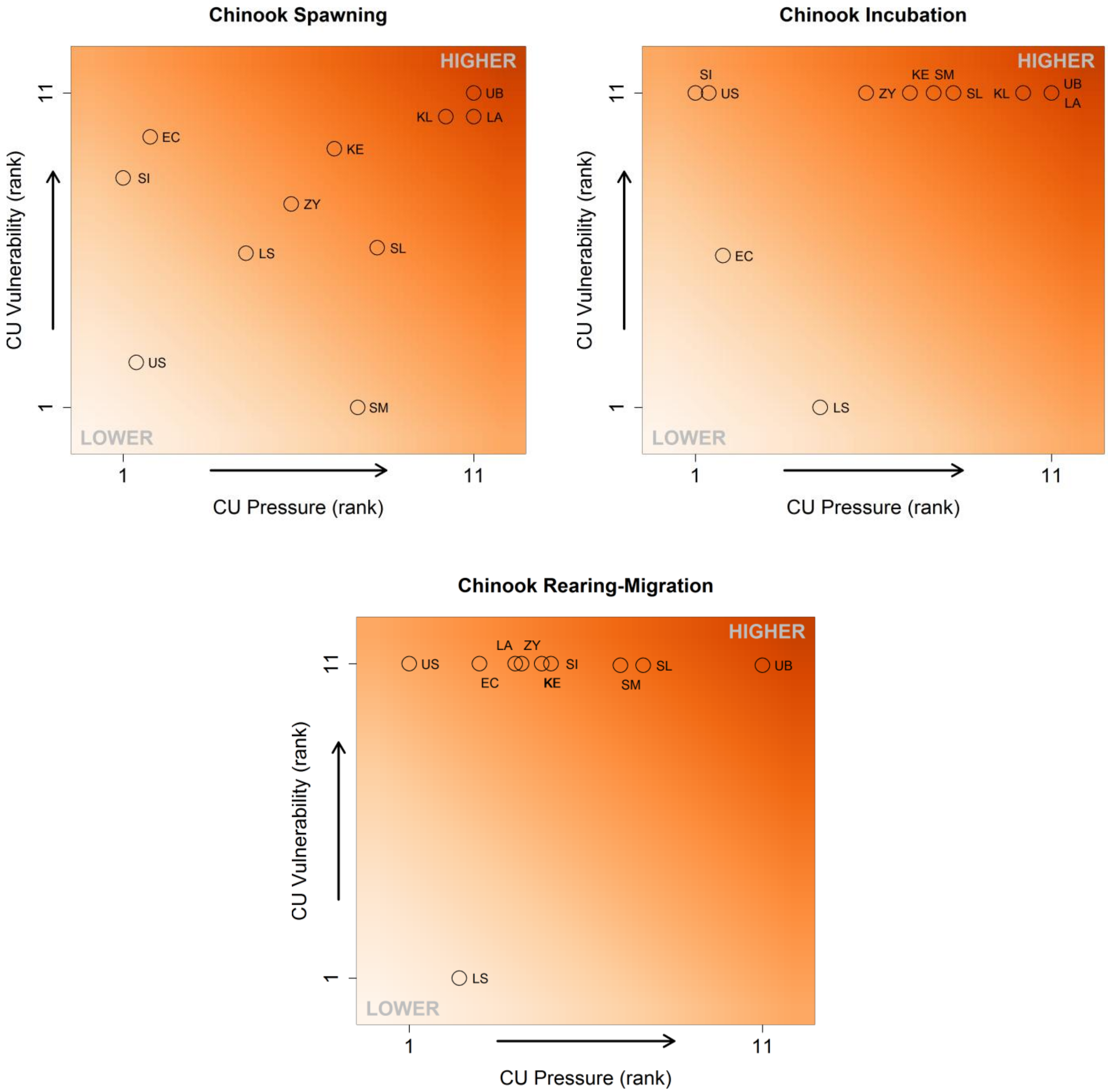

Figure 7 Integrated cumulative habitat pressure CU rankings vs. habitat vulnerability CU rankings for the different life history stages (spawning, incubation, migration/rearing) across Skeena Chinook CUs. Colour intensification indicates general increasing CU rankings along the axes (lower to higher relative rankings). The ranking position of each of the 11 Skeena Chinook CUs relative to each other is identified in the figure by a two-letter code: Ecstall=EC, Kalum (early) =KE, Kalum (late) =KL, Lakelse=LA, Lower Skeena=LS, Middle Skeena Large Lakes=SL, Middle Skeena Main Tributaries=SM, Upper Bulkley=UB, Upper Skeena=US, Zymoetz=ZY, Sicintine=SI.

