Skeena Lake Sockeye Conservation Units: Habitat Report Cards

Prepared for:

Skeena Salmon Program
Pacific Salmon Foundation
300 - 1682 West 7th Avenue
Vancouver, British Columbia V6J 4S6

Prepared by:

Marc Porter, Darcy Pickard, Simon Casley, Nick Ochoski, K. Bryan and S. Huang

ESSA Technologies Ltd.
Suite 600-2695 Granville St.
Vancouver, BC

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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.
Lake sockeye / lake-type sockeye	Sockeye belonging to one of the two distinct life history types found among Skeena sockeye CUs. After hatching, fry from lake-type sockeye CUs migrate to a rearing lake where they spend a year feeding and maturing into smolts. In contrast, juveniles from river-type sockeye CUs rear in flowing water and may smolt soon after emergence.
Life history stage	An arbitrary age classification of salmon into categories related to body morphology, behaviour and reproductive potential, such as migration, spawning, egg incubation, fry, and juvenile rearing.
Mainstem	The main channel of a river in a watershed that tributary streams and smaller rivers feed into.
Pacific Salmon	Salmon of the Pacific Ocean regions, five species of which are managed by DFO in British Columbia: sockeye (*Oncorhynchus nerka*), pink

	(*Oncorhynchus gorbuscha*), chum (*Oncorhynchus keta*), coho (*Oncorhynchus kisutch*), and Chinook (*Oncorhynchus tshawytscha*).
Population	A group of interbreeding salmon that is sufficiently isolated (i.e., reduced genetic exchange) from other populations such that persistent adaptations to the local habitat can develop over time.
Pressure indicator	Measurable extent/intensity of natural processes or human activities that can directly or indirectly induce qualitative or quantitative changes in habitat condition/state.
Productive capacity	The maximum natural capability of habitats to produce healthy salmon or to support or produce aquatic organisms on which salmon depend.
Riparian zone	The area of vegetation near streams and other bodies of water that is influenced by proximity to water. For management purposes DFO guidelines generally recognize a defined riparian zone of 30m adjacent to waterbodies.
Risk	For analyses undertaken in this report risk is defined as the 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 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 Sockeye

The Skeena River is the second largest producer of sockeye salmon after the Fraser River. The drainage has one very large sockeye nursery lake (Babine Lake) and numerous smaller nursery lakes that are distributed from the coast to the high interior regions and vary in size and productivity (DFO 2003). Babine Lake compromises 67% of the total sockeye rearing area and traditionally accounts for about 75%-95% of total Skeena sockeye production (DFO 2003). Sockeye salmon represent the main target species for commercial fisheries harvest in the Skeena and represent 80% or more of the landed value of inside fisheries in the basin (SISRP 2008).

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). There are currently 31 lake-type sockeye CUs defined by DFO for the Skeena River Basin (see Appendix 1) and two river-type sockeye CUs. Within this report analyses are also included for a lake-rearing sockeye population in Onerka Lake, which DFO has indicated that they will be proposing for discussion as a potential CU. In addition to the currently defined Skeena lake sockeye CUs there are thought to have been Skeena lake rearing sockeye populations in Seeley, Canyon, Toboggan, Owen, and Lamprey lakes but these populations are now considered to be extinct (K. Rabnett, pers. comm.).

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 (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/stakeholders will look to pressure indicators to understand general policies that could be affective in alleviating pressures/stresses on habitats across salmon CUs. At more local scales, state indicators will be used to assess actual habitat condition and better understand watershed-specific conservation and restoration priorities.

The first tier of information in the pressure-state framework is provided by pressure indicators that represent proactive measures of potential impacts on salmon habitats. Based principally on remote-sensed information, pressure indicators can be captured/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/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 lake sockeye life history stages. For instance, lake-rearing sockeye use stream/river habitats for migration and spawning (Figure 1a), lake habitats for juvenile rearing (Figure 1b), and estuary habitats while transitioning between freshwater and marine environments (Figure 1c). Within these model diagrams, potential cause-effect linkages are represented by a series of boxes and arrows illustrating interactions among system components. Indicators of habitat pressures are represented by dark red boxes, indicators of habitat status are represented by white or light grey boxes, and life stages affected are represented by dark grey boxes. To illustrate, in Figure 1a *land cover alterations* (an example of a pressure indicator) can affect *stream discharge* (a state indicator). This linkage is supported by an understanding that the amount of water in a stream can affect spawning success by dictating the extent/quality of spawning habitat and by influencing egg viability.

1a – Stream/river habitats

1b – lake habitats

1c – estuary habitats

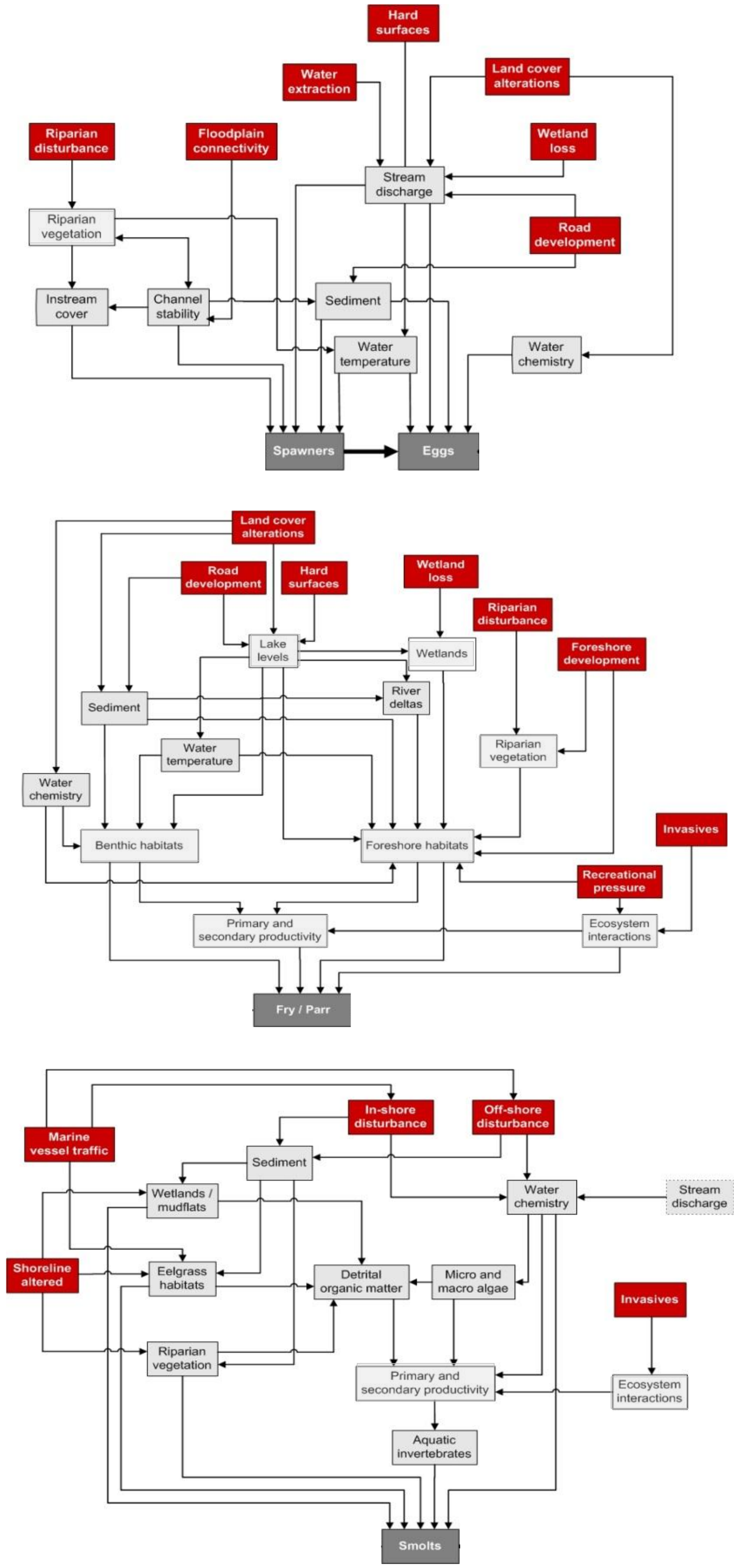

Figure 1 Examples of potential linkages between habitat pressure indicators (red boxes), habitat state indicators (light gray boxes), and lake sockeye life history stages (dark gray boxes) in stream/river (a), lake (b) and estuary (c) habitats (modified from Nelitz et al. 2007).

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 Skeena lake sockeye. The project is intended to provide a summary of the regional pressures facing Skeena lake sockeye habitats and a description of relative habitat risk for individual Skeena lake sockeye Conservation Units (CUs) (i.e., analogous to a CU Overview Report). Project methodology was based on approaches recently used for broad-scale evaluations of the status of freshwater habitats for the Lower Thompson coho CU (Beauchamp 2008), Fraser River sockeye CUs (Nelitz et al. 2011) and Southern Chinook CUs (Porter et al. 2012). These projects employed a varied suite of habitat pressure and habitat quantity/quality (vulnerability) indicators for assessment of lake, stream and estuary 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 lake sockeye CUs across the Skeena River Basin

2. Develop map-based Skeena lake sockeye CU habitat report cards that:

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

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

    c. Provide descriptions of key habitat state indicators (given information locally available within the Skeena River Basin) that could be linked to habitat conditions for Skeena sockeye CUs.

This report describes the methods and results of the synoptic regional-scale overview of habitat pressures and vulnerabilities within defined ZOIs for 32 lake sockeye CUs located in British Columbia's Skeena River Basin (31 CUs recognized currently by DFO and an additional proposed Onerka Lake CU). The list of Skeena lake sockeye CUs evaluated for this project is provided in Appendix 1, and the mapped location of each rearing/nursery lake is provided in Appendix 2.

2 Methods

2.1 Data Processing

All GIS data processing and map production was implemented using ESRI's ArcMap Desktop software, version 10.0. CU report cards were developed using Microsoft Publisher software and R programming language.

Appendix **3.** List of databases and GIS layers used or created for this project and the associated processing steps3 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 lake sockeye 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. 2013. Summaries in this report 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 core WSP habitat indicators used include: total land cover alteration, road development, water allocations, riparian disturbance, permitted discharges, estuary disturbance, estuary habitat area, accessible stream length, spawning areas, lake shore spawning, lake productive capacity). The additional indicators used in this report (i.e., ECA, insect and disease defoliation, stream crossing density, impervious surfaces, acid-generating mines, migration distance, low flow sensitive areas, ratio of lake influenced spawning to total spawning, area of nursery lakes, number of migration obstructions) are considered valuable for providing more information on salmon habitats but most were not thought technically feasible to acquire at broad scales at the time of the Stalberg et al. 2009 paper. They are now more readily available through improvements in agency/local reporting and supporting GIS layers. The habitat indicators proposed for analysis and reporting by ESSA were reviewed/vetted by the project's TAC before final selection and supplemented with local datasets where feasible.

2.2.1 Habitat Pressure Indicators (Current)

Watersheds/CU ZOIs

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

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

Mining Development (# of mines): current and past mine sites (of all types) within a watershed

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

Mining Development (# of acid-generating mines): current and past mine sites within a watershed that have been identified by the Skeena TAC as being acid-generating.

- *Acid-generating mining sites can cause additional impacts to water quality through changes to water chemistry, introduction of heavy metals, and other contaminants that may have lethal or sublethal effects on different salmon life history stages (Meehan 1991; Nelson et al. 1991; Kondolf 1991).*

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Stream Crossing Density (#/km): the number of stream crossings per km of the total linear length of modeled salmonid habitat in a watershed (delineation of salmonid "habitat" based on MOE Fish Habitat model).

- *Stream crossings at roads can (dependent on the type of crossing structure) create fish passage problems by interfering with or blocking access to upstream habitats that include spawning or rearing areas and reduce the total amount of available salmonid habitat in a watershed (Harper and Quigley 2000; BC MOF 2002). Stream crossings can also influence the efficiency of water delivery to the stream network so that high densities can increase peak flows and become a chronic source of fine sediment delivery to streams (MOF 1995a; Smith and Redding 2012).*

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

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

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

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

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

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

<u>Skeena Estuary</u>

Current Development (Skeena Estuary): mapped locations and extents of major development infrastructure currently occurring within the Skeena Estuary.

- *Increasing development in the estuary has the potential to cause loss of salmon habitat directly through the footprint of associated infrastructure (e.g., wharfs, jetties, weirs, embankments, anchorages, etc.) or more indirectly through disruption of current patterns and sediment distribution (Cooper et al. 1994). Continued activities (e.g., dredging, transport of goods) around development could also impact water quality through effects on water chemistry and potentially exposes fish to contaminants that could have lethal or sublethal effects on salmon during periods of estuary residence. Alteration and/or loss of estuarine habitat through development tends to reduce the overall amount of useable habitat, and reduces the general productivity of estuaries (and food production), which can limit the overall utility of these areas for sockeye.*

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 Skeena lake sockeye habitats. A broad suite of habitat pressure indicators have been quantified for this report and used to define relative risk of adverse effects to sockeye habitat within CU watersheds. However, it must be noted that the actual "risk" to sockeye populations using these habitats will be a combination both of the intensity/extent of habitat pressures and life-stage-specific sensitivities/vulnerabilities. Vulnerability/sensitivity 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 as possible with information on the relative vulnerability of CUs to freshwater habitat pressures (vulnerability being 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 by which 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.

Migration Period

Total Migration Distance (km): the linear length of the CU migration distance as measured from the mouth of the Skeena River to the outlet of the CU rearing lake.

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

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

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

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

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

Spawning Period

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

- *The total length of areas of identified lake sockeye spawning indicates the scope of opportunities for successful spawning for a CU.*

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

- *Reflects the known amount of lakeshore spawning habitat used by Skeena lake sockeye.*

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

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

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

- *Reflects the known amount of mainstem and lake outlet spawning (i.e., lake influenced) habitat used by Skeena lake salmon.*

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

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

Accessible Stream Length (km): the total linear length of stream within a lake sockeye CU's rearing lake ZOI that is 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 sockeye which are likely to have a more restricted distribution within a watershed.]

- *The total length of (modelled) salmonid accessible stream length will determine the total amount of useable habitat that sockeye could (theoretically) access for spawning and rearing needs.*

<u>**Rearing Period**</u>

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

- *Given their use of lake habitats, it is possible to estimate the quantity and quality of sockeye salmon rearing habitat in BC from lake size and measures of lake productivity such as photosynthetic rate (PR) (Hume et al. 1996; Shortreed et al. 2000). Lake area is also considered a reasonable surrogate of habitat productivity since it is a primary driver in productivity relationships (Randall 2003). While annual lake-to-lake differences in productivity per unit area are important, the extent of the* *rearing habitat available can strongly dictate the potential total smolt production from a CU.*

Rearing Lake Productive Capacity (R_{max} – estimated) (kg/ha): the annual biomass of sockeye smolts that could be produced theoretically in lake sockeye rearing lakes based on DFO's Photosynthetic Rate (PR) model for estimating the intrinsic lake rearing capacity (Cox-Rogers et al. 2010; Cox-Rogers 2012).

- *Sockeye salmon fry are almost exclusively limnetic planktivores, so they are strongly coupled to limnetic zooplankton production (Shortreed et al. 2000). While fry models provide a direct estimate of rearing capacity, many years of data are required to generate a relationship for any lake. DFO's photosynthetic rate (PR) model appears to be a useful predictor of rearing capacity, and predictions can be made after only 1–2 years (Hume et al. 1996). PR-based estimates of productive capacity have been proposed for habitat benchmark setting within DFO's Wild Salmon Policy (Stalberg et al. 2009). Correlations between PR and juvenile sockeye salmon abundance can be used to estimate the maximum capacity of a nursery lake to produce smolts (biomass and numbers), as well as estimate optimum escapement (Shortreed et al. 2001). DFO's PR-based estimates therefore provide a comparative measure of juvenile productive capacity across sockeye salmon CUs (although not yet available for all Skeena sockeye CU rearing lakes).*

Sockeye Escapements (as surrogate for marine nutrient inputs) (# spawners): the average number of wild sockeye spawners returning to the CU rearing lake each year (averaged from 1991 to 2010).

- *Average escapement numbers for each lake sockeye CU (derived from English 2013) provide a relative indication of the amounts of marine-derived nutrients inputs to the CU rearing lake that are derived from the carcasses of returning sockeye spawners. Marine-derived nutrients deposited by salmon carcasses are retained in lakes and can be important for enhancing nutrient levels present in naturally low productivity coastal lakes (Schmidt et al. 1998; Schindler et al. 2003).*

<u>**Estuary Residence Period**</u>

Estuary Area (km^2): the total surface area of the Skeena Estuary, boundaries as defined by the Skeena TAC.

- *The total area represented by the Skeena Estuary provides an indication of the potential amount of useable estuarine habitat that is available to sustain staging smolts and returning adult spawners for sockeye and other salmon species migrating through the Skeena Estuary (Stalberg et al. 2009).*

2.2.3 Habitat State/Condition Indicators

Review of available data for the Skeena River Basin suggests that measures of freshwater habitat state/condition are scarce and scattered spatially, generally not allowing comparisons of habitat condition to be made broadly at the resolution of CU ZOI watersheds. There is however a moderate amount of water quantity data available for most parts of the Skeena River Basin, although the majority of the data is from relatively low-elevation gauging stations

(Rabnett 2009). Water monitoring data is lacking in the upper Skeena above Babine River, in the lower Skeena downstream of Terrace, and in some sub-basins. These sub-basins include the Zymoetz (Copper), the upper Bulkley, the Morrison (Babine), and the Suskwa (Rabnett 2009). Given the growing need to examine measures of water quality and quantity in order to strengthen the understanding of potential effects from climate change that could affect salmon habitats in the Skeena we developed time series assessments of patterns in key water quantity indicators using the available datasets for the Skeena. While this information is limited spatially (i.e., cannot resolve/compare patterns at the scale of individual lake sockeye CUs) it can provide an indication of whether there are any recent trends in water quantity/quality across the Skeena River Basin (focused on the critical period of summer low flows) that could conceivably have general impacts on migration, spawning and rearing habitats used by sockeye and other salmon species. Additionally, some mapping of the distribution of key habitat types in the Skeena Estuary has been undertaken by local entities, and we provided this as indicators of current habitat state/condition in the estuary.

Skeena River Basin

Glacier Extent (km^2): the area extent of glaciers within Skeena River Basin subdrainages as determined in 1985 and again in 2005, and the change in that extent over that 20 year period (GIS data provided by Matt Beedle (University of Northern British Columbia) based on analyses within Bolch et al. 2010).

- *Glacier runoff can be a vital component of surface flows in glaciated drainage basins of British Columbia, especially during summer when water demand is high (Stahl and Moore 2006). Glaciers represent natural reservoirs that can yield the most water during the driest periods of late summer. As glaciers retreat the size of the reservoir shrinks and so does the available runoff to support sufficient flows to maintain salmon habitats (although the significance of this impact will vary by drainage dependent on the contribution of glacier runoff to natural stream flows).*

Summer Flows (m^3/s): the minimum average monthly water flow each year measured during the summer period (July- September) at Water Survey of Canada (WSC) gauging stations from various locations within the Skeena River Basin (all active stations with at least 18 years of data from between 1991-2010). This period of flow monitoring coincides with the peak period of sockeye spawning in the Skeena River Basin, which occurs from late July to October (DFO 1999).

- *Sockeye migrating and spawning through the summer months need adequate stream flows to provide unimpeded access to spawning areas and to provide proper spawner distributions on the spawning grounds. In addition to potential impacts on water quality (i.e., water temperature and dissolved oxygen), low stream flows can limit sockeye spawner distribution to sub-optimal stream reaches, or force fish to spawn in the center of the stream channel which can lead to increased egg and alevin mortalities during winter floods (WDFW 2013).*

Snowpack (mm): the depth of snow pack/pillow each year as defined by snow water equivalent (SWE) as measured on April 1st at BC River Forecast Center (RFC) automatic and manual snow monitoring sites from varied locations throughout the Skeena River Basin (all stations with at least 10 years of data between 1991-2010). Recent workups of RFC provincial snow pack datasets provided by Russell Smith (WaterSmith Research Inc.).

- *Surface runoff from snowmelt can be essential for maintaining seasonal flows in coastal streams, especially during the summer when demand for water is high (Barnett et al. 2005). Snow field extents can have significant influences on water quantity, water quality (e.g., water temperature), and timing of flow events; all critical factors for maintaining aquatic habitat conditions for salmon.*

Skeena Estuary

Eelgrass (ha): the current location and mapped extents of eelgrass beds within the defined boundaries of the Skeena Estuary. GIS layer provided by Barb Faggetter (Ocean Ecology).

- *Juvenile sockeye smolts emigrate to salt water after one or two years, and early marine survival is dependent on abundant food resources and sheltered estuarine habitats (WDFW 2013). Juvenile sockeye salmon spend the first part of their marine lives in estuaries. Although their residence time in these areas may be the shortest for any of the salmon species, sockeye salmon are still dependent to a degree on healthy estuarine habitats to maintain populations. Eelgrass supports high biodiversity of forage fish and plankton and represents an important nearshore habitat for staging sockeye smolts*.

BORSTAD Habitat Mapping: Surveys of the location and extent of different foreshore and intertidal habitats undertaken within the Skeena Estuary along Flora Banks and Prince Rupert Harbour. Undertaken originally by Borstad Associates Ltd in 1996 and updated by WWF in 2010. The updated BORSTAD GIS layer was provided by James Casey (WWF).

- *Estuaries contain a diversity of habitat types, each of which supports different assemblages of species. Maintaining a high diversity of productive estuary foreshore vegetation and healthy intertidal habitats is important for supporting a productive food base for staging salmon smolts (FREMP 2006; MOE 2006)*.

2.2.4 Habitat Pressure Indicators (Future)

Watersheds/CU ZOIs

Proposed Resource Development Projects in CU ZOI-Associated Watersheds (#/extent): The number, length, or density of different key resource development related indicators (i.e., mines, acid-generating mines, linear development, water licenses, power tenures) known to be planned (as of 2010) across watersheds within lake sockeye CU ZOIs (migration, spawning, and rearing), as well as the increase in development extent that the proposed projects represent over the current base level of development within the ZOIs.

- *Information on proposed development activities, while not a measure for defining or comparing current relative habitat pressures on sockeye habitats, will be important to consider/evaluate from a longer term cumulative effects perspective (i.e., habitat status of watersheds currently experiencing limited pressures could potentially change in the future given proposed regional resource development/extraction activities).*

Skeena Estuary

Proposed Resource Development Projects in the Skeena Estuary (#/extent): The location and general mapped extents of proposed new developments (e.g., wind power tenures, container terminals, LNG facilities, marine wharfs, transmission lines, utility corridors, etc.) known to be planned (as of 2013) within the defined boundaries of the Skeena Estuary. Tenure information on proposed development in the Skeena Estuary was provided by the Skeena TAC while information on specific proposed projects was extracted from the websites for the Canadian Environmental Assessment Agency (CEAA) and the BC Environmental Assessment Office (EAO). Mapped extents for projects represent general digitized approximations undertaken by ESSA; accuracy varying dependent on quality of engineering plans/information publicly available for each project and cannot be used for impact quantification purposes.

- *Information on additional proposed development activities will be important to consider/evaluate from a longer term cumulative effects perspective (i.e., status of the Skeena Estuary habitats could potentially change in the future given proposed regional development plans (Robertson et al. 2012).*

WWF Climate Change Impact Model (sea surface temperature, acidity and UV): potential climate impact maps (based on exposure and sensitivity) of projected sea surface temperature (SST), acidity, and UVB changes along BC's Pacific Coast (Okey et al. 2012). GIS layers depicting the modelled potential impact scores for surface waters (2 km x 2 km grid resolution) for the Skeena Estuary (derived from the Okey et al. 2012 analyses) were provided by Selina Agbayani (WWF).

- *Estuarine habitats are important as nursery and juvenile rearing habitats and are considered to be sensitive to changes in physical and chemical conditions that may result from climate stressors like temperature change, acidification and UV exposure (Okey et al. 2012). Increases in UV levels, for example, have been shown to increase mortality of early fish life stages (Poloczanska et al. 2007), while the combined effects of changes in SST and ocean acidity could cause shifts in fish distributions and community assemblages by depth and latitude (Orr et al. 2005 and Byrne et al. 2010 as cited in Okey et al. 2012).*

Skeena River Basin

A warming and changing climate is likely to exacerbate existing stresses from local land management. While impacts to watersheds across the Skeena River Basin will likely vary depending on geographic location, some potential increased risks to conditions for sockeye habitats could include:

- Warmer air and water temperatures
- Reduced snowpack
- Changes in seasonal precipitation (lower in some seasons, potentially more intense and concentrated in others)
- Changes in streamflow volume and seasonal timing (potentially higher in early spring, lower in summer)

Modelling of projected changes in actual stream flows and water temperature is a complicated exercise (not possible within this project) but estimates of projected changes in air temperature and precipitation (potential drivers to varying degrees of both water quantity (flows) and water quality (water temperature) can be extracted fairly easily from provincial climate models available from the ClimateBC/WNA website. The potential effects of changing air temperature and precipitation are considered to be integrated over time and space through various hydrological and land atmosphere feedback processes (Leung et al. 2004). While these modelled future predictions cannot inform assessment/comparisons at the spatial resolution of individual Skeena lake sockeye CU ZOIs, nor can they be used directly to define possible thresholds of concern for air temperature or precipitation effects on sockeye stream/lake habitats, they can be used to indicate possible future patterns of concern across salmon habitats in the Skeena River Basin.

Predicted Future Summer Air Temperature (^{o}C) and Predicted Future Summer Precipitation (mm): ClimateBC/WNA-modeled estimates of the maximum average monthly air temperature and the minimum monthly precipitation at various locations across the Skeena River Basin during the potentially critical period of summer low flow (July-September) for the historical baseline (1960-1990), the current time period (2000-2009), and as projected into future time periods (2020, 2050, and 2080). Projected air temperatures and precipitation at the three future time periods were determined across three alternative climate models (CHCM3, HADCM3, and HADGEM) which are considered to represent an illustrative set of model scenarios for exploring potential climate change impacts within British Columbia (Murdock and Spittlehouse 2011).

- *High water temperatures and low flows can affect salmon by increasing energy expenditures, create physical or thermal blockages to migration, exacerbate the progression of diseases and parasites, and decrease fecundity of eggs (Carter 2005; Crossin et al. 2008). Modelling of both projected future water temperatures and flow conditions within specific Skeena lake sockeye CU habitats, while potentially a doable analysis (see Nelitz et al. 2009 for an example), was considered beyond the scope of this project. We instead used air temperature as a surrogate pressure indicator that would potentially have an influence on actual water temperatures within CU-associated habitats and precipitation as a surrogate pressure indicator that would have a potential influence on stream flows. While snow melt and groundwater are important in maintaining summer flows there are undoubted linkages between rainfall patterns and seasonal stream flow (e.g., Siegel 2009; Hu et al. 2011; BC Ministry of Environment streamflow and drought conditions: Information Bulletins). There is also a well-known relationship between air and water temperatures (e.g., Stefan and Preud'homme1993; Morrison et al. 2002; Voss et al. 2008), although the strength of this relationship is highly variable as stream thermal response to air temperature can depend on a suite of local influences (e.g., groundwater inputs, riparian type, hydrology, geomorphology, etc.) (Isaak et al. 2010). [**Note:** No benchmarks have been defined for the air temperature or precipitation indicators; only information on projected trends (change) (if any) is provided*]. *As indicated,* climate *change could also affect the timing and intensity of precipitation across other seasonal periods that would have different effects on fish habitat conditions beyond our targeted summer low flow period (e.g., winter rains triggering high flows that could cause scour damage). Our analyses did not cover this broader scope of potential climate change impacts.*

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 interim benchmarking step until regional science/expert-based indicator benchmarks can be further developed, the weakness of a relative ranking approach is that all of the watersheds could in reality be quite healthy or alternatively they could all be at risk in an absolute sense, regardless of their relative ranking. However, this approach at 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 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 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 50^{th} and 75^{th} percentiles we simply categorized watersheds that had this pressure present as being at relatively high risk (i.e., binary risk classification based on presence/absence of the pressure in the watershed). This approach suffers from the same pitfall as the first in that presence does not necessarily imply a watershed-level problem. However, as described above, the relative benchmarking approach reliably identifies potential problem watersheds and is a useful way to compare and contrast similar habitat pressures across numerous watersheds and CUs, until such time as more research is conducted to produce empirically based benchmarks for all indicators.

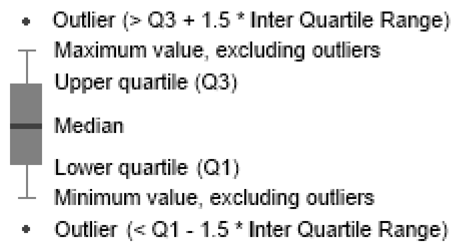

Figure 2 Key to interpreting a "box plot" used for assigning a relative risk score to a habitat pressure indicator value. The plot includes a box indicating the inner 50th percentile of the data (known as the interquartile range, IQR), whiskers showing the robust data range, outliers, and median. The top and bottom of the box are the 25th (Q1) and 75^{th} (Q3) percentiles. The size of the box is called the Interquartile Range (IQR) and is defined as IQR = Q(3) - Q(1). The whiskers extend to the most extreme data points which are not considered outliers. The horizontal line inside the box represents the median (50^{th} 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 Lake Sockeye 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 lake sockeye CUs (as defined in Holtby et al. 2007), and in which life-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-stage-specific ZOIs that could be used to bound our comparative analyses of habitat status for the different Skeena lake sockeye CUs.

2.4.1 Rearing Lake ZOI

For each CU, we identified the principal nursery lake and defined an upstream ZOI simply by delineating the areas of all 1:20K FWA “fundamental” watersheds present upstream of the lake outlet. For instances where there are other lake sockeye CUs located upstream, the ZOI for the lower lake is terminated at the outlet of the upstream CU lake. Hence, for situations where there are three lakes in close proximity (for example), each lake in the sequence will have its own upstream, non-overlapping ZOI defined, even though the three lakes and the full surrounding drainage area might be considered as a single unit for management purposes.

2.4.2 Mainstem, Lake and Tributary Spawning ZOIs

1. The ZOI for any mainstem/lake outlet or lake spawning sites identified in a CU will be the same as the ZOI that has been defined for the CU rearing lake.
2. The ZOIs for lake inlet/tributary spawners, while embedded within the broader area of each CU's rearing lake ZOI, are more precisely defined. The individual 1:20K FWA assessment watersheds in which spawning areas are identified/mapped **and** the FWA assessment watersheds directly upstream of these areas represent the ZOI around any tributary spawning areas. The composite of all these FWA watersheds represents the total ZOI area for lake inlet/tributary spawning within a CU.

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

2.4.3 Migration Corridor ZOI

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

2.5 Calculation of Cumulative Risk Ratings for Watersheds within Skeena Lake Sockeye 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 lake sockeye 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. 20011) and an indicators mapping project for the Lower Thompson coho CU (Beauchamp 2008) generated cumulative habitat stressor/impact scores based on a simple summation of all the individually scored indictors (i.e., a higher total score equates to higher risk). Habitat assessments undertaken in Porter et al. 2013 employed an alternative approach for rating relative risk (green/amber/red) for Southern Chinook CU-associated watersheds in which cumulative risk scoring was instead based on an indicator “roll-up” rule set. The rule set (based on five unweighted key habitat pressure indicators) required a defined number (at least four) of the pressure indicators to be rated lower risk (green) for the cumulative risk score to also be green. If a defined number of pressure indicators (two or more) were rated higher risk (red) then the cumulative risk score would be red. Any other combination of individual indicator risk ratings would result in a moderate-risk (amber) cumulative risk rating for a CU watershed. For our analyses we used derivations of both approaches (i.e., simple risk score summations and scoring rollup rule sets) for assigning cumulative risk scoring for watersheds in Skeena lake sockeye CU ZOIs, depending on the life-history stage assessed.

For watersheds in CU rearing lake and tributary spawning ZOIs, we developed (similarly to Porter et al. 2013) a cumulative risk rule set that was based on roll-ups of both 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 with lake sockeye habitats.

Table 1 provides descriptions of the specific rule sets used for defining cumulative habitat risk ratings for watersheds in lake sockeye CU rearing lake and tributary spawning ZOIs.

Table 1 Habitat pressure indicator and habitat Impact Category “roll-up” rule sets used for developing cumulative habitat risk ratings for watersheds within Skeena lake sockeye CU rearing lake and tributary spawning zones of influence.