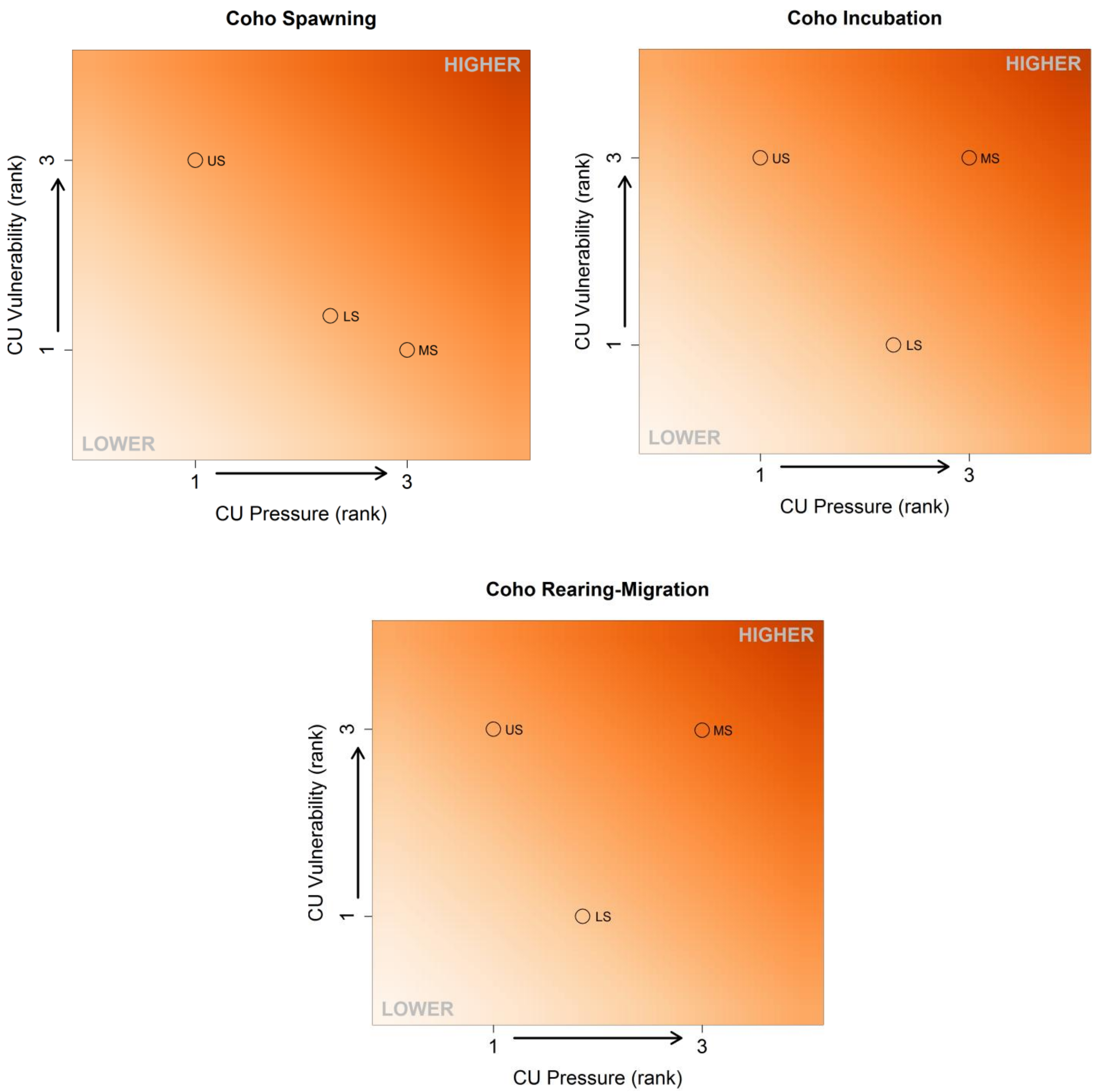

Figure 8 Integrated cumulative habitat pressure CU rankings vs. habitat vulnerability CU rankings for the different life history stages (spawning, incubation, migration/rearing) across Skeena coho CUs. Colour intensification indicates general increasing CU rankings along the axes (lower to higher relative rankings). The ranking position of each of the three Skeena coho CUs relative to each other is identified in the figure by a two-letter code: Lower Skeena=LS, Middle Skeena=MS, Upper Skeena=US.

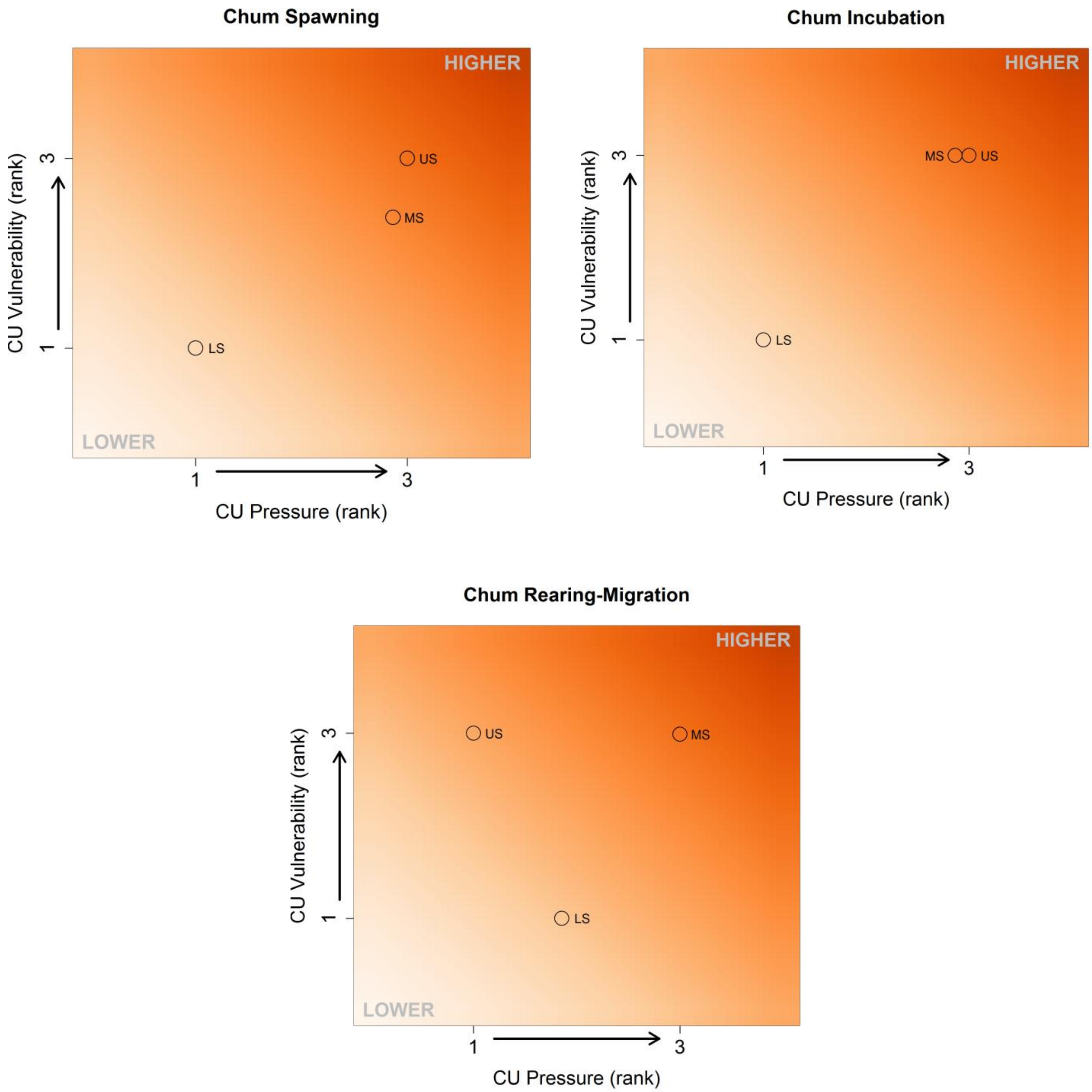

Figure 9 Integrated cumulative habitat pressure CU rankings vs. habitat vulnerability CU rankings for the different life history stages (spawning, incubation, migration/rearing) across Skeena chum CUs. Colour intensification indicates general increasing CU rankings along the axes (lower to higher relative rankings). The ranking position of each of the three Skeena chum CUs relative to each other is identified in the figure by a two-letter code: Lower Skeena=LS, Middle Skeena=MS, Upper Skeena=US.