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

Impact Categories	Embedded Habitat Pressure Indicators	Individual Impact Category Roll-up
Hydrologic Processes	ECA, forest disturbance	if ≥ 1 indicator rated red then Impact Category rated red, if 2 Indicators rated green then Impact Category rated green, else Impact Category rated amber

Surface Erosion	road density	if the indicator is rated green then Impact Category rated green, if the indicator is rated amber then Impact Category rated amber, if the indicator is rated red then Impact Category rated red
Fish Passage/Habitat Connectivity	stream crossing density in 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 $\geq$ 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 $\geq$ 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 $\geq$ 2 indicators rated red then Impact Category rated red, if $\geq$ 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	$\geq$ 5/7	-
Red	-	$\geq$ 3/7
Amber	< 5/7	< 3/7

For scoring of cumulative risk within the CU migration corridor ZOI, we employed the same 1st level "within Impact Category" rule set as used for tributary and 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 migration corridor 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 migration corridor 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 migration corridor ZOI. Scoring of the cumulative risks along the migration corridor ZOI using this alternative approach provides a better spatial representation of the changing pressure intensities along the migration route and also better accounts for the more diffuse nature of the impacts (i.e., migrating sockeye are not using the ZOI-defined watersheds themselves but are instead experiencing the effects as they are manifested and potentially compounded downstream in the receiving mainstem river migration corridor).

2.6 Summary of Habitat Indicator Information

Table 2 provides a summary of the indicators for habitat vulnerability (based on measures of habitat quantity and quality) and habitat pressure that have been included in the 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 lake sockeye 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[1]			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			Sockeye spawning distribution (provided by Skeena TAC), FWA hydrology	Stalberg et al. 2009 (WSP)
	Length of lake shore spawning areas	km	CU spawning ZOI	n/a	No specific CU benchmarks defined – comparisons based on each CU's ranked value relative to the other CUs			Sockeye lakeshore spawning zones (provided by Skeena TAC); FWA hydrology	Stalberg et al. 2009 (WSP)
	Length of lake influenced (mainstem/lake outlet) spawning areas	km	CU spawning ZOI	n/a	No specific CU benchmarks defined – comparisons based on each CU's ranked value relative to the other CUs			Sockeye mainstem/lake outlet spawning zones (provided by Skeena TAC), FWA hydrology	Nelitz et al. 2011; Arp et al. 2006; Myers et al. 2007; Jones 2010
	Length of tributary/lake inlet spawning areas	km	CU spawning ZOI	n/a	No specific CU benchmarks defined – comparisons based on each CU's ranked value relative to the other CUs			Sockeye tributary spawning zones (provided by Skeena TAC), FWA hydrology	Nelitz et al. 2011; Arp et al. 2006; Myers et al. 2007; Jones 2010
	Ratio of all lake influenced spawning to total spawning	0 – 1 scale	CU spawning ZOI	n/a	No specific CU benchmarks defined – comparisons based on each CU's ranked value relative to the other CUs			Sockeye spawning distribution (provided by Skeena TAC), FWA hydrology	Nelitz et al. 2011; Arp et al. 2006; Myers et al. 2007; Jones 2010
	Accessible habitat	km	CU spawning ZOI	n/a	No specific CU benchmarks defined – comparisons based on each CU's ranked value relative to the other CUs			MOE Fish Passage Model; FWA hydrology	Stalberg et al. 2009 (WSP)
Rearing period	Nursery lake area	ha	CU rearing ZOI	n/a	No specific CU benchmarks defined – comparisons based on each CU's ranked value relative to the other CUs			FWA lakes, DFO designated sockeye CU nursery lakes (+ Onerka Lake)	Nelitz et al. 2011; Randall 2003

[1] **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

	Nursery lake productive capacity	kg/ha	CU rearing ZOI	n/a	No specific CU benchmarks defined – comparisons based on each CU's ranked value relative to the other CUs	DFO designated nursery lakes; S.Cox-Rogers et al. (2010, 2012)	Stalberg et al. 2009 (WSP); Cox-Rogers et al. 2010, 2012
	Sockeye escapement	Average annual # of spawners (1991 – 2010)	CU	n/a	No specific CU benchmarks defined within this project– comparisons based on each CU's average escapement relative to the other CUs	Corrected Skeena sockeye CU escapement numbers based on English 2013.	Porter et al. 2013
Migration period	Migration distance	km	CU migration ZOI	n/a	No specific CU benchmarks defined – comparisons based on each CU's ranked value relative to the other CUs	DFO and Skeena TAC designated sockeye CU nursery lakes, FWA hydrology	Nelitz et al. 2011; Crossin et al. 2004
	Flow sensitivity	Distance (km) **and** % of CU migration route defined as summer low flow sensitive	CU migration ZOI	Science based/expert based (Ptolemy unpubl.)	No specific CU benchmark defined – comparisons based on each CU's ranked value relative to the other CUs	BC MOE ecoregional flow sensitivity mapping (R. Ptolemy, unpubl.)	Richter et al. 1997; R. Ptolemy (unpubl.)
Estuary residence	Estuary area	km^2	Skeena estuary (applies to all CUs)	n/a	No CU benchmarks defined – single value for Skeena Estuary	Skeena TAC	Stalberg et al. 2009 (WSP); Robertson et al. 2012
Habitat Pressure Indicators							
Migration Corridor ZOI	Migration obstructions (total)	# of obstructions	CU migration ZOI	n/a	No specific CU benchmark defined – comparisons based on each CU's ranked value relative to the other CUs	FISS Obstructions layer, FWA Obstructions layers	Wood 2001; Ricker 1987
	Licensed water use permits (total)	# of water permits	CU migration ZOI	n/a	No specific CU benchmark defined – comparisons based on each CU's ranked value relative to the other CUs	LMB Water License Points of Diversion (POD)	Nelitz et al. 2007; Stalberg et al. 2009 (WSP), Nelitz et al. 2011

	Cumulative CU migration corridor stressor score Combined stressor rating across pressure Impact Categories and their associated indicators	n/a	CU migration ZOI	Indicator roll-up decision rule set	Summation of the seven Impact Category ratings within watersheds in the migration corridor 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 migration ZOI therefore ranges from 0 to 14.			Multiple data sources used across the habitat pressure indicators to inform the 7 Impact Categories	Rollup and summation of individual pressure indicator risk ratings for presentation of a composite score for assessing relative cumulative habitat risk status Nelitz et al. 2011; Nelitz et al. 2007; Porter et al. 2012; Beauchamp 2008, Porter et al. 2013
Rearing and 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/km^2	watershed	green/amber (science/expert based – Stalberg et al. 2009); amber/red (science based – MOF 1995a,b & Porter et al. 2012)	< 0.4	≥ 0.4 to < 1.2	≥ 1.2	DRA, FTEN	Stalberg et al. 2009 (WSP), MOF 1995a,b; MOF 2001
	Fish Passage/Habitat Connectivity								

	Stream crossing density + 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/km²	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 rearing and spawning ZOIs Combined stressor rating across 7 Impact Categories and their associated habitat pressure indicators	n/a	watershed	Indicator roll-up decision rule set	Roll up rule set criteria for defining lower relative risk of cumulative impacts (i.e., ≥ 5 Impact Categories rated green)	Roll up rule set criteria for defining a moderate relative risk of cumulative impacts (i.e., < 5 Impact Categories rated green and < 3 Impact Categories rated red)	Roll up rule set criteria for defining higher relative risk of cumulative impacts (i.e., ≥ 3 Impact Categories rated red	Multiple data sources used across the habitat pressure indicators to inform the 7 Impact Categories roll up and summation of individual pressure indicator Impact Category risk ratings for presentation of a composite score for assessing relative cumulative habitat risk status in each watershed	Nelitz et al. 2011; Nelitz et al. 2007; Porter et al. 2012; Beauchamp 2008, Porter et al. 2013

Skeena Estuary	Protected areas and current development activities	General mapped extents	Skeena estuary (applies to all CUs)	n/a	No specific CU benchmarks defined – single measurement for Skeena Estuary	BC PECP tenures. Wildlife Management Areas; Conservancy Areas; Parks, Ecological Reserves and Protected Areas; Current Skeena Estuary development activities – Skeena TAC	Stalberg et al. 2009; Robertson et al. 2012
Habitat Condition Indicators							
Skeena River Basin	Summer stream flow	m^3/sec	Skeena River Basin WSC flow gauging sites	n/a	No specific CU benchmarks defined – comparisons based on flow trends across Skeena flow gauging stations	Water Survey of Canada (WSC) flow gauges database	Stalberg et al. 2009; Nelitz et al. 2007; Robertson et al. 2012
	Snowpack	mm	Skeena River Basin RFC snowpack monitoring sites	n/a	No specific CU benchmarks defined – comparisons based on snowpack trends across Skeena snow monitoring stations	BC River Forecast Centre snowpack monitoring database	Robertson et al. 2012
	Glacier extent	km^2	Skeena River Basin subdrainages	n/a	No specific CU benchmarks defined – comparisons based on trends in glacier extent across Skeena subdrainages	GIS layer of Skeena glacier extent (1985 vs. 2005) (provided by M. Beedle, UNBC)	Robertson et al. 2012
Skeena Estuary	Eelgrass and kelp extents	ha	Skeena Estuary (applies to all CUs)	n/a	No specific CU benchmarks defined – single measurement for Skeena Estuary	GIS layer of the current location and extent of marine plants/macroalgae within the Skeena Estuary (provided by B. Faggetter, Ocean Ecology)	Nelitz et al. 2007 Robertson et al. 2012
	Intertidal habitat mapping	ha	Limited area of Skeena Estuary (applies to all CUs)	n/a	No specific CU benchmarks defined – identification of intertidal habitats within surveyed areas of the Skeena Estuary (Flora Banks and Prince Rupert Harbour)	Updated GIS layer of Skeena intertidal habitat mapping undertaken by BORSTAD Associates Ltd. (provided by J. Casey, WWF).	Nelitz et al. 2007 Robertson et al. 2012

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, spawning & migration	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 (provided by Skeena TAC – from multiple data sources)	Skeena TAC
Skeena Estuary	Proposed resource development (future pressures) - proposed development infrastructure in the Skeena Estuary	Multiple indicators - various unit (#, ha)	Skeena Estuary (applies to all CUs)	n/a	No specific CU benchmarks defined. Potential increases in development within the Skeena Estuary (appropriate only for general mapping purposes, information too crude for quantification purposes)	Proposed development within the defined boundaries of the Skeena Estuary (GIS layers provided by Skeena TAC or digitized (approximations) by ESSA using planning documents available from CEAA and BC EAO websites)	Skeena TAC
	Climate Change Impacts Scoring (WWF model)	Rated scale of climate change impacts	Skeena Estuary (applies to all CUs)	n/a	No specific CU benchmarks defined – impact scores apply generally for Skeena Estuary	GIS layer for modeled potential climate change impacts (based on exposure and sensitivity) from SST, acidification and/or UV changes for habitats within Skeena Estuary (2 km x 2 km grid) (provided by Selina Agbayani, WWF)	Nelitz et al. 2007; Ban et al. 2010
Skeena River Basin	Modelled Air temperature	°C	Skeena River Basin – selected sites: broad geographic representation	n/a	No specific CU benchmarks defined – comparisons based on trends in modelled future air temperature across air temperature modeling sites	ClimateBC/WNA model database	Nelitz et al. 2007; Nelitz et al. 2011; Robertson et al. 2012; Porter et al. 2013
	Modelled Precipitation (rainfall)	mm	Skeena River Basin – selected sites: broad geographic representation	n/a	No specific CU benchmarks defined – comparisons based on trends in modelled future precipitation across precipitation modelling sites (same locations as for air temperature)	ClimateBC/WNA model database	Nelitz et al. 2009; Robertson et al. 2012

2.7 "Average" Habitat Pressure Indicator Risk Ratings across Watersheds within Skeena Lake Sockeye CU ZOIs

In addition to individual and composite/cumulative indicator risk scoring for individual watersheds within life stage ZOIs we also determined the "average" risk scores for the pressure indicators across all watersheds in each lake sockeye CU's rearing lake 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 rearing lake ZOI). The area-weighted average risk scores were then normalized to a 0 to 1 scale for each habitat pressure indicator, with a low to moderate risk benchmark (i.e., green to amber transition) set at 0.33 and a moderate to high risk benchmark (i.e., amber to red transition) set at 0.66 on the normalized scale for each indicator. The normalized area weighted indicator averages are presented in each lake sockeye 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 rearing lake's ZOI.

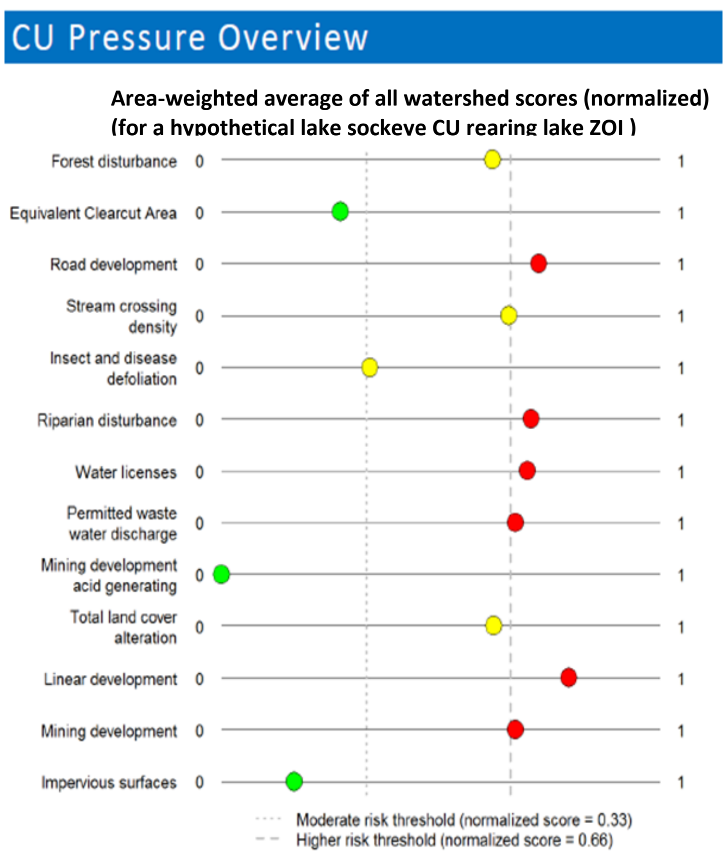

Figure 3 Example "slider" for illustrating the normalized area-weighted average watershed pressure indicator risk scores across a (hypothetical) rearing lake zone of influence (ZOI) for a Skeena lake sockeye CU.

2.8 Integrated Habitat Pressures and Vulnerabilities Rankings Across Skeena Lake Sockeye CU Migration, Spawning, and Rearing ZOIs

Given a general lack of comprehensive information that could be used to reliably assess differences in habitat condition across all spawning, rearing, and migratory habitats for Skeena lake sockeye we have instead defined relative lake sockeye 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, rearing and/or migratory habitats, would be considered to have a relatively poor habitat status. Conversely, a CU with limited vulnerability (relatively less sensitive) and minimal human development pressure would be considered as having a relatively good habitat status. We stress that these are only relative indices based on CU rankings for these indicators at this time. Even those CUs rated as having relatively high habitat pressures and relatively high vulnerability may not have any demonstrated actual negative impacts of human stressors on sockeye salmon freshwater survival. In the future, with continued work on the effects of landscape habitat pressures and sockeye 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 CU Migration Corridor Vulnerability/Cumulative Pressure Index

<u>Migration Corridor Habitat Vulnerability Indicators (Habitat Quantity and Quality):</u>

1. Total migration distance (km) for the CU (longer distance = greater vulnerability to impacts).
2. Length (km) of CU migration route (km) that goes through areas that are considered to be summer low flow sensitive (July –September) (longer distance = greater vulnerability to impacts).
3. Percentage (%) of CU migration route that goes through areas that are considered to be summer low flow sensitive (July – September) (greater percentage = greater vulnerability to impacts).

<u>Migration Corridor Vulnerability Index Rule Set:</u>

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

Migration Corridor Cumulative Habitat Pressure Indicators:

1. Total # of water license allocations within the CU migration corridor ZOI. A higher number of water licenses = greater cumulative pressure.
2. Total # of identified FISS/FWA obstructions along the CU migration corridor. A higher number of potential migration obstructions = greater cumulative pressure.
3. Cumulative migration pressure score: Area-weighted total of all scored cumulative risk classifications for watersheds along the length of a CU migration corridor (see Section 2.6 for a description of cumulative risk scoring approach for each watershed in the migration corridor ZOI). An area-weighted total for the migration corridor was generated by multiplying the cumulative risk scores for individual watersheds by the percentage of the total migration corridor ZOI area that is represented by watersheds with that particular cumulative risk score [e.g., Area-weighted total score for CU migration corridor pressures = (7*0.21) + (3*0.23) + (13*0.18) + (9*0.18) + (2*0.14) + (1*0.06) = 6.46 (where whole numbers in this example calculation represent cumulative risk scores for individual watersheds and fractional values represent the proportion of the total area for all watersheds in the migration corridor that are represented by watersheds having that particular cumulative pressure score (numbers hypothetical)]. A higher total area-weighted cumulative risk score across all migration corridor ZOI watersheds = greater cumulative pressure.

Migration Cumulative Pressure Index Rule Set:

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

Figure 4 provides an example of the outputs of this analysis, showing (for a hypothetical CU) its ranked index score relative to other Skeena lake sockeye CUs along the two axes of habitat vulnerability and cumulative habitat pressure (together providing a broad relative assessment of a CU's migratory corridor habitat status).

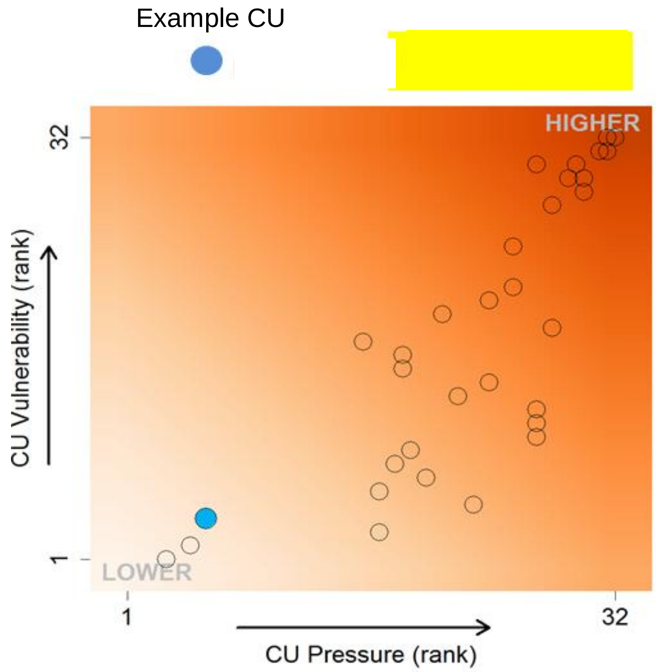

Figure 4 Example output from integrated CU habitat vulnerability and cumulative habitat pressures analysis for defining the relative ranking of habitat "status" across migration corridors for Skeena lake sockeye CUs (blue circle represents a hypothetical ranking for an example CU). CUs in the upper right hand quadrant would have both the highest vulnerability and are experiencing the highest cumulative habitat pressures in the migration corridor relative to other CUs.

2.8.2 CU Spawning Areas Vulnerability/Pressure Index

Spawning Areas Habitat Vulnerability Indicators (Habitat Quantity and Quality):

1. Total extent (km) of known spawning habitat mapped for the CU (less spawning habitat = greater vulnerability to impacts).
2. Length (km) of CU spawning that occurs in a lake (less lake spawning = greater vulnerability to impacts).
3. Length (km) of CU spawning that occurs in tributary/lake inlet stream (more tributary spawning = greater vulnerability to impacts).
4. Length (km) of CU spawning that occurs in the mainstem/lake outlets (less mainstem/lake outlet spawning = greater vulnerability to impacts).
5. Ratio of lake influenced (i.e., lake and mainstem/lake outlet) spawning to total spawning (lower ratio = greater vulnerability to impacts).
6. Length (km) of accessible salmonid habitat within the rearing lake ZOI (less accessible habitat = greater vulnerability to impacts).

Spawning Areas Vulnerability Index Rule Set:

Use either the total spawning length or the ratio of lake influenced spawning to total spawning habitat vulnerability indicators[2]. Consider both indicators to be equally weighted and plot the lowest (worst) ranking between the two indicators (i.e., ranked as relatively the more vulnerable compared to other lake sockeye CUs) as the particular CU's ranking point (e.g., if ranked 12th for total spawning length and 14th for lake influenced/tributary spawning ratio plot the 14th rank to represent the relative spawning areas vulnerability score for the CU). This approach is intended to identify the most serious spawning habitat vulnerability for a particular CU relative to other lake sockeye CUs in the Skeena.

Spawning Areas Cumulative Habitat Pressure Indicators:

1. Percentage (%) of all watersheds within a CU in which spawning is occurring (mainstem, lake or tributary/lake inlet) that are classified as either red or amber for cumulative habitat pressures. A higher % of "at risk" watersheds in a CU = greater cumulative pressure. All watersheds in which spawning is occurring are considered of critical importance and no differentiation is made as to red or amber watershed risk classifications for this overall pressure assessment.

Spawning Areas Cumulative Pressure Index Rule Set:

Plot the ranked score for this one spawning area pressure indicator as this CU's ranking point (i.e., CUs with a greater % of watersheds with red or amber cumulative risk classifications will have parallel higher relative rankings for the spawning areas cumulative risk index). **Figure 5** provides an example of the outputs of this analysis, showing (for a hypothetical CU) its ranked index score relative to other Skeena lake sockeye 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).

[2] Lake spawning is embedded in the "ratio of lake influenced to total spawning" indicator so is considered already captured. Accessible salmonid habitat could be considered a unique and equally important indicator to also include. However, the current estimate in this regard is based on the general BC MOE Fish Habitat model which is based on salmonid passage criteria focused on bull trout/Dolly Varden trout that will overestimate the amount of stream habitat that might actually be accessible to sockeye spawners. If sockeye-specific passage models were developed this indicator would become a more meaningful measure of relative CU vulnerability.

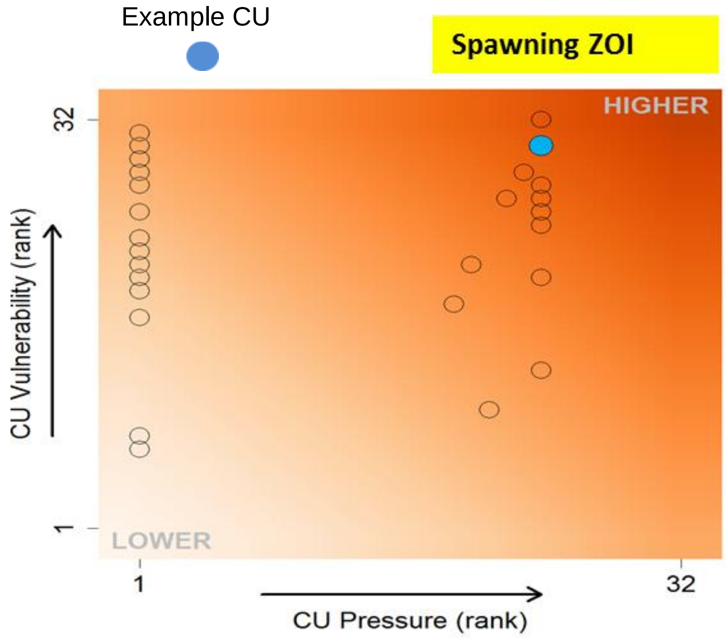

Figure 5 Example output from integrated CU habitat vulnerability and cumulative habitat pressures analysis for defining the relative ranking of habitat "status" across spawning areas for Skeena lake sockeye CUs (blue circle represents a hypothetical ranking for an example CU). CUs in the upper right hand quadrant would have both the highest vulnerability and are experiencing the highest cumulative habitat pressures in spawning areas relative to other CUs.

2.8.3 CU Rearing Lakes Vulnerability/Pressure Index

<u>Rearing Lake Habitat Vulnerability Indicators (Habitat Quantity and Quality):</u>

1. Area (km^2) of CU nursery/rearing lakes (smaller lakes = greater vulnerability to impacts).
2. Nursery lake productive capacity (Rmax estimated kg/ha) (lower productivity = greater vulnerability to impacts).

<u>Rearing Lake Vulnerability Index Rule Set:</u>

Use either the lake size or the lake productivity indicator. Consider both vulnerability indicators to be equally weighted and plot the lowest (worst) ranking between the two indicators (i.e., ranked as relatively the more vulnerable compared to other lake sockeye CUs) as the particular CU's ranking point (e.g., if ranked 6th for lake size and 11th for lake productivity plot the 11th rank to represent the relative migration corridor 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 lake sockeye CUs in the Skeena. For some CUs, however, there is no lake productivity information available. For these CUs the vulnerability assessment is based on the CU lake size ranking only.

Rearing Lake Cumulative Habitat Pressure Indicators:

1. Total score of all combined individual habitat pressure indicator risk classifications within a CU's rearing lake ZOI (based on the area-weighted averages of all rearing lake ZOI watershed scores – see Section 2.8). The sum of these individual scores represented the total cumulative pressure index score for the CU rearing lake (the CU's cumulative pressure index score ranges from 0 to 13, based on the normalized 0-1 risk scoring across the 13 individual habitat pressure indicators). A higher combined score across the rearing lake habitat pressure indicators = greater cumulative pressure.

Rearing Lake Cumulative Pressure Index Rule Set:

Plot the combined score for the cumulative rearing lake pressures as this CU's ranking point for the cumulative pressure index. **Figure 6** provides an example of the outputs of this analysis, showing (for a hypothetical CU) its ranked index score relative to other Skeena lake sockeye CUs along the two axes of habitat vulnerability and cumulative habitat pressure (together providing a broad relative assessment of a CU's rearing lake habitat status).

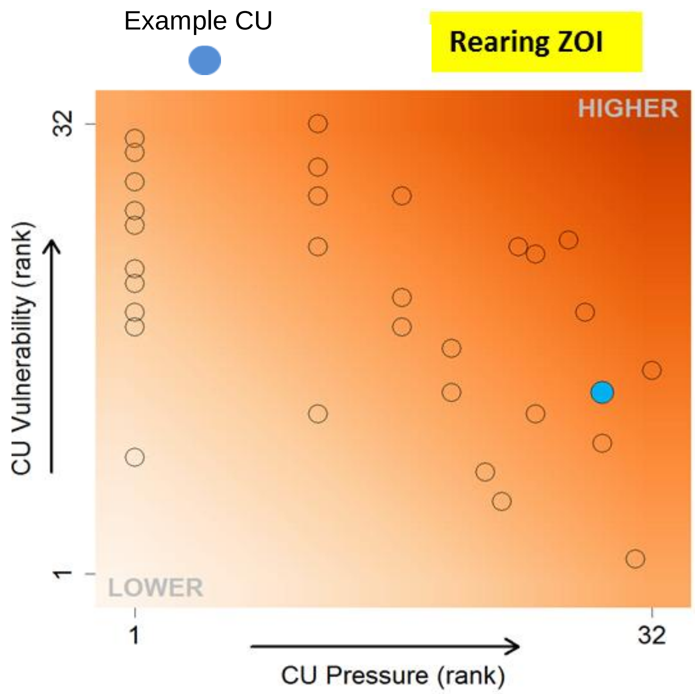

Figure 6 Example output from integrated CU habitat vulnerability and cumulative habitat pressures analysis for defining the relative ranking of habitat "status" across rearing lakes for Skeena lake sockeye CUs (blue circle represents a hypothetical ranking for an example CU). CUs in the upper right hand quadrant would have both the highest vulnerability and are experiencing the highest cumulative habitat pressures in rearing lakes relative to other CUs.

3 Results

3.1 Skeena Lake Sockeye CU Habitat Report Cards

Summaries of habitat indicator information within defined life history stage-specific ZOIs have been developed for all Skeena lake sockeye 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 32 lake sockeye CUs defined for the Skeena River Basin. Current habitat pressure indicators within delineated CU ZOI watersheds are rated for their relative risk (higher, moderate, or lower) of degrading fish habitat, while vulnerability indicators are rated for their relative (ranked) sensitivity to those potential habitat disturbances. Summary information is presented for each CU in graphical and map-based presentation formats. Results of these comparative habitat analyses are presented in Habitat Report Cards for each of the Skeena lake sockeye CUs (see Lakelse CU Habitat Report Card example in Appendix 4 and the associated descriptive summary of report card elements in Appendix 5) and can be viewed and/or downloaded at the Pacific Foundation (PSF) Skeena Salmon Program website: www.skeenasalmonprogram.ca.

These report cards provide a considerable amount of detail, describing the current and potential future habitat pressures/risks affecting each Skeena lake sockeye CU. The CU report cards are based on similar approaches used by Nelitz et al. 2011 and Porter et al. 2013 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 lake sockeye and that could contribute to the overall performance of a lake sockeye CU.

Walking through the results presented for the Lakelse lake sockeye CU will illustrate how a user would assess freshwater habitat information for an individual CU using the Habitat Report Cards.

PAGE 1 provides an **Introduction** to the lake sockeye CU habitat reporting project, **Definitions** for the key terms used within the report, and **Narrative** bullets of key local habitat issues for the CU that have been identified by the Skeena TAC. The lake sockeye CU is then set within a geographic context to orient the user to the **Location** of its rearing lake within the larger Skeena River Basin, employing maps to show the CU's rearing lake at different spatial scales, its migration route from/to the Skeena Estuary, and the general habitat setting within its defined rearing lake ZOI. The Lakelse rearing lake ZOI is located near Terrace and has some degree of urbanization within its boundaries but also areas that are protected in parks and ecological reserves.

PAGE 2 provides a summary **Overview of habitat vulnerabilities and pressures** for the CU with an initial identification of the particular habitat pressure indicators (grouped into Impact Categories) and vulnerability indicators developed for the project analyses. The **Cumulative pressure – migration** map shows a concentrated zone of higher-risk cumulative habitat pressures being experienced by the CU within the areas of its migration corridor near the rearing lake itself and diminishing farther downriver towards the Skeena Estuary. The **Summary of pressure indicators – rearing** "slider" indicates that the CU's rearing lake ZOI area would be considered to be at relatively higher risk (red) from a number of individual habitat pressures (i.e., riparian disturbance, road development, water licenses, linear development, mining development, permitted waste discharges), moderate risk (amber) for a number of other habitat pressure indicators, and only lower risk (green) for a few indicators (i.e., ECA, impervious surfaces, and acid-generating mines). The **Cumulative pressure – rearing & spawning** map indicates that the majority of the FWA-defined watersheds in the CU rearing/spawning ZOIs would be considered at either higher (red) or moderate (amber) risk from cumulative habitat pressures. The **Integrated vulnerability/habitat pressures** figures show that the Lakelse CU (relative to other lake sockeye CUs in the Skeena) would be rated by each life stage as:

Migration: lower vulnerability to impacts and lower cumulative habitat pressures
Spawning: higher vulnerability to impacts and higher cumulative habitat pressures
Rearing: moderate/low vulnerability to impacts and higher cumulative pressures

PAGE 3 provides detailed information on the CU **Migration vulnerability & pressure** displaying a more zoomed-in map showing the **Migration period pressures** (cumulative risk classifications for ZOI watersheds and the locations/types of potential obstructions to migration and the locations/types of water licensed withdrawals along the migration route). While the Lakelse migration corridor has many adjoining watersheds with intense cumulative habitat pressures there are only minimal obstructions or water withdrawals along the route. This is illustrated by the absolute numbers and the relative ranking of migration pressures for the Lakelse displayed in the bar charts for Number of obstructions and Licensed water allocations. The bar charts for **Migration period vulnerability** indicators (i.e., Migration distance, Distance and Percentage summer low flow sensitive) also indicate lower vulnerability for the Lakelse CU to migration corridor pressures as the total migration distance is relatively short and does not traverse areas considered naturally prone to low flows.