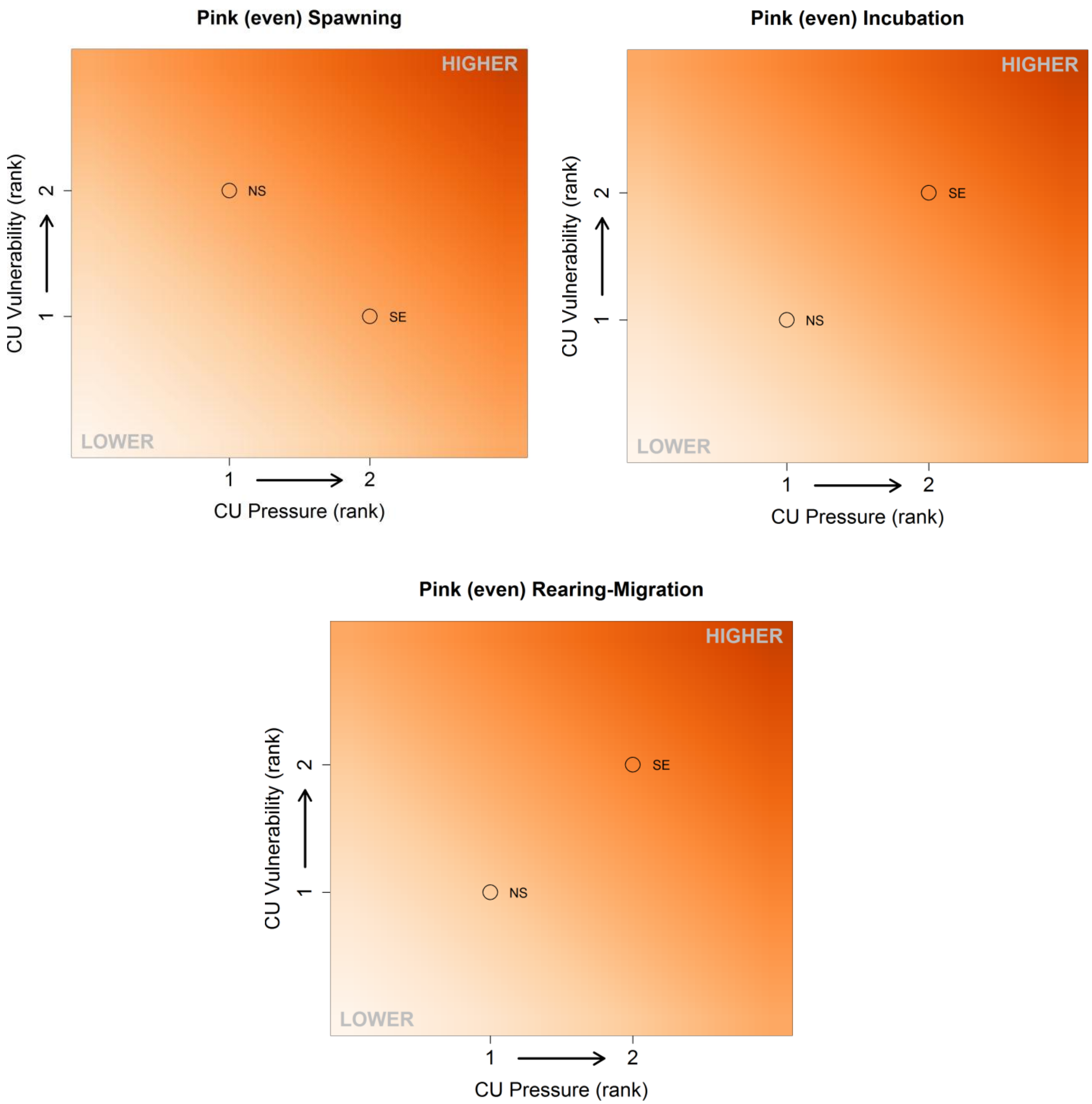

Figure 10 Integrated cumulative habitat pressure CU rankings vs. habitat vulnerability CU rankings for the different life history stages (spawning, incubation, migration/rearing) across Skeena pink (even) CUs. Colour intensification indicates general increasing CU rankings along the axes (lower to higher relative rankings). The ranking position of each of the two Skeena pink (even) CUs relative to each other is identified in the figure by a two-letter code: Nass-Skeena Estuary (even) =NS, Middle-Upper Skeena (even)=SE.