PAGE 4 provides a summary of all CU ZOI **Rearing & spawning vulnerability** indicators. A detailed map is provided showing the extent of the CU rearing lake ZOI and delineated 1:20K FWS watersheds within the ZOI. All known sockeye **Spawning locations** associated with CU are shown on the map. Spawn map is broken down and colour coded by type (i.e., lake inlet/tributary, lake, mainstem/lake outlet). The map indicates that all known spawning for the Lakelse lake sockeye CU occurs in tributary streams. The map also shows distinct ZOIs for tributary spawning areas (stippled green zones) that are embedded within the larger rearing lake ZOI. The bar charts display **Spawning period vulnerability** indicators (absolute values and ranking for each relative to other Skeena lake sockeye CUs). The Lakelse CU spawning life stage rates as being of higher vulnerability across most indicators as it has a limited amount of total known spawning habitat (i.e., 18.19 km), all of which is in unbuffered tributaries/lake inlets making it more at risk from landscape disturbances. There is a considerable amount of theoretically accessible fish habitat within the Lakelse rearing lake ZOI which could reduce vulnerability (however much of this modeled fish habitat may not actually be physically accessible to spawning sockeye). **Rearing period vulnerability** indicator bar charts suggest that the Lakelse CU would be considered only of moderate/low vulnerability during the rearing period given its large lake area and moderately high nursery lake productive capacity.

PAGE 5 presents the habitat risk ratings for **Spawning and rearing pressure** indicators within the CU rearing lake and spawning ZOIs. Box plots for each habitat pressure indicator display the spread of risk scores across: 1) all Skeena River Basin watersheds (n = 1141), 2) across all CU rearing lake ZOI watersheds (n = 8 for the Lakelse CU), and 3) across all CU tributary spawning ZOI watersheds (n = 8 for the Lakelse CU). For the first pressure indicator (Forest disturbance) the box plot indicates that the spread of values in the Skeena ranges from 0% to over 90%. In the eight watersheds defining the rearing and spawning ZOIs for the Lakelse CU, forest disturbance ranges from 0% to approximately 25%, with a median value of about 15%. Most watersheds in the rearing and spawning ZOIs for the Lakelse CU are rated as being either higher (red) or moderate (amber) risk for forest disturbance. The associated map for this indicator shows the actual location of the watersheds in the Lakelse CU ZOIs that are rated as being higher (red), moderate (amber), or lower (red) risk for the forest disturbance indicator. The areas indicated as being Data Deficient represent areas where higher quality/better resolution VRI data were not available to inform indicator quantification; datasets with poorer spatial resolution have been used to "patch" these areas so as to inform the watershed risk classifications. Similar assessments are undertaken with each of the four individual habitat pressure indicators presented on page 5 (i.e., forest disturbance, equivalent clear-cut area (ECA), insect and disease defoliation, and riparian disturbance). Of these, higher risk ratings for Lakelse CU watersheds are mostly associated with forest disturbance and riparian disturbance.

PAGE 6 continues with presentation of individual habitat pressure indicator risk ratings for road development, number of water licenses, and stream crossing density. Locations and types of water licenses within the CU ZOIs are shown on the associated water licenses map. As a supplement to the stream crossing density indicator, this page displays information on stream culvert fish passage ratings (i.e., Passable/Barrier/Unknown) as available from local FPCI surveys. Maps for the culvert passability indicator also include unsurveyed 1:20K-defined stream crossings in the CU rearing lake ZOI (crossings on very small streams are not depicted). Road development and water licenses are rated as being higher risk in many of the watersheds encompassing most of the area directly adjacent to Lakelse Lake.

PAGE 7 continues with presentation of risk ratings for another four habitat pressure indicators, total land cover alteration, impervious surfaces, linear development, and mining development (total mines). Specific locations/types of mines are shown on the associated map for the mining development indicator. The box plots and maps indicate moderate (amber) risk from urban/rural development (as rated for impervious surfaces) in the northern part of the Lakelse CU rearing lake ZOI, although total land cover alteration and linear development are rated as either higher (red) or moderate (amber) risk for most watersheds in the Lakelse CU ZOI. Mining is relatively limited within the CU ZOI, with aggregate mining occurring at two locations at the southern end of Lakelse Lake.

PAGE 8 continues with presentation of risk ratings for two final habitat pressure indicators, mining development (acid-generating mines) and permitted waste discharges. Locations of acid-generating mines and permitted waste water discharge sites are also mapped for these two indicators. There are no acid-generating mines located within the Lakelse CU ZOIs, so all watersheds are rated lower (green) risk for this indicator. Permitted waste discharges are also absent from most Lakelse CU ZOI watersheds, with the only known location being directly adjacent to Lakelse Lake on the northeast side of the lake. Given that the actual impact from waste water discharge sites is unknown, the presence of even a single discharge site generates a higher (red) risk rating to the surrounding watershed.

PAGE 9 presents a summary of potential **Future pressures** for lake sockeye CUs as quantified by **Proposed resource development projects** (identified by the Skeena TAC). An overview map shows locations and types of proposed resource development projects (as of 2010) across the Skeena River Basin. Zoomed in maps also show the locations/types of proposed resource development projects specific to the CU migration corridor, spawning, and rearing ZOIs. A summary table shows the expected increase in the amount of development by categories (i.e., mines, acid-generating mines, linear development, water licenses, power tenures) within each of the life-stage-specific ZOIs. For each resource development category the potential increase (by absolute amount and by % change) over the current baseline condition is identified. Currently, little new resource development appears to be planned within the Lakelse rearing and spawning ZOIs, with proposals for two new water licenses and a 1.1% increase in linear development (i.e., an increase of 0.02 km/km^2). In contrast, proposed development in the Lakelse CU migration corridor ZOI may be more significant, with a new mine (non-acid-generating) being proposed, projects requiring seven new water licenses, and 38.35 km^2 of new proposed water power tenures.

Supplementary Habitat Report Cards have been developed for indicators that, while important for sockeye and other salmon populations in the Skeena, cannot be clearly associated with individual CUs. This includes analytical results for:

1. ***Skeena River Basin***: Key habitat condition/state indicators (i.e., historical patterns of summer flows, glacier extent, snowpack) and indicators of possible pressures on salmon habitats due to potential climate change effects (i.e., predicted future air temperatures and precipitation) presented at the scale of the entire Skeena River basin. Historical escapements (average number of spawners) across Skeena lake sockeye CUs are also displayed in the Skeena River Basin Report Card, although escapement data is lacking for many of the CUs. These average escapement numbers (period 1991 – 2010) are also presented in Appendix 1.

2. ***Skeena Estuary***: Indicators of the general intensity/extent of current and future predicted habitat pressures within the Skeena Estuary, as well as some key habitat state/condition indicators (i.e., eelgrass extents, and foreshore and intertidal habitats in key locations).

These Skeena River Basin and Skeena Estuary report cards are also available for viewing/download at the Pacific Salmon Foundation's Skeena Salmon Program website: www.skeenasalmonprogram.ca.

3.2 Habitat Pressure Indicators (Current)

3.2.1 Watersheds/CU ZOIs

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

1) the percentage of watersheds within each CU's rearing lake ZOI that were rated as higher, moderate, or lower risk (i.e., red/amber/green) for cumulative habitat pressures (see **Table 3**) based on pressure indicator roll-up rules,

2) the percentage of watersheds within each rearing lake ZOI that were rated as higher, moderate, or lower risk (i.e., red/amber/green) for each of the individual habitat pressure indicators evaluated (see **Table 4**, **Table 5**, and **Table 6**),

3) the percentage of watersheds within each CU's tributary spawning ZOI (where applicable) that were rated as higher, moderate, or lower risk (i.e., red/amber/green) for cumulative habitat pressures (see **Table 7**) based on pressure indicator roll-up rules,

4) the percentage of watersheds within each rearing lake CU that were rated as higher, moderate, or lower risk (i.e., red/amber/green) for each of the individual habitat pressure indicators evaluated (see **Table 8**, **Table 9** and **Table 10**), and

5) the cumulative risk scores (total and total area-weighted) for each CU's migration corridor ZOI (see **Table 11**) based on pressure indicator roll-up rules, as well as the total number of obstructions and permitted water licenses along the migration corridor.

Assessment of our defined measure of cumulative habitat risk across CUs indicates that the majority of habitat associated with rearing lakes would be considered to be in relatively good shape, with many CUs having 100% of the watersheds compromising their rearing lake ZOI rated as being at lower risk (green) from cumulative habitat pressures (**Table 3**). However, there are some notable exceptions. All (100%) of the rearing lake watersheds in the Bulkley (6 watersheds) and Aldrich (1 watershed) CUs are considered at higher cumulative risk (red), the Babine CU has 56% of its 120 CU-associated watersheds rated at higher risk (red) while only 10% of its watersheds are rated lower risk for cumulative impacts. Similarly, 50% of the rearing lake ZOI watersheds for the Maxan (3 of 6 watersheds) and Nilkitkwa (6 of 12 watersheds) CUs are rated as higher cumulative risk (red) with only 17% (1 of 6 and 2 of 12, respectively) of their associated watersheds rated as lower cumulative risk (green). Other CUs may have no or a limited number of rearing lake ZOI watersheds rated as higher risk (red) but may still have a large percentage of their watersheds rated as moderate risk (amber), and none or only a small percentage of their watersheds rated as lower risk (green). CUs fitting this description include Dennis (67% of watersheds moderate risk: 2 of 3), Gitanyow (75% of watersheds rated moderate risk: 3 of 4), and Tahlo/Morrison (80% of watersheds rated moderate risk: 8 of 10).

Similarly, evaluation of individual habitat pressure indicators in CU rearing lake ZOIs (**Table 4**, **Table 5**, and **Table 6**) indicates that many are relatively undisturbed, with the majority of CUs generating lower risk ratings (green) across all the pressure indicators evaluated for this project. Examples of CUs conversely showing higher risk ratings (red) for various individual habitat pressures across a large percentage of watersheds in their rearing lake ZOI are Aldrich (disturbed forest, mines, acid-generating mines and riparian disturbance), Dennis (disturbed forest), McDonnell (disturbed forest, crossing density), Babine (land cover altered, disturbed forest, road density, crossing density, riparian disturbance, ECA, defoliation), Bulkley (land cover altered, disturbed forest, linear development, road density, crossing density, water licenses, riparian disturbance, ECA, defoliation), Gitanyow (forest disturbed, road density, crossing density), Maxan (land cover altered, disturbed forest, crossing density, riparian disturbance, ECA, defoliation), Morice (defoliation), Azuklotz (defoliation), Bear (defoliation), Onerka (defoliation), and Nilkitkwa (land cover altered, disturbed forest, linear development, road density, riparian disturbance).

Assessment of cumulative habitat risk within tributary spawning ZOIs (for CUs where tributary spawning is known to occur) indicates that the majority of lake sockeye CU tributary spawning-associated habitats would also be considered in relatively good shape, with many of the CUs having 100% of the watersheds compromising their tributary spawning ZOI rated as being at lower risk (green) from cumulative habitat pressures (**Table 7**). Notable exceptions to this include the Lakelse CU (50% of its tributary spawning ZOI watersheds rated higher risk (red) (4 of 8) and 38% of them (3 of 8) rated moderate risk (amber), the Babine CU (58% of its watersheds rated higher risk (47 of 81) and only 12% rated lower risk (10 of 81), and the Kitsumkalum CU (20% of its watersheds (6 of 30) rated higher risk (red) and 30% of them (9 of 30) rated moderate risk (amber).

Evaluation of individual habitat pressure indicators in CU tributary spawning ZOIs (**Table 8**, **Table 9**, and **Table 10**) indicates, similarly, that many of the associated watersheds are relatively undisturbed, with the majority of CUs generating lower risk ratings (green) across all the habitat pressure indicators. Examples of CUs showing higher risk ratings (red) for various individual habitat pressures across some of the watersheds in their tributary spawning ZOI are Kitsumkalum CU (land cover altered, disturbed forest, mines, linear development, road density, crossing density, water licenses, riparian disturbance, ECA), Lakelse CU (land cover altered, disturbed forest, mines, linear development, road density, crossing density, water licenses, riparian disturbance, waste water discharges, ECA), Babine CU (land cover altered, disturbed forest, linear development, road density, crossing density, riparian disturbance, ECA, defoliation), Bear (defoliation), Azuklotz (defoliation) and Onerka (defoliation). While higher-risk watersheds were fairly rare across tributary spawning ZOIs, a number of CUs did have a majority of watersheds rated as moderate risk (amber) for various individual habitat pressures. These included Dennis CU (land cover altered, forest disturbed, road density, crossing density, riparian disturbance, defoliation), Lakelse CU (land cover altered, disturbed forest, crossing density), Babine CU (linear development, crossing density), Tahlo/Morrison CU (land cover altered, disturbed forest, linear development, road density, defoliation), and Sustut CU (defoliation).

The area-weighted total cumulative risk scoring for CU migration corridor ZOIs (**Table 11**) suggests that the CUs experiencing the greatest amount of overall habitat pressure along the migration route include Maxan CU (score = 6.95), Bulkley CU (score = 6.84), Morice CU (score = 6.68), and Atna CU (score = 6.52). The lowest cumulative risk scores for migration were shown by Alastair CU (score = 2.20), Ecstall/Lower CU (score = 1.63), and Johnston CU (score = 1.86). Not surprisingly, these three CUs have much shorter migration distances than other CUs in the Skeena River basin. The total number of identified obstructions/obstacles that the migrating lake sockeye CUs would experience during migration varied from as few as 0 (for Aldrich CU) to as many as 357 (Johanson CU). The potential overall risk to migrating salmon from water diversions/extractions, represented by the number of water licenses along the CU migration corridors, ranged from as little as 0 water licenses (Alastair CU) to over 700 water licenses (Atna = 737 water licenses, Bulkley = 774 water licenses, Maxan = 775 water licenses, Morice = 737 water licenses).

Table 3 The percentage of watersheds in the **rearing lake** "zone of influence" (ZOI) for each Skeena lake sockeye Conservation Unit (CU) that are rated as being at relatively higher, moderate, or lower risk from "cumulative" habitat impacts. **Cumulative risk** is based on a composite risk scoring roll-up rule set using the identified individual risk status for seven habitat pressure Impact Categories: Hydrological processes, Vegetation quality, Surface erosion, Fish passage/habitat connectivity, Water quantity, Human development footprint, and Water quality.

CU_NAME	CU_INDEX	ZOI area (km^2)	Watersheds in ZOI (# of)	Higher-risk Watersheds (%)	Moderate-risk Watersheds (%)	Lower Risk Watersheds (%)
Alastair	L_20_01	85.46	1	0%	0%	100%
Aldrich	L_20_02	27.92	1	100%	0%	0%
Dennis	L_20_03	66.67	3	33%	67%	0%
Ecstall/Lower	L_20_04	20.59	1	0%	0%	100%
Johnston	L_20_05	52.45	1	0%	0%	100%
Kitsumkalum	L_20_06	1930.38	39	18%	38%	44%
Lakelse	L_20_07	382.63	8	50%	38%	13%
Mcdonell	L_20_08	190.07	5	40%	40%	20%
Atna	L_21_01	275.55	6	0%	0%	100%
Babine	L_21_02	5892.48	120	56%	34%	10%
Bulkley	L_21_03	266.50	6	100%	0%	0%
Club Lake	L_21_04	5.51	1	0%	0%	100%
Gitanyow	L_21_05	177.05	4	25%	75%	0%
Maxan	L_21_06	235.94	6	50%	33%	17%
Morice	L_21_07	1612.06	32	16%	3%	81%
Nilkitkwa	L_21_08	401.44	12	50%	33%	17%
Stephens	L_21_09	29.10	1	0%	0%	100%
Swan	L_21_10	109.64	3	0%	0%	100%
Tahlo/Morrison	L_21_11	435.18	10	20%	80%	0%
Asitika	L_22_01	29.93	1	0%	0%	100%
Azuklotz	L_22_02	102.18	1	0%	0%	100%
Bear	L_22_03	286.57	9	0%	22%	78%
Damshilgwit	L_22_04	63.96	1	0%	0%	100%
Johanson	L_22_05	53.97	2	0%	50%	50%
Kluatantan	L_22_06	39.29	1	0%	0%	100%
Kluayaz	L_22_07	169.11	2	0%	0%	100%
Motase	L_22_08	131.70	4	0%	0%	100%
Sicintine	L_22_09	44.95	1	0%	0%	100%
Slamgeesh	L_22_10	156.04	3	0%	0%	100%
Spawning	L_22_11	27.13	1	0%	0%	100%
Sustut	L_22_12	50.20	1	0%	0%	100%
Onerka	L_99_99	13.93	1	0%	0%	100%

Table 4 The percentage of watersheds in the **rearing lake** "zone of influence" (ZOI) for each Skeena lake sockeye Conservation Unit (CU) that were identified as relatively **higher risk** (red rating) for each of the **individual habitat pressure indicators** evaluated.

CU_NAME	CU_INDEX	Watersheds (#)	Land Cover Altered (%)	Forest Disturbed (%)	Impervious surface (%)	Mines (#)	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 (%)
Alastair	L_20_01	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Aldrich	L_20_02	1	0%	100%	0%	100%	100%	0%	0%	0%	0%	100%	0%	0%	0%
Dennis	L_20_03	3	0%	67%	0%	33%	33%	0%	0%	0%	0%	33%	0%	0%	0%
Ecstall/Lower	L_20_04	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Johnston	L_20_05	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Kitsumkalum	L_20_06	39	15%	15%	0%	10%	0%	18%	21%	38%	10%	26%	0%	10%	3%
Lakelse	L_20_07	8	38%	38%	0%	13%	0%	50%	38%	13%	38%	50%	13%	13%	0%
Mcdonell	L_20_08	5	40%	60%	0%	0%	0%	20%	20%	60%	20%	40%	0%	20%	0%
Atna	L_21_01	6	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	17%
Babine	L_21_02	120	58%	66%	0%	3%	1%	43%	49%	46%	5%	63%	4%	46%	75%
Bulkley	L_21_03	6	100%	100%	0%	33%	17%	100%	100%	100%	67%	100%	17%	100%	100%
Club Lake	L_21_04	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Gitanyow	L_21_05	4	25%	75%	0%	0%	0%	0%	50%	50%	0%	25%	0%	0%	0%
Maxan	L_21_06	6	50%	67%	0%	0%	0%	33%	33%	50%	0%	83%	0%	50%	100%
Morice	L_21_07	32	19%	16%	0%	0%	0%	9%	9%	9%	0%	19%	0%	16%	72%
Nilkitkwa	L_21_08	12	67%	75%	0%	0%	0%	58%	58%	33%	0%	75%	8%	25%	0%
Stephens	L_21_09	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Swan	L_21_10	3	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Tahlo/Morrison	L_21_11	10	20%	20%	0%	0%	0%	30%	20%	10%	10%	20%	0%	20%	10%
Asitika	L_22_01	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Azuklotz	L_22_02	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
Bear	L_22_03	9	0%	0%	0%	0%	0%	22%	0%	0%	33%	0%	0%	0%	78%
Damshilgwit	L_22_04	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Johanson	L_22_05	2	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Kluatantan	L_22_06	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Kluayaz	L_22_07	2	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Motase	L_22_08	4	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Sicintine	L_22_09	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Slamgeesh	L_22_10	3	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Spawning	L_22_11	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Sustut	L_22_12	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Onerka	L_99_99	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%

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

CU_NAME	CU_INDEX	Watersheds (#)	Land Cover Altered (%)	Forest Disturbed (%)	Impervious surface (%)	Mines (#)	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 (%)
Alastair	L_20_01	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Aldrich	L_20_02	1	100%	0%	0%	0%	0%	100%	100%	100%	0%	0%	0%	0%	100%
Dennis	L_20_03	3	100%	33%	0%	0%	0%	67%	100%	100%	0%	67%	0%	0%	100%
Ecstall/Lower	L_20_04	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Johnston	L_20_05	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Kitsumkalum	L_20_06	39	44%	46%	0%	0%	0%	31%	36%	21%	0%	28%	0%	8%	13%
Lakelse	L_20_07	8	50%	50%	13%	0%	0%	25%	38%	75%	0%	25%	0%	13%	38%
Mcdonell	L_20_08	5	40%	40%	0%	0%	0%	60%	60%	20%	0%	40%	0%	20%	100%
Atna	L_21_01	6	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Babine	L_21_02	120	31%	24%	0%	0%	0%	43%	41%	40%	0%	22%	0%	18%	24%
Bulkley	L_21_03	6	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Club Lake	L_21_04	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Gitanyow	L_21_05	4	75%	25%	0%	0%	0%	100%	50%	50%	0%	50%	0%	25%	0%
Maxan	L_21_06	6	33%	17%	0%	0%	0%	50%	50%	33%	0%	0%	0%	17%	0%
Morice	L_21_07	32	3%	6%	0%	0%	0%	6%	6%	16%	0%	3%	0%	0%	0%
Nilkitkwa	L_21_08	12	17%	8%	0%	0%	0%	25%	25%	42%	0%	8%	0%	25%	75%
Stephens	L_21_09	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Swan	L_21_10	3	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Tahlo/Morrison	L_21_11	10	80%	80%	0%	0%	0%	40%	70%	40%	0%	30%	0%	0%	80%
Asitika	L_22_01	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
Azuklotz	L_22_02	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Bear	L_22_03	9	11%	11%	0%	0%	0%	33%	22%	22%	0%	11%	0%	0%	22%
Damshilgwit	L_22_04	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Johanson	L_22_05	2	0%	0%	0%	0%	0%	50%	50%	50%	0%	0%	0%	0%	100%
Kluatantan	L_22_06	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Kluayaz	L_22_07	2	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Motase	L_22_08	4	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	25%
Sicintine	L_22_09	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Slamgeesh	L_22_10	3	0%	0%	0%	0%	0%	0%	0%	0%	0%	33%	0%	0%	0%
Spawning	L_22_11	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
Sustut	L_22_12	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
Onerka	L_99_99	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

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

CU_NAME	CU_INDEX	Watersheds (#)	Land Cover Altered (%)	Forest Disturbed (%)	Impervious surface (%)	Mines (#)	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 (%)
Alastair	L_20_01	1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Aldrich	L_20_02	1	0%	0%	100%	0%	0%	0%	0%	0%	100%	0%	100%	100%	0%
Dennis	L_20_03	3	0%	0%	100%	67%	67%	33%	0%	0%	100%	0%	100%	100%	0%
Ecstall/Lower	L_20_04	1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Johnston	L_20_05	1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Kitsumkalum	L_20_06	39	41%	38%	100%	90%	100%	51%	44%	41%	90%	46%	100%	82%	85%
Lakelse	L_20_07	8	13%	13%	88%	88%	100%	25%	25%	13%	63%	25%	88%	75%	63%
Mcdonell	L_20_08	5	20%	0%	100%	100%	100%	20%	20%	20%	80%	20%	100%	60%	0%
Atna	L_21_01	6	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	83%
Babine	L_21_02	120	12%	10%	100%	97%	99%	14%	10%	14%	95%	15%	96%	37%	1%
Bulkley	L_21_03	6	0%	0%	100%	67%	83%	0%	0%	0%	33%	0%	83%	0%	0%
Club Lake	L_21_04	1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Gitanyow	L_21_05	4	0%	0%	100%	100%	100%	0%	0%	0%	100%	25%	100%	75%	100%
Maxan	L_21_06	6	17%	17%	100%	100%	100%	17%	17%	17%	100%	17%	100%	33%	0%
Morice	L_21_07	32	78%	78%	100%	100%	100%	84%	84%	75%	100%	78%	100%	84%	28%
Nilkitkwa	L_21_08	12	17%	17%	100%	100%	100%	17%	17%	25%	100%	17%	92%	50%	25%
Stephens	L_21_09	1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Swan	L_21_10	3	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Tahlo/Morrison	L_21_11	10	0%	0%	100%	100%	100%	30%	10%	50%	90%	50%	100%	80%	10%
Asitika	L_22_01	1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%
Azuklotz	L_22_02	1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%
Bear	L_22_03	9	89%	89%	100%	100%	100%	44%	78%	78%	67%	89%	100%	100%	0%
Damshilgwit	L_22_04	1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Johanson	L_22_05	2	100%	100%	100%	100%	100%	50%	50%	50%	100%	100%	100%	100%	0%
Kluatantan	L_22_06	1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Kluayaz	L_22_07	2	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Motase	L_22_08	4	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	75%
Sicintine	L_22_09	1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Slamgeesh	L_22_10	3	100%	100%	100%	100%	100%	100%	100%	100%	100%	67%	100%	100%	100%
Spawning	L_22_11	1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%
Sustut	L_22_12	1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%
Onerka	L_99_99	1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%

Table 7 The percentage of watersheds in the **tributary spawning** "zone of influence" (ZOI) for each Skeena lake sockeye Conservation Unit (CU) in which tributary spawning occurs that are rated as being at relatively higher, moderate, or lower risk from "cumulative" habitat impacts. **Cumulative risk** is based on a composite risk scoring roll-up rule set using the identified individual risk status for seven habitat pressure Impact Categories: Hydrological processes, Vegetation quality, Surface erosion, Fish passage/habitat connectivity, Water quantity, Human development footprint, and Water quality.

CU_NAME	CU_INDEX	ZOI area (km^2)	Watersheds in ZOI (# of)	Higher-risk Watersheds (%)	Moderate-risk Watersheds (%)	Lower Risk Watersheds (%)
Alastair	L_20_01	30.65	1	0%	0%	100%
Aldrich	L_20_02	0.00	0			
Dennis	L_20_03	34.71	1	0%	100%	0%
Ecstall/Lower	L_20_04	0.00	0			
Johnston	L_20_05	38.07	1	0%	0%	100%
Kitsumkalum	L_20_06	1337.19	30	20%	30%	50%
Lakelse	L_20_07	320.16	8	50%	38%	13%
Mcdonell	L_20_08	0.00	0			
Atna	L_21_01	0.00	0			
Babine	L_21_02	3723.85	81	58%	30%	12%
Bulkley	L_21_03	0.00	0			
Club Lake	L_21_04	0.00	0			
Gitanyow	L_21_05	0.00	0			
Maxan	L_21_06	0.00	0			
Morice	L_21_07	932.24	19	11%	0%	89%
Nilkitkwa	L_21_08	0.00	0			
Stephens	L_21_09	0.00	0			
Swan	L_21_10	47.68	3	0%	0%	100%
Tahlo/Morrison	L_21_11	209.55	6	0%	100%	0%
Asitika	L_22_01	0.00	0			
Azuklotz	L_22_02	88.67	1	0%	0%	100%
Bear	L_22_03	67.16	3	0%	0%	100%
Damshilgwit	L_22_04	59.32	1	0%	0%	100%
Johanson	L_22_05	0.00	0			
Kluatantan	L_22_06	0.00	0			
Kluayaz	L_22_07	0.00	0			
Motase	L_22_08	63.28	2	0%	0%	100%
Sicintine	L_22_09	0.00	0			
Slamgeesh	L_22_10	0.00	0			
Spawning	L_22_11	0.00	0			
Sustut	L_22_12	10.89	1	0%	0%	100%
Onerka	L_99_99	13.93	1	0%	0%	100%

Table 8 The percentage of watersheds in the **tributary spawning** "zone of influence" (ZOI) for each Skeena lake sockeye Conservation Unit (CU) in which tributary spawning occurs that were identified as relatively **higher risk** (red rating) for each of the **individual habitat pressure indicators** evaluated.

CU_NAME	CU_INDEX	Watersheds (#)	Land Cover Altered (%)	Forest Disturbed (%)	Impervious surface (%)	Mines (#)	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 (%)
Alastair	L_20_01	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Aldrich	L_20_02	0													
Dennis	L_20_03	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Ecstall/Lower	L_20_04	0													
Johnston	L_20_05	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Kitsumkalum	L_20_06	30	17%	17%	0%	7%	0%	20%	23%	30%	10%	20%	0%	13%	3%
Lakelse	L_20_07	8	38%	38%	0%	13%	0%	50%	38%	13%	38%	50%	13%	13%	0%
Mcdonell	L_20_08	0													
Atna	L_21_01	0													
Babine	L_21_02	81	60%	67%	0%	4%	0%	42%	47%	51%	4%	68%	1%	44%	74%
Bulkley	L_21_03	0													
Club Lake	L_21_04	0													
Gitanyow	L_21_05	0													
Maxan	L_21_06	0													
Morice	L_21_07	19	11%	11%	0%	0%	0%	0%	0%	11%	0%	11%	0%	11%	74%
Nilkitkwa	L_21_08	0													
Stephens	L_21_09	0													
Swan	L_21_10	3	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Tahlo/Morrison	L_21_11	6	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Asitika	L_22_01	0													
Azuklotz	L_22_02	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
Bear	L_22_03	3	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
Damshilgwit	L_22_04	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Johanson	L_22_05	0													
Kluatantan	L_22_06	0													
Kluayaz	L_22_07	0													
Motase	L_22_08	2	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Sicintine	L_22_09	0													
Slamgeesh	L_22_10	0													
Spawning	L_22_11	0													
Sustut	L_22_12	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Onerka	L_99_99	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%

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

CU_NAME	CU_INDEX	Watersheds (#)	Land Cover Altered (%)	Forest Disturbed (%)	Impervious surface (%)	Mines (#)	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 (%)
Alastair	L_20_01	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Aldrich	L_20_02	0													
Dennis	L_20_03	1	100%	100%	0%	0%	0%	0%	100%	100%	0%	100%	0%	0%	100%
Ecstall/Lower	L_20_04	0													
Johnston	L_20_05	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Kitsumkalum	L_20_06	30	37%	40%	0%	0%	0%	27%	27%	20%	0%	27%	0%	7%	7%
Lakelse	L_20_07	8	50%	50%	13%	0%	0%	25%	38%	75%	0%	25%	0%	13%	38%
Mcdonell	L_20_08	0													
Atna	L_21_01	0													
Babine	L_21_02	81	27%	23%	0%	0%	0%	43%	42%	35%	0%	16%	0%	16%	25%
Bulkley	L_21_03	0													
Club Lake	L_21_04	0													
Gitanyow	L_21_05	0													
Maxan	L_21_06	0													
Morice	L_21_07	19	0%	0%	0%	0%	0%	11%	11%	11%	0%	0%	0%	0%	0%
Nilkitkwa	L_21_08	0													
Stephens	L_21_09	0													
Swan	L_21_10	3	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Tahlo/Morrison	L_21_11	6	100%	100%	0%	0%	0%	50%	83%	33%	0%	33%	0%	0%	83%
Asitika	L_22_01	0													
Azuklotz	L_22_02	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Bear	L_22_03	3	0%	0%	0%	0%	0%	33%	0%	0%	0%	0%	0%	0%	0%
Damshilgwit	L_22_04	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Johanson	L_22_05	0													
Kluatantan	L_22_06	0													
Kluayaz	L_22_07	0													
Motase	L_22_08	2	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Sicintine	L_22_09	0													
Slamgeesh	L_22_10	0													
Spawning	L_22_11	0													
Sustut	L_22_12	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
Onerka	L_99_99	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Table 10 The percentage of watersheds in the **tributary spawning** “zone of influence” (ZOI) for each Skeena lake sockeye Conservation Unit (CU) in which tributary spawning occurs that were identified as relatively **lower risk** (green rating) for each of the **individual habitat pressure indicators** evaluated.

CU_NAME	CU_INDEX	Watersheds (#)	Land Cover Altered (%)	Forest Disturbed (%)	Impervious surface (%)	Mines (#)	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 (%)	F Forest stands defoliated (%)
Alastair	L_20_01	1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Aldrich	L_20_02	0													
Dennis	L_20_03	1	0%	0%	100%	100%	100%	100%	0%	0%	100%	0%	100%	100%	0%
Ecstall/Lower	L_20_04	0													
Johnston	L_20_05	1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Kitsumkalum	L_20_06	30	47%	43%	100%	93%	100%	53%	50%	50%	90%	53%	100%	80%	90%
Lakelse	L_20_07	8	13%	13%	88%	88%	100%	25%	25%	13%	63%	25%	88%	75%	63%
Mcdonell	L_20_08	0													
Atna	L_21_01	0													
Babine	L_21_02	81	12%	10%	100%	96%	100%	15%	11%	15%	96%	16%	99%	40%	1%
Bulkley	L_21_03	0													
Club Lake	L_21_04	0													
Gitanyow	L_21_05	0													
Maxan	L_21_06	0													
Morice	L_21_07	19	89%	89%	100%	100%	100%	89%	89%	79%	100%	89%	100%	89%	26%
Nilkitkwa	L_21_08	0													
Stephens	L_21_09	0													
Swan	L_21_10	3	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Tahlo/Morrison	L_21_11	6	0%	0%	100%	100%	100%	50%	17%	67%	100%	67%	100%	100%	17%
Asitika	L_22_01	0													
Azuklotz	L_22_02	1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%
Bear	L_22_03	3	100%	100%	100%	100%	100%	67%	100%	100%	100%	100%	100%	100%	0%
Damshilgwit	L_22_04	1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Johanson	L_22_05	0													
Kluatantan	L_22_06	0													
Kluayaz	L_22_07	0													
Motase	L_22_08	2	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Sicintine	L_22_09	0													
Slamgeesh	L_22_10	0													
Spawning	L_22_11	0													
Sustut	L_22_12	1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%
Onerka	L_99_99	1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%

Table 11 Total **cumulative risk** scoring elements for habitat in the **migration corridor** “zone of influence” (ZOI) for each Skeena lake sockeye Conservation Unit (CU). Cumulative risk across the migration corridor ZOI is based on a summation of watershed scores for each of the seven habitat pressure Impact Categories: Hydrological processes, Vegetation quality, Surface erosion, Fish passage/habitat connectivity, Water quantity, Human development footprint, and Water quality. A higher-risk Impact Category is scored as 2, a moderate-risk Impact Category is scored as 1, and a lower risk Impact Category in scored as 0. Additional cumulative impact summaries are the total number of identified obstructions and the total number of permitted water licenses located in the migration corridor ZOI.