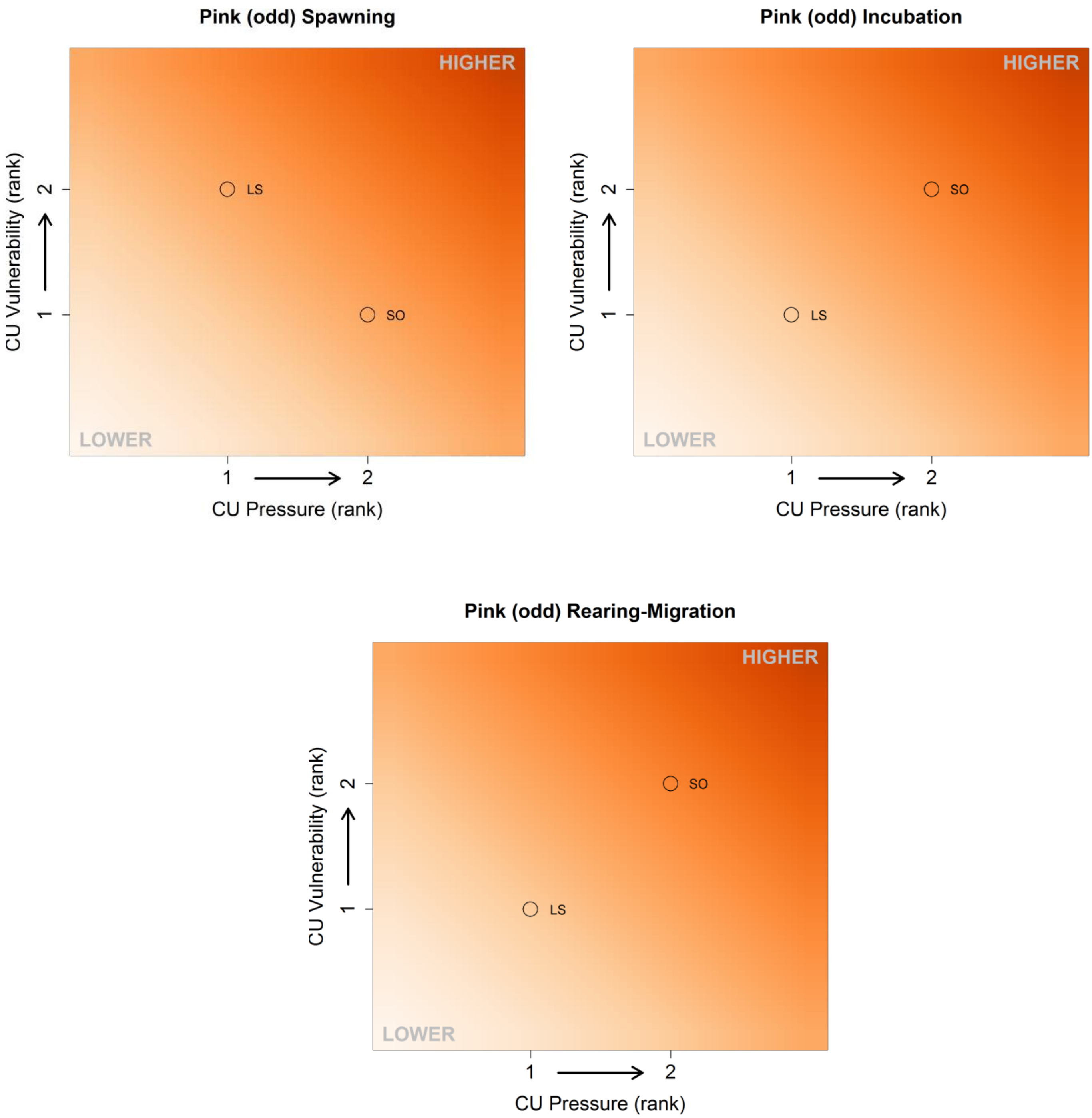

Figure 11 Integrated cumulative habitat pressure CU rankings vs. habitat vulnerability CU rankings for the different life history stages (spawning, incubation, migration/rearing) across Skeena pink (odd) CUs. Colour intensification indicates general increasing CU rankings along the two axes (lower to higher relative rankings). The ranking position of each of the two Skeena pink (odd) CUs relative to each other is identified in the figure by a two-letter code: Lower Skeena (odd)=LS, Middle-Upper Skeena (odd)=SO.