CU_NAME	CU_INDEX	ZOI area (km^2)	Watersheds in ZOI (# of)	Migration distance (km)	Total cumulative risk score across migration ZOI watersheds	Area-weighted total cumulative risk score across migration ZOI watersheds	Total obstructions (#)	Total permitted water licenses (#)
Alastair	L_20_01	1839.20	34	98.08	74	2.20	119	0
Aldrich	L_20_02	4134.90	80	277.81	384	4.96	0	67
Dennis	L_20_03	4068.23	78	272.49	371	4.93	116	67
Ecstall/Lower	L_20_04	1376.98	23	80.09	42	1.63	7	6
Johnston	L_20_05	1155.74	21	67.70	42	1.86	6	6
Kitsumkalum	L_20_06	2718.46	49	161.27	264	5.17	6	62
Lakelse	L_20_07	2146.30	39	130.80	159	4.16	1	2
Mcdonell	L_20_08	3878.16	74	253.34	347	4.86	115	66
Atna	L_21_01	8984.70	177	556.28	1201	6.52	150	737
Babine	L_21_02	7603.14	147	446.64	783	5.17	116	171
Bulkley	L_21_03	8454.38	165	528.08	1149	6.84	152	774
Club Lake	L_21_04	6347.82	119	398.26	687	5.75	53	178
Gitanyow	L_21_05	4593.42	85	266.53	429	4.98	24	118
Maxan	L_21_06	8627.11	168	545.66	1183	6.95	153	775
Morice	L_21_07	8493.93	171	526.71	1175	6.68	146	737
Nilkitkwa	L_21_08	7288.00	140	435.28	723	5.06	115	171
Stephens	L_21_09	6324.22	119	392.43	687	5.75	51	178
Swan	L_21_10	6331.37	119	400.14	687	5.75	53	178
Tahlo/Morrison	L_21_11	9089.19	171	513.80	990	5.67	116	183
Asitika	L_22_01	8677.88	171	586.55	756	4.42	275	173
Azuklotz	L_22_02	8343.90	169	538.30	760	4.54	233	175
Bear	L_22_03	8081.59	162	522.54	742	4.64	233	173
Damshilgwit	L_22_04	7346.74	147	469.71	659	4.52	129	171
Johanson	L_22_05	9150.34	182	608.84	776	4.31	357	175
Kluatantan	L_22_06	9007.09	181	581.45	702	3.95	235	171
Kluayaz	L_22_07	9112.37	184	588.19	702	3.90	234	171
Motase	L_22_08	7827.84	157	516.86	688	4.45	163	171
Sicintine	L_22_09	7160.06	142	471.31	667	4.75	80	171
Slamgeesh	L_22_10	7311.93	146	466.02	659	4.56	129	171
Spawning	L_22_11	9144.75	182	602.24	776	4.31	357	175
Sustut	L_22_12	8947.35	177	584.09	767	4.35	356	175
Onerka	L_99_99	8050.82	155	514.45	787	4.98	117	171

3.2.2 Skeena Estuary

The location and general mapped "footprint" of development infrastructure currently occurring within the defined boundaries of the Skeena Estuary (as provided to ESSA by the Skeena TAC) are presented in the Skeena Estuary Habitat Report Card developed for this project. However, lack of comprehensive information and imprecision in available GIS layers (i.e., roughly digitized information in some cases) does not allow adequate capture of the full suite of development infrastructure currently in place in the Estuary. Therefore, an estuary-scale quantified analysis of current development pressures could not be undertaken at this time.

3.3 Integrated Cumulative Habitat Pressures/Vulnerability

Figure 7 presents assessments of relative CU habitat status for each life stage, 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 stage, experiencing lower cumulative habitat pressures and having lower vulnerability to the impacts of those pressures (e.g., Lakelse, Ecstall/Lower, and Johnston CUs for migration). Conversely, CUs located in the upper right of each figure would be considered to have poor relative habitat status, experiencing higher cumulative habitat pressures and higher vulnerability to the impacts of those pressures (e.g., Aldrich, Johanson, and Lakelse for spawning).

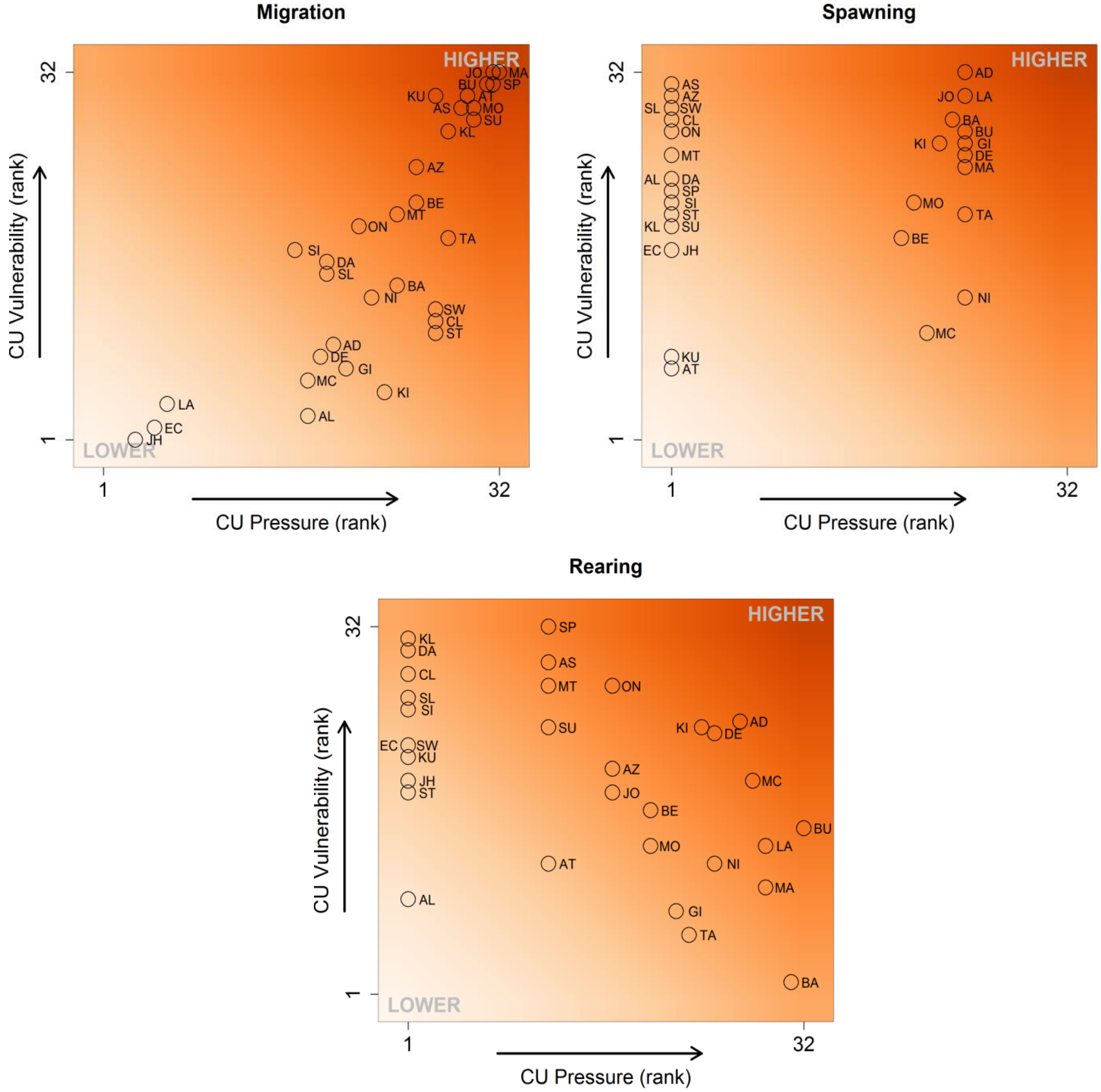

Figure 7 Integrated cumulative habitat pressure CU rankings vs. habitat vulnerability CU rankings for the different life history stage (migration, spawning and rearing) zones of influence (ZOIs) across the Skeena lake sockeye CUs. Colour intensification indicates general increasing CU rankings along either and both of the two figure axes (lower to higher relative rankings). The ranking position of each of the 32 Skeena lake sockeye CUs relative to each other is identified in the figure by a 2 letter code: Al=Alastair, AD=Aldrich, AS=Asitika, AT=Atna, AZ=Azuklotz, BA=Babine, BE=Bear, BU=Bulkley, CL=Club Lake, DA=Damshilgwit, DE=Dennis, EC=Ecstall/Lower, GI=Gitanyow, JO=Johanson, JH=Johnston, KI=Kitsumkalum, KL=Kluatantan, KU=Kluayaz, LA=Lakelse, MA=Maxan, MC=Mcdonell, MO=Morice, MT=Motase, NI=Nilkitkwa, ON=Onerka, SI=Sicintine, SL=Slamgeesh, SP=Spawning, ST=Stephens, SU=Sustut, SW=Swan, TA=Tahlo/Morrison.

3.4 Habitat State/Condition Indicators

Analyses of historical patterns for key state/condition indicators that relate to seasonal water quantity/quality for salmon habitats at the scale of the whole Skeena River Basin during the critical summer period (i.e., summer low flows, glacier extent, and snowpack) are summarized in **Table 12**, **Table 13**, and **Table 14** respectively.

Summer low flows (based on measurement of the minimum average monthly flow from July to September, inclusive, over a 20 year period (1991 to 2010)) showed no statistically detectable trend across all but one of 14 Skeena River Basin WSC gauging stations evaluated (**Table 12**). The one station was on Kloiya River, which showed a significant trend of increasing summer flows over the assessed time period (although the time series data was incomplete for this station). For all stations the historical pattern in annual summer low flows was highly variable, with CVs ranging from 18% to 68% across stations. While this data suggests that some years may have been stressful to salmon (e.g., 2006 is a year in which summer flows were consistently lower than average across most gauging stations), detailed modeling of seasonal low flow thresholds of concern in these stream systems (e.g., Hatfield et al. 2003, etc.) would be required to determine if any recent years of lower summer flows in Skeena River Basin streams would have been expected to cause detrimental effects in resident salmon species.

Skeena River Basin glacier extent was shown to have declined over a 20 year period (1985 vs. 2005) in 10 of 11 subdrainages across the Skeena River Basin (**Table 13**). One subdrainage (Kitseguecla) showed no change in glacier extent. In the other 10 subdrainages glacier retreat over the 20 year time period ranged from 13.22% to 37.75%, with total glacier area lost ranging from 1.79 to 75.98 km^2. The total loss of glacier across the Skeena River Basin was 231.58 km^2, representing a loss of almost 20% (18.99%) of all Skeena River Basin glaciers from 1985 to 2005. Consequences of this loss of glacier runoff is uncertain and may vary by subdrainage, dependent on the overall extent of glaciers and their contribution to seasonal stream flows. The total percentage of each Skeena subdrainage represented by glaciers still existing in 2005 ranged from 0.11% for the Sustut to 9.7% for the Exchamsiks. The total percentage of the whole Skeena River Basin represented by glaciers was 1.81% in 2005 vs. 2.24% in 1985, a reduction of 0.43%.

Snow water equivalent (SWE) showed no statistically detectable trend over a 20-year period (1991 – 2010) as measured on April 1st at BC River Forecast Center snowpack monitoring sites evaluated across the Skeena River Basin. Annual measurements were highly variable, however, with CVs at sites ranging from 14% to 114%. Additionally, annual patterns in SWE measurements were generally highly correlated across the monitoring sites (**Figure 8**); indicating common patterns for available annual snow pack across much of the Skeena and the potential for shared problems in some years in Skeena streams dependent on snow melt to maintain late summer flows. Expanded historical analysis of annual patterns in SWE at later times throughout the summer (i.e., more closely linked with fish habitat needs for snow melt water in late summer) was not possible given a lack of consistent SWE reporting across Skeena snow pack stations in May, June, and July.

Table 12 Minimum average monthly stream flow (m^3/sec) during the summer period (July - Sept.) as measured at Water Survey Canada (WSC) gauging stations located across the Skeena River Basin as measured between 1991- 2010.

Minimum Average Monthly Flow (m^3/sec) - Summer

	Skeena Basin WSC Stream Flow Gauges													
Year	**08EB004**	**08EC013**	**08ED001**	**08ED002**	**08EE004**	**08EE008**	**08EE012**	**08EE013**	**08EE020**	**08EE025**	**08EF001**	**08EF005**	**08EG012**	**08EH016**
1991	31.8	30.3	20.7	74.9	92.4	0.702	0.142	0.223	22.8	0.094	854	130	64.6	1.79
1992	15.2	30.1	24	88.2	102	0.978	0.166	0.138	16.7	0.128	564	81.6	44.8	0.716
1993	14.4	52.3	13.6	60.3	69	0.729	0.077	1.05	17.3	0.126	422	109	38.3	1.11
1994	28.8	40.1	26.8	85.3	103	1.24	0.163	0.534	20.7	0.119	728	113	57.3	2.34
1995	15.2	23.9	15.1	58.1	64.7	0.603	0.048	0.303	14.7	0.059	459	94.5	42.1	2.42
1996	44.3	53.6	27.8	89.2	136	2.13	0.169	1.14	22.9	0.193	867	132	50.2	3.62
1997	20.5	57.3	18.8	68.1	82.6	1.55	0.174	0.694	22.7	0.153	628	123	32.7	2.71
1998	23.2	23.6	22	74.5	88.3	0.773	0.083	0.483	17.8	0.09	561	103	49.4	2.79
1999	48.7	60.2	26.1	83.1	114	1.14	0.184	1.43	26.7	0.172	816	166	52.4	4.81
2000	60	35.2	23.5	75.4	90.5	1.07	0.217	0.364	21.3	0.124	1040	117	64.6	6.4
2001	56	43	28.9	80.4	106	1.04	0.246	0.815	20.3	0.132	1050	126	74.9	5.2
2002	43.5	58.5	37.3	110	139	1.48	0.309	0.356	22.8	0.175	968	123	73.5	5.49
2003	23	38.9	25.3	77.8	95.6	1.33	0.244	0.487	18.2	0.13	670	96.9	52	
2004	28.2	42.4	23.7	86.6	102	1.29	0.18	0.965	17.2	0.097	667	89.2	45.4	1.29
2005	32.5	38.8	18.2	62.9	74.2	0.672	0.113	1.05	21	0.098	732	120	56.6	4.44
2006	21.8	21.9	12.6	49.3	60	0.711	0.089	0.444	14.4	0.083	517	75.9	41.8	2.7
2007	45.4	81.7	27.4	89.3	112	1.13	0.171	2.03	24.6	0.193	950	140	61.1	2.86
2008	30.1	49.1	20	72	96.3	1.12	0.249	0.897	25.3	0.135	618	147	42.9	7.06
2009	31	40.2	21.8	75.2	91.4	1.26	0.124	0.37	19.2	0.111	772	108	63.9	5.56
2010	17.1	29	27.6	69.5	96.5	1.16	0.187	0.248	19.7	0.083	596	105	49.5	3.66
Trend Line														
Detectable Trend	No	No	No	No	No	No	No	No	No	No	No	No	No	+
CV (%)	44	35	25	18	21	33	40	68	17	30	26	19	22	52

Table 13 Change in glacier extent (km^2) within Skeena River Basin subdrainages as mapped in 1985 vs. 2005 (as described in Bolch et al. 2010). GIS data provided by M. Beedle, UNBC.