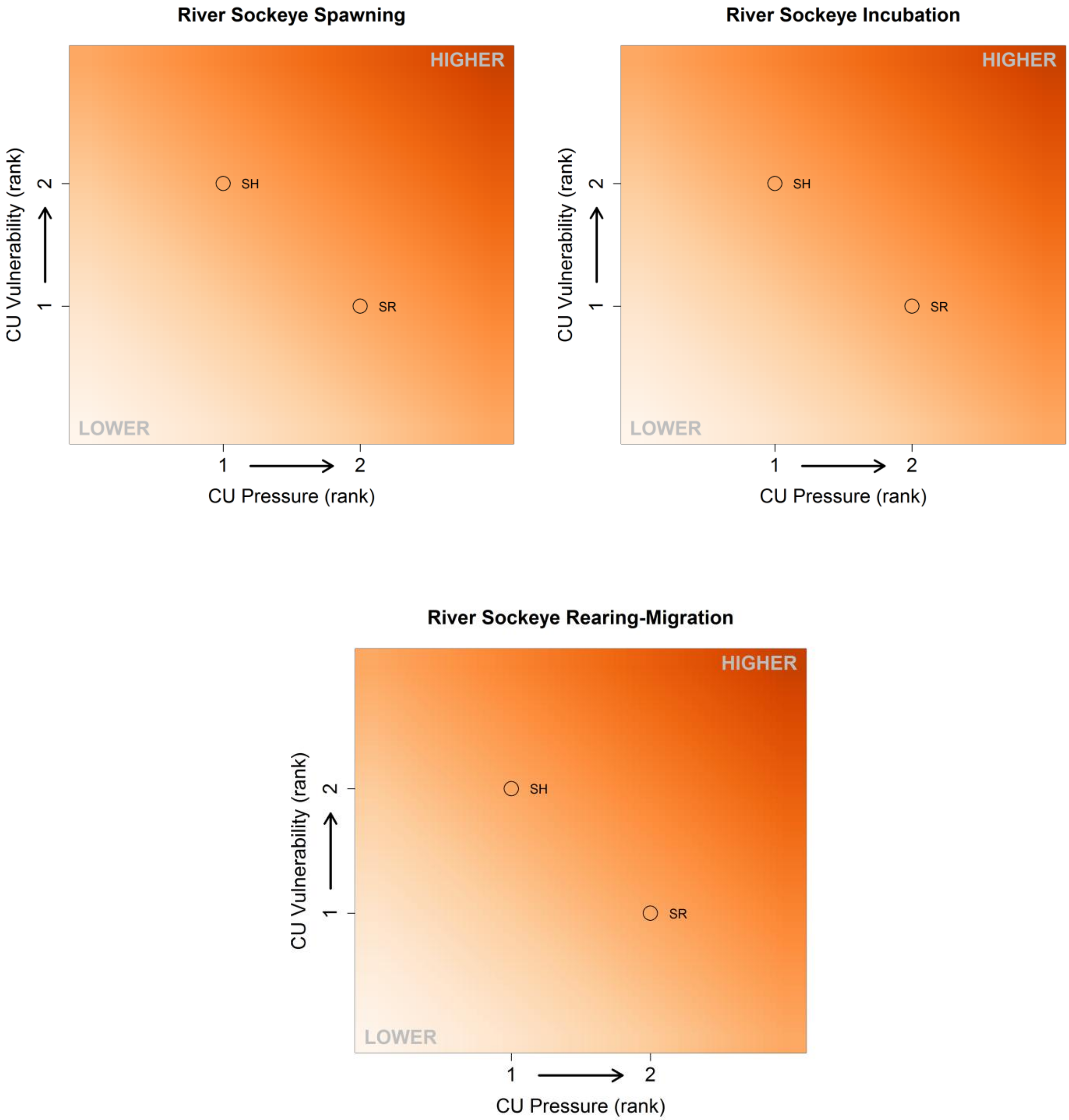

Figure 12 Integrated cumulative habitat pressure CU rankings vs. habitat vulnerability CU rankings for the different life history stages (spawning, incubation, migration/rearing) across Skeena river sockeye CUs. Colour intensification indicates general increasing CU rankings along the axes (lower to higher relative rankings). The ranking position of each of the two Skeena river sockeye CUs relative to each other is identified in the figure by a two-letter code: Skeena River=SR, Skeena River-High Interior=SH.

3.4 Habitat Pressure Indicators (Future)

3.4.1 Watersheds/CU ZOIs

The extent of potential new resource development activities (based on planning information available for the Skeena region as of 2010) within life-stage-specific ZOIs (spawning and rearing/migration) for each Skeena salmon CU is summarized in **Table 8.** Proposed development activities quantified for analyses were non-acid-generating mines, acid-generating mines, linear development, water licenses, and power tenures. The extent of proposed resource development activities varies across CUs, but most CUs show at least some level of potential new development planned within their spawning and rearing/migration ZOIs; exceptions are the spawning ZOIs for the river sockeye Skeena River – High Interior CU, the Chinook Sicintine CU, and the Chum Upper Skeena CU for which no proposed development is indicated.

Spawning ZOIs are embedded with the larger rearing/migration ZOIs for each CU, so the absolute extent of new development proposed within spawning ZOIs will be relatively smaller. However, any new development occurring within the bounds of the more geographically restricted spawning ZOIs could potentially present more concentrated impacts on critical spawning areas than would development activities spread throughout the larger rearing/migration ZOIs. CUs projected to have notable projected increases in resource development activities within their ***spawning ZOIs*** include **Chinook** – Mid Skeena Main Tributaries CU (seven new mines, two of which may be acid generating), Zymoetz CU (five new mines, two of which may be acid generating), Lower Skeena CU (11 new water licenses representing a 10.5% increase), Kalum (early) CU (0.051 km/km^2 increase in density of linear developments representing a 5.7% increase in linear development and 143 km^2 of new power tenures); **chum** – Lower Skeena CU (four new non-acid generating mines representing a 20% increase and seven new water licenses representing a 5.7% increase); **coho** - Lower Skeena CU (11 new mines, four of which may be acid generating, 16 new water licenses representing a 9% increase, and 180 km^2 of new power tenures), Middle Skeena CU (0.029 km/km^2 increase in density of linear development representing a 2.5% increase); **pink** - Lower Skeena (odd) and Nass-Skeena Estuary (even) CUs (14 new water licenses representing a 8.1% increase), Middle-Upper Skeena (odd and even) CUs (0.029 km/km^2 increase in linear developments representing a 2.2% increase).

Proposed development with the larger CU rearing/migration ZOIs can be quite extensive. CUs with notable levels of projected new development with their rearing/migration ZOIs are **Chinook** – Mid Skeena Large Lakes CU (30 new mines of which 11 may be acid generating, 26 new water licenses representing a 3% increase, and 335 km^2 of new power tenures), Upper Bulkley CU (20 new mines of which six may be acid generating, 0.023 km/km^2 of new linear development representing a 2.3 % increase, 292 km^2 of new power tenures); **chum** – Middle Skeena CU (27 new mines, of which 11 may be acid generating, 26 new water licenses representing a 2.9% increase, and 342 km^2 of new power tenures); **coho** – Middle Skeena CU (27 new mines, of which 11 may be acid generating, 26 new water licenses representing a 2.9% increase, and 342 km^2 of new power tenures); **pink** – Middle-Upper Skeena (odd and even) CUs (31 new mines of which 11 may be acid generating, 26 new water licenses representing a 2.9% increase, and 342 km^2 of new power tenures); **river sockeye** – Skeena River CU (29 new mines of which 13 may be acid generating, 0.018 km/km^2 increase in density of linear development representing a 1.9% increase, 31 new water licenses representing a 3.4% increase, and 498 km^2 of new power tenures).

Table 8 Potential increases in future resource development in spawning and rearing/migration Zones of Influence (ZOIs) for Skeena salmon CUs (based on new development activities proposed for the Skeena region as of 2010). Increases within each development category for each CU life history stage ZOI are identified by the absolute amount of proposed increase (#, km/km^2, or km^2) and by the percentage (%) increase over the current baseline development for that category (where known).

Species	CU Name	Life history stage ZOI	Proposed Non-Acid-Generating Mines (#)	Proposed Non-Acid-Generating Mines (%)	Proposed Acid-Generating Mines (#)	Proposed Acid-Generating Mines (%)	Proposed Linear Development (km/km^2)	Proposed Linear Development (%)	Proposed Water Licenses (#)	Proposed Water Licenses (%)	Proposed Power Tenures (km^2)
Chinook	Ecstall	Spawning	2	NA	0	NA	0.000	0.0	2	33.3	7
		Rearing/Migration	4	9.5	1	100.0	0.006	0.9	18	16.1	116
Chinook	Zymoetz	Spawning	3	100.0	2	200.0	0.018	2.0	2	5.6	39
		Rearing/Migration	8	17.8	3	150.0	0.013	2.0	20	16.5	155
Chinook	Lower Skeena	Spawning	2	6.7	1	100.0	0.010	1.2	11	10.5	78
		Rearing/Migration	4	9.5	1	100.0	0.005	0.9	18	16.1	116
Chinook	Kalum (early)	Spawning	0	0.0	2	NA	0.051	5.7	3	27.3	143
		Rearing/Migration	4	5.9	3	300.0	0.014	2.0	23	16.1	272
Chinook	Kalum (late)	Spawning	0	0.0	0	NA	0.069	3.7	3	8.3	51
		Rearing/Migration	4	5.9	3	300.0	0.014	2.0	23	16.1	272
Chinook	Lakelse	Spawning	1	50.0	0	NA	0.023	1.3	2	3.6	10
		Rearing/Migration	5	11.4	1	100.0	0.007	1.0	20	12.1	119
Chinook	Sicintine	Spawning	0	NA	0	NA	0.000	0.0	0	NA	0
		Rearing/Migration	10	18.2	6	150.0	0.004	0.6	19	12.2	159
Chinook	Mid Skeena Large Lakes	Spawning	1	8.3	6	300.0	0.038	3.8	1	1.9	31
		Rearing/Migration	19	18.4	11	157.1	0.014	1.8	26	3.0	335
Chinook	Mid Skeena Main Tributaries	Spawning	5	16.1	2	200.0	0.003	0.2	4	0.7	22
		Rearing/Migration	19	19.6	6	120.0	0.015	1.9	25	2.9	299
Chinook	Upper Bulkley	Spawning	0	0.0	0	0.0	0.066	3.7	1	1.1	84
		Rearing/Migration	14	15.2	6	120.0	0.023	2.3	25	3.0	292
Chinook	Upper Skeena	Spawning	4	80.0	0	NA	0.008	2.0	0	0.0	0
		Rearing/Migration	9	17.3	1	50.0	0.004	0.8	18	12.3	116
Chum	Lower Skeena	Spawning	4	20.0	0	0.0	0.014	1.4	7	5.7	32
		Rearing/Migration	9	12.3	5	250.0	0.018	2.5	27	13.2	315
Chum	Middle Skeena	Spawning	2	28.6	0	NA	0.013	1.0	0	0.0	7
		Rearing/Migration	16	15.8	11	157.1	0.017	1.7	26	2.9	342
Chum	Upper Skeena	Spawning	0	NA	0	NA	0.000	0.0	0	0.0	0

Species	CU Name	Life history stage ZOI	Proposed Non-Acid-Generating Mines (#)	Proposed Non-Acid-Generating Mines (%)	Proposed Acid-Generating Mines (#)	Proposed Acid-Generating Mines (%)	Proposed Linear Development (km/km^2)	Proposed Linear Development (%)	Proposed Water Licenses (#)	Proposed Water Licenses (%)	Proposed Power Tenures (km^2)
		Rearing/Migration	9	17.3	1	50.0	0.004	0.8	18	12.3	116
Coho	Lower Skeena	Spawning	7	12.7	4	200.0	0.021	2.2	16	9.0	180
		Rearing/Migration	9	12.3	5	250.0	0.018	2.5	27	13.2	315
Coho	Middle Skeena	Spawning	4	9.3	7	116.7	0.029	2.5	3	0.6	111
		Rearing/Migration	16	15.8	11	157.1	0.017	1.7	26	2.9	342
Coho	Upper Skeena	Spawning	3	150.0	0	NA	0.007	1.9	0	0.0	0
		Rearing/Migration	9	17.3	1	50.0	0.004	0.8	18	12.3	116
Pink	Nass-Skeena Estuary (even)	Spawning	3	9.4	1	100.0	0.014	1.3	14	8.1	60
		Rearing/Migration	9	12.3	5	250.0	0.018	2.5	27	13.2	315
Pink	Middle-Upper Skeena (even)	Spawning	3	11.1	2	200.0	0.029	2.2	3	0.9	32
		Rearing/Migration	20	18.9	11	157.1	0.013	1.7	26	2.9	342
Pink	Lower Skeena (odd)	Spawning	3	9.4	1	100.0	0.013	1.2	14	8.1	60
		Rearing/Migration	9	12.3	5	250.0	0.018	2.5	27	13.2	315
Pink	Middle-Upper Skeena (odd)	Spawning	3	11.1	2	200.0	0.029	2.2	3	0.9	32
		Rearing/Migration	20	18.9	11	157.1	0.013	1.7	26	2.9	342
Sockeye - River	Skeena River	Spawning	0	0.0	1	50.0	0.046	4.1	0	0.0	10
		Rearing/Migration	16	12.6	13	185.7	0.018	1.9	31	3.4	498
Sockeye - River	Skeena River-High Interior	Spawning	0	NA	0	NA	0.000	0.0	0	0.0	0
		Rearing/Migration	9	17.3	1	50.0	0.004	0.8	18	12.3	116

4 Summary and Recommendations

To improve our understanding of habitat status across Skeena salmon CUs, monitoring of habitat pressure and state/condition indicators needs to be undertaken in a more consistent manner on a regular basis across the Skeena Basin. Monitoring of habitat pressures and condition across the Skeena is largely uncoordinated, with monitoring responsibilities distributed across many different government agencies. Habitat evaluations may tend to focus on a particular issue (i.e., linkage to a specific habitat variable or stressor activity) in a particular location, using a particular methodology. Without consistent and repeatable methodologies, information on habitat trends will be lost and comparisons across CUs will not be possible. The CU habitat report cards for Chinook, coho, pink, chum and river sockeye developed for this project are largely based on habitat pressure indicators, as habitat state/condition indicator data (when available) tend to be localized, sporadic, and not generally amenable to broad synoptic overviews of relative habitat condition across CU watersheds. Expanded field-based monitoring of key habitat state/condition indicators within representative Skeena watersheds (as is currently being undertaken/planned in the Morice drainage as part of the MOE's cumulative effects assessment pilot project) would significantly improve the quality of information available for future reporting on the status of habitats used by Skeena salmon.

To improve understanding about the effects of stressors on freshwater habitats, there is a need for more precise estimates of the consequences of increasing habitat pressures on habitat state/condition (i.e., more defensible pressure indicator benchmarks). For most landscape pressures, the general mechanisms of effect on freshwater habitats are known, but estimates of the significance of a given pressure level are crude, especially when occurring in the presence of other types of pressure. Attempts to consistently define habitat pressure benchmarks/thresholds of concern 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 indicator values across the Skeena, rather than hard science/expert based benchmarks. While benchmarking based on relative ranking 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 Skeena 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 with the provincial agencies, would have the benefit of supporting the monitoring needs of both DFO (WSP Strategy 2) and the province (cumulative effects). Habitat indicator benchmarking exercises of this nature are now in early development, both provincially (e.g., Robertson et al. 2012) and within the Skeena region (e.g., Morice Salmon Cumulative Effects Assessment Workshop, June 12, 2013, Smithers, BC).

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) for persistence of salmon in freshwater habitats so that future issues in the Skeena might be better anticipated and avoided. Given the importance and extent of legislation and policies designed to govern land and water use, we believe 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 Skeena salmon.

For improved access to information by stakeholders, better communication tools are needed to relay the status of salmon and their habitats. The salmon species CU habitat report cards developed for this project provide an example of condensing large quantities of information into a digestible summary to inform Skeena stakeholders on salmon habitat issues. The report cards themselves will be downloadable from the Pacific Salmon Foundation's Skeena Salmon Program website (www.skeenasalmonprogram.ca), and the core Skeena habitat datasets that were assembled and analyzed for this project will be directly viewable on the website though a map-based interface.

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 Skeena salmon and their habitats. As such, there is a need to more consistently acquire information on freshwater habitats used by salmon in the Skeena River Basin, bring this information into useable formats for analyses, and share this information through data systems that are readily accessible/useable by multiple stakeholders. To improve access to information by scientists, formal data sharing agreements, pooling of resources for monitoring, and more integrated decision making are needed. Many federal and provincial agencies are responsible for collecting, summarizing, and reporting out on key variables of relevance to Skeena salmon (e.g., Fisheries and Oceans Canada, Environment Canada, Ministry of Natural Resource Operations, Ministry of Forests, Mines, and Lands, and Ministry of Environment). There is a need for a well-resourced body of scientists across agencies and local stakeholders (in terms of staff and funding) to coordinate an integrated fish and fish habitat monitoring program for the Skeena River Basin. The current cumulative effects pilot project ongoing in the Morice represents a potential opportunity to develop an example of a multi-agency/multi-stakeholder coordinated approach to freshwater habitat monitoring.

4.1 Future Improvements to CU Habitat Report Cards

Measures in the current CU habitat report cards of the total length of accessible fish habitat within Skeena salmon CUs were based on the province's Fish Passage Model criteria, which uses generalized salmonid passage abilities (based on stream gradient and identified major obstructions). These criteria are intended to help define the extent of upstream salmonid distributions. They are, however, based on the strong swimming abilities of bull trout and therefore are likely to overestimate the amount of habitat actually available and used by Pacific salmon species. Passage models specific to different salmon species would be a useful undertaking to better define the extent of habitat that could theoretically be accessible for use by Skeena salmon CUs.

The habitat pressure indicators used for this report represent a broad suite of information that has been derived using currently available provincial/federal agency models/GIS layers. Local datasets/GIS layers provided by the Skeena TAC have greatly improved the quality of the current data compilation/analyses undertaken for this project. Even with better local data, time series information for most habitat pressure indicators is generally lacking. However, as advances are made in capture of remote-sensed information through satellite imagery and associated development of supporting map-based products, it should soon become possible to greatly improve CU habitat reporting for a greater number of habitat pressure indicators and allow effective tracking of changing status of indicators at improved spatial resolutions.

The approaches taken in this project for aggregating habitat pressure indicators into cumulative risk scores for watersheds in CU life-stage-specific ZOIs (spawning, rearing/migration) were similar to (but expanded on) those used for scoring suites of indicators in other recent salmon habitat projects (e.g., Nelitz et al. 2011, Porter et al. 2013a,b) and were vetted by the Skeena TAC. Outputs from the analyses were also generally seen as realistic by the Skeena TAC (within their ability to evaluate results for CU watersheds they knew well). The approaches used for scoring effects to date should, however, be considered only a broad first-cut attempt at quantifying cumulative effects across suites of habitat indicators in the Skeena 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). Similar exploration of indicator aggregation approaches could potentially be a useful element of Skeena regional workshops currently intended for assessment of cumulative effects in Skeena watersheds (i.e., Morice cumulative effects pilot project).

Habitat risk across salmon CU ZOIs is defined in this report based solely on the relative intensity/magnitude of habitat pressures/stressors. While this does reflect the potential relative risk of causing 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 salmon CU life history 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 starting point. Further work is needed to identify additional vulnerability indicators that might be used to more fully capture and compare the potential vulnerabilities of Skeena salmon to habitat impacts and to determine how to incorporate them into expanded/improved CU risk scoring approaches.

Identification of potential salmon CU vulnerability indicators is a developing component of ongoing multi-stakeholder workshops currently being undertaken by DFO as they pilot approaches for developing a comprehensive risk assessment framework for Pacific salmon (W. Luedke, pers. comm.).

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Appendices

Appendix 1. List of Skeena Salmon Conservation Units (CUs) evaluated for this project.

Species	CU name
Chinook	Ecstall
	Zymoetz
	Lower Skeena
	Kalum (early)
	Kalum (late)
	Lakelse
	Sicintine
	Mid Skeena Large Lakes
	Mid Skeena Main Tributaries
	Upper Bulkley
	Upper Skeena
Coho	Lower Skeena
	Middle Skeena
	Upper Skeena
Chum	Lower Skeena
	Middle Skeena
	Upper Skeena
Pink	Nass-Skeena Estuary (even)
	Middle-Upper Skeena (even)
	Lower Skeena (odd)
	Middle-Upper Skeena (odd)
River Sockeye	Skeena River
	Skeena River-High Interior

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						
Spatial Scale	**Indicator**	**Input Data**	**Input Attributes/Features Used**	**Processing**	**Outputs**	**Notes**
Watersheds / CU ZOIs	Forest Disturbance	VRI, RESULTS, 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, 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 (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.	Watershed layer identifying the percentage ECA for each watershed.	See total land cover alteration.
	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[1]	Total Land Cover Alteration (below)	Total land cover alteration input features – See total land cover alteration indicator for	A layer representing the riparian zone (30 m buffer around streams and water bodies) for the	Watershed layer identifying the total	See total land cover alteration notes.

		restricted to riparian zone, FWA (streams, lakes, wetlands), MTS Consulting (2011)	details. Streams – <u>FTRCD</u> ‘GA24850000’ – River/Stream - Definite ‘GA24850140’ – River/Stream – Indefinite ‘GA24850150’ – River/Stream – Intermittent *’GA08800110’ – Ditch *’GA0395000’ – Canal Rivers – <u>FTRCD</u> ‘GA24850000’ – River/Stream - Definite Lakes – <u>WTRBDTP</u> *’L’ – Lake Wetlands – <u>WTRBDTP</u> *’W’ – Wetland ** See processing notes*	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 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.	altered riparian zone for each watershed.	

				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 Passage layer, BC MOE Road Crossings	FishHabitat – FISH_HABITAT 'FISH HABITAT – INFERRED' 'FISH HABITAT – OBSERVED' '<NULL>' RoadStreamCrossings – FISH_HABITAT 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.
	Culvert passability	PCIS culvert assessments, local Skeena culvert assessments (Skeena TAC)	Attributes relating to culvert passability – i.e., barrier/no barrier etc.	PCIS assessments and local Skeena assessments were merged into one single assessed culverts layer, with a single barrier attribute representing a state of 'barrier', 'passable', or 'unknown'.	Skeena culvert assessment layer.	This output was only used for presentation purposes at a watershed/CU scale.
	Number of water licenses (watersheds)	LMB Water License Points of Diversion	LIC_STATUS 'CURRENT' PURPOSE used for classification	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 was summarized by watershed. Licenses were also categorized into the following classes: power, domestic, agriculture, industrial, or storage.	Watershed layer identifying the total number of licenses within each watershed.	
	Total land cover alteration	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)	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 OPENING_IND 'Y': forestry OPENING_ID Not null: forestry HARVEST_DATE All polygons with a harvest date within last 60 years: forestry	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 VRI, RESULTS and FTEN. 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.	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. Neither the VRI, RESULTS nor FTEN cutblocks layers contain all logged areas, with each dataset containing logged polygons that the others do not contain. A 60 year cut off was used in

			H_FIRE_PLY – FIRE_YEAR >= 1993: fire C_FIRE_PLY – All features: fire RESULTS – DISTURBANCE_START_DATE All openings within last 60 years: forestry FTEN cutblocks– DISTURBANCE_START_DATE All cutblocks within last 60 years: forestry BTM - PLU_LABEL 'MINE': mining FTEN road segments – All features: roads DRA – All features: roads NMBRFLNS ROAD_CLASS TA_CROWN_TENURES_SVW – All current utility tenures: utility NTS – ENTITYNAME "RAILWAY": rail	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. 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.		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)
	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 <	Watershed layer identifying the percent of watershed area covered by impervious surface for each watershed.	

				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.		
	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, TAC identification of currently producing, past producing, and acid-generating mines	Mineral and coal mines from MINFILE – STATUS_D 'Developed Prospect', 'Past Producer' COMMODIT_D 'Coal' Aggregate mines from AGGINV04 and North Coast Aggregate Potential gravel pits. Placer mines from MTA_ACQ_TE_polygon – TNRTPDSCRP 'Placer'	Developed prospects and past producing mineral and coal mines were extracted from MINFILE and combined with aggregate mines. Mine locations were sent to the TAC for confirmation and identification of which mines are/were acid rock generating. Placer mine tenure polygons were converted to point features (center point), 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.	Watershed layer identifying the total number of mines for each watershed.	
	Mining development - # of acid-generating mines	MEM & PR database, Skeena TAC identification of currently producing, past producing, and acid-generating mines	Mineral and coal mines from MINFILE – STATUS_D 'Developed Prospect', 'Past Producer'	See mining development – total # of mines for a description. The total number of acid-generating mines was calculated for each watershed.	Watershed layer identifying the total number of acid-generating mines 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	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	Table of CU migration routes and total number of	Although the FISS obstructions layer is based on the 1:50K

		layers, CU Migration routes (see migration distance vulnerability indicator for details)		migration routes were selected. The total number of obstructions alone each migration route was calculated.	obstructions along each route.	Watershed Atlas, each point has the corresponding 1:20K FWA watershed code attributes associated with it.

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

Vulnerability Indicators						
Life History Stage	**Indicator**	**Input Data**	**Input Attributes/Features Used**	**Processing**	**Outputs**	**Notes**
Spawning period	Total spawning length	Spawning distributions for CUs of Chinook, coho, pink, chum, and river sockeye (provided by Skeena TAC)	<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	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	Percentage of spawning	<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	Table identifying the % of winter flow	

	flow sensitive (%)	reaches for each CU that are considered to be winter low flow sensitive	ACTIVITY 'spawning –% winter flow sensitive'	sensitive spawning was calculated for each CU.	sensitive spawning reaches for each CU.	
Rearing/Migration periods	Accessible habitat length	MOE Fish Passage Model	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**
CU ZOIs	Proposed resource development activities in CU ZOIs	MEM & PR database (Skeena TAC identification of prospects & potential acid-generating mines), LMB Water License Points of Diversion (proposed), Proposed BC Advance Exploration Sites From the Skeena TAC: Proposed NWBC-Wind, Proposed Pipelines, Proposed Transmission Lines, Proposed Wind & Water Power	Water License Points of Diversion – LIC_STATUS 'ACTIVE_APPL', 'PENDING'	Proposed resource developments were split into 5 indicators and summarized by watershed and by CU for life history stage ZOIs (rearing/migration, and), along with a percentage increase based on current values for that indicator. *Proposed mines* – Skeena TAC identified prospect mineral and coal mines (from MINFILE data) were combined with the BC advance exploration sites to give all potential new mines. *Proposed acid-generating mines* – Skeena TAC identified prospect acid-generating mines from MINFILE data. *Proposed linear development* – proposed transmission lines and pipelines (from Skeena TAC digitized data) were summarized as a density of linear development within each ZOI. *Proposed water licenses* – proposed POD license locations were summarized as a total number per ZOI. *Proposed power tenures* – proposed wind power and water power tenure areas were summed within each ZOI. No current wind or water power tenure data were available to provide a comparison, so no % increase value could be calculated.	Summary table of proposed developments in each of the 5 indicators within CU life history stage ZOIs (rearing/migration and spawning)	