Skeena Glaciers Extent

Skeena Subdrainage	Subdrainage Area (km^2)	1985 Glacial Area (km2)	Total Area 1985 (% of drainage)	2005 Glacial Area (km2)	Total Area 2005 (% of drainage)	km^2 Lost (1985 to 2005)	% Lost (1985 to 2005)
Lower Skeena River	9985.58	355.62	3.56	279.64	2.80	75.98	21.37
Sustut River	3573.77	6.49	0.18	4.11	0.11	2.39	36.75
Kispiox River	2088.06	8.60	0.41	6.30	0.30	2.30	26.75
Babine River	10476.58	130.91	1.25	113.61	1.08	17.30	13.22
Bulkley River	12155.11	171.45	1.41	132.89	1.09	38.56	22.49
Kitsumkalum River	2255.14	203.44	9.02	160.20	7.10	43.24	21.25
Kitseguecla River	717.07	3.78	0.53	3.78	0.53	0.00	0.00
Zymoetz River	3028.30	136.89	4.52	116.99	3.86	19.91	14.54
Exchamsiks River	514.97	62.22	12.08	49.94	9.70	12.28	19.73
Lakelse River	589.26	5.17	0.88	3.39	0.57	1.79	34.53
Upper Skeena River	9048.12	134.73	1.49	116.88	1.29	17.85	13.25
Skeena Basin Summary	54431.95	1219.31	2.24	987.72	1.81	231.58	18.99

Table 14 Snow water equivalent (SWE) (mm) as measured annually on April 1st from 1991 – 2010 at BC River Forecast Center snow pack monitoring sites located across the Skeena River Basin.

Snow Water Equivalent (SWE) (mm) as measured on April 1st

Skeena Basin Snow Pack Monitoring Sites														
YEAR	4B15P	4B16P	4B17P	4B18P	4B01	4B02	4B03A	4B04	4B06	4B07	4B08	4B13A	4B14	4B15
1991					1093	342	618	529	235	320	680	79	464	342
1992					995	390	679	581	261	327	697	0	436	336
1993					763	303	378	377	186	233	502	0	318	243
1994					881	290	477	451	211	292	548	0	412	336
1995					925	281	432	365	227	228	443	158	432	300
1996		1024			969	401	520	601	282	323	613	38	452	360
1997		949			1095	284	698	641	362	398	725	228	640	484
1998	225	791	1054		840	259	463	460	184	243	574	0	358	232
1999	311	776	1225		1084	269	475	515	244	301	615	302	372	314
2000	150	908	953		768	258	381	406	190	221	479	18	288	202
2001	231	919	968	589	817	266	388	384	187	210	510	96	332	222
2002	398	1020	1556	780	1169	337	609	577	264	311	686	192	458	352
2003	165	731	915	454	664	280	399	392	178	251	476	19	258	162
2004	195		941	600	712	277	383	341	140	204	473	0	282	222
2005	248	1016	1084	960	874	329	482	403	186	228	495	0	314	214
2006	203	765	1013	488	767	249	367	362	178	204	478	32	314	196
2007	484	1050	1827	1114	1601	394	755	666	358	373	726	257	610	504
2008	279	927	1247	717	863	345	544	466	280	317	581	216	382	296
2009	305	1004	1224	1069	1029	344	540	442	252	276	532	188	442	296
2010	236	660	1144	346	824	254	440	410	168	213	510	0	350	246
Detectable Trend	No	No	No	No	No	No	No	No	No	No	No	No	No	No
CV (%)	36	14	23	37	22	16	23	21	26	21	16	114	26	31

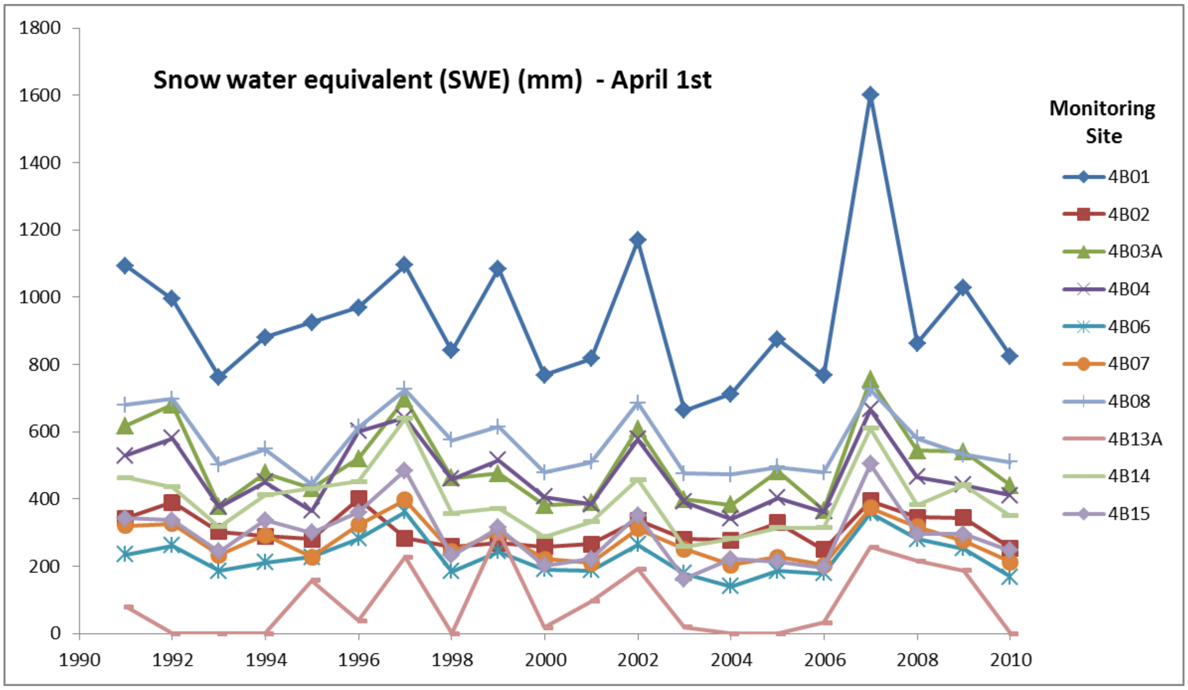

Figure 8 Time series of snow water equivalent (SWE) (mm) as measured annually on April 1st at 10 snow pack monitoring sites in the Skeena River Basin that have 20 continuous years of data collection between 1991 – 2010, showing a high degree of correlated response in SWE patterns (i.e., annual peaks/troughs) across the suite of Basin snow monitoring sites.

3.5 Habitat Pressure Indicators (Future)

3.5.1 Watersheds/CU ZOIs

Proposed resource development activities (i.e., mines, acid-generating mines, linear development, water licenses, power tenures) within sockeye life stage-specific ZOIs are identified across the 32 Skeena lake sockeye CUs in **Table 15.** While proposed development in rearing lake ZOIs is generally limited, there are some notable exceptions such as the rearing lake ZOIs for Babine and Kitsumkalum CUs (e.g., Kitsumkalum: 2 proposed acid-generating mines, a 5.3% increase in linear development, 5 new water licenses, 155.9 km^2 of new power tenures). The Kitsumkalum CU also has a considerable amount of this proposed development slated to take place within its tributary spawning ZOI, as do some of the other CUs (e.g., Lakelse CU: 1.1% increase in linear development, and 2 new water licenses; Babine CU: 1.5% increase in linear development, 1 new water license, 37.7 km^2 of new power tenures). Generally, though, proposed development is limited in tributary spawning ZOIs across the CUs. All of the lake sockeye CUs, however, have some level of new development activities proposed within their migration corridor ZOIs, with notable examples like the Maxan CU with seven new mines proposed, three of which would be acid generating, 0.8% increase in linear development, 14 new water licenses, and 149.7 km^2 of new power tenures.

Table 15 Proposed increases in future resource development in migration, rearing, and tributary spawning Zones of Influence (ZOIs) for Skeena lake sockeye CUs. Increases within each development category for each CU life 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).

CU Name	CU Number	Life stage ZOI	Proposed Mines (#)	Proposed 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)
Alastair	171	Migration	0	0.0	0	NA	0.000	0.0	3	NA	13.8
		Spawning	0	NA	0	NA	0.000	NA	0	NA	0.0
		Rearing	0	NA	0	NA	0.000	NA	0	NA	0.0
Aldrich	172	Migration	4	18.2	2	100.0	0.007	0.6	7	10.4	82.4
		Spawning	0	NA	0	NA	NA	NA	0	NA	0.0
		Rearing	0	0.0	0	0.0	0.000	0.0	0	NA	0.0
Dennis	173	Migration	4	20.0	2	200.0	0.007	0.6	7	10.4	82.4
		Spawning	0	NA	0	NA	0.000	0.0	0	NA	0.0
		Rearing	0	0.0	0	0.0	0.000	0.0	0	NA	0.0
Ecstall/Lower	174	Migration	2	50.0	0	NA	0.000	0.0	2	33.3	7.5
		Spawning	0	NA	0	NA	0.000	NA	0	NA	0.0
		Rearing	0	NA	0	NA	0.000	NA	0	NA	0.0
Johnston	175	Migration	1	25.0	0	NA	0.000	0.0	2	33.3	7.5
		Spawning	0	NA	0	NA	0.000	NA	0	NA	0.0
		Rearing	0	NA	0	NA	0.000	NA	0	NA	0.0
Kitsumkalum	176	Migration	1	5.0	0	0.0	0.024	1.8	7	11.1	43.3
		Spawning	0	0.0	1	NA	0.042	5.4	0	0.0	100.0
		Rearing	0	0.0	2	NA	0.042	5.3	5	41.7	155.9
Lakelse	177	Migration	1	10.0	0	NA	0.006	0.6	7	19.4	38.2
		Spawning	0	0.0	0	NA	0.018	1.1	2	3.8	0.0
		Rearing	0	0.0	0	NA	0.018	1.1	2	3.8	0.0
Mcdonell	178	Migration	4	20.0	2	200.0	0.007	0.7	7	10.6	82.4
		Spawning	0	NA	0	NA	NA	NA	0	NA	0.0
		Rearing	0	NA	0	NA	0.000	0.0	0	0.0	0.0
Atna	179	Migration	7	9.0	3	300.0	0.026	1.9	14	1.9	77.3
		Spawning	0	NA	0	NA	NA	NA	0	NA	0.0
		Rearing	0	NA	0	NA	0.000	NA	0	NA	0.0

Babine	180	Migration	5	9.4	1	50.0	0.004	0.4	10	5.8	63.1
		Spawning	0	0.0	0	NA	0.018	1.5	1	33.3	37.7
		Rearing	0	0.0	5	250.0	0.012	1.1	1	6.3	43.2
Bulkley	181	Migration	7	9.0	3	300.0	0.009	0.6	14	1.8	134.3
		Spawning	0	NA	0	NA	NA	NA	0	NA	0.0
		Rearing	0	0.0	0	0.0	0.065	2.9	0	0.0	22.2
Club Lake	182	Migration	4	7.5	1	50.0	0.004	0.4	10	5.6	63.1
		Spawning	0	NA	0	NA	0.000	0.0	0	NA	0.0
		Rearing	0	NA	0	NA	0.000	0.0	0	NA	0.0
Gitanyow	183	Migration	2	4.4	1	100.0	0.006	0.6	10	8.5	55.8
		Spawning	0	NA	0	NA	NA	NA	0	NA	0.0
		Rearing	0	NA	0	NA	0.000	0.0	0	NA	0.0
Maxan	184	Migration	7	8.2	3	150.0	0.011	0.8	14	1.8	149.7
		Spawning	0	NA	0	NA	NA	NA	0	NA	0.0
		Rearing	0	NA	0	NA	0.121	9.1	0	NA	0.0
Morice	185	Migration	7	9.0	3	300.0	0.028	2.0	14	1.9	77.3
		Spawning	1	NA	2	NA	0.000	0.0	0	NA	30.9
		Rearing	2	NA	2	NA	0.002	1.1	0	NA	30.9
Nilkitkwa	186	Migration	5	9.4	1	50.0	0.004	0.4	10	5.8	63.1
		Spawning	0	NA	0	NA	NA	NA	0	NA	0.0
		Rearing	0	NA	0	NA	0.000	0.0	0	NA	0.0
Stephens	187	Migration	4	7.5	1	50.0	0.004	0.4	10	5.6	63.1
		Spawning	0	NA	0	NA	0.000	0.0	0	NA	0.0
		Rearing	0	NA	0	NA	0.000	0.0	0	NA	0.0
Swan	188	Migration	4	7.5	1	50.0	0.004	0.4	10	5.6	63.1
		Spawning	0	NA	0	NA	0.000	0.0	0	NA	0.0
		Rearing	0	NA	0	NA	0.000	0.0	0	NA	0.0
Tahlo/Morrison	189	Migration	6	8.9	5	150.0	0.003	0.3	10	5.4	63.1
		Spawning	0	NA	0	NA	0.000	0.0	0	NA	0.0
		Rearing	0	NA	2	NA	0.000	0.0	0	0.0	0.0
Asitika	190	Migration	4	7.1	1	50.0	0.003	0.3	10	5.8	63.1
		Spawning	0	NA	0	NA	NA	NA	0	NA	0.0
		Rearing	0	NA	0	NA	0.000	0.0	0	NA	0.0
Azuklotz	191	Migration	4	7.1	1	50.0	0.003	0.3	10	5.7	63.1
		Spawning	0	NA	0	NA	0.000	0.0	0	NA	0.0
		Rearing	0	NA	0	NA	0.000	0.0	0	NA	0.0

Bear	192	Migration	4	7.1	1	50.0	0.004	0.3	10	5.8	63.1
		Spawning	0	NA	0	NA	0.000	0.0	0	NA	0.0
		Rearing	0	NA	0	NA	0.000	0.0	0	0.0	0.0
Damshilgwit	193	Migration	4	7.5	1	50.0	0.004	0.4	10	5.8	63.1
		Spawning	0	NA	0	NA	0.000	NA	0	NA	0.0
		Rearing	0	NA	0	NA	0.000	NA	0	NA	0.0
Johanson	194	Migration	4	7.1	1	50.0	0.007	0.7	10	5.7	63.1
		Spawning	0	NA	0	NA	NA	NA	0	NA	0.0
		Rearing	0	NA	0	NA	0.056	13.7	0	NA	0.0
Kluatantan	195	Migration	5	9.1	1	50.0	0.003	0.3	10	5.8	63.1
		Spawning	0	NA	0	NA	NA	NA	0	NA	0.0
		Rearing	0	NA	0	NA	0.000	0.0	0	NA	0.0
Kluayaz	196	Migration	5	9.1	1	50.0	0.003	0.3	10	5.8	63.1
		Spawning	0	NA	0	NA	NA	NA	0	NA	0.0
		Rearing	0	NA	0	NA	0.000	NA	0	NA	0.0
Motase	197	Migration	5	9.3	1	50.0	0.004	0.4	10	5.8	63.1
		Spawning	0	NA	0	NA	0.000	NA	0	NA	0.0
		Rearing	0	NA	0	NA	0.000	NA	0	NA	0.0
Sicintine	198	Migration	4	7.5	1	50.0	0.004	0.4	10	5.8	63.1
		Spawning	0	NA	0	NA	NA	NA	0	NA	0.0
		Rearing	0	NA	0	NA	0.000	NA	0	NA	0.0
Slamgeesh	199	Migration	4	7.5	1	50.0	0.004	0.4	10	5.8	63.1
		Spawning	0	NA	0	NA	0.000	NA	0	NA	0.0
		Rearing	0	NA	0	NA	0.000	NA	0	NA	0.0
Spawning	200	Migration	4	7.1	1	50.0	0.007	0.7	10	5.7	63.1
		Spawning	0	NA	0	NA	NA	NA	0	NA	0.0
		Rearing	0	NA	0	NA	0.000	NA	0	NA	0.0
Sustut	201	Migration	4	7.1	1	50.0	0.006	0.6	10	5.7	63.1
		Spawning	0	NA	0	NA	0.000	NA	0	NA	0.0
		Rearing	0	NA	0	NA	0.000	NA	0	NA	0.0
Onerka	999	Migration	5	9.4	1	50.0	0.004	0.4	10	5.8	63.1
		Spawning	0	NA	0	NA	0.000	NA	0	NA	0.0
		Rearing	0	NA	0	NA	0.000	NA	0	NA	0.0

3.5.2 Skeena Estuary

The location and general mapped extents of proposed new developments (e.g., wind power tenures, container terminals, LNG facilities, marine wharfs, transmission lines, utility corridors, etc.) known to be planned (as of 2013) within the defined boundaries of the Skeena Estuary are presented in the Skeena Estuary Habitat Report Card developed for this project, with descriptions of specific development projects in the estuary (as extracted from CEAA and BC EAO documents) provided in supporting database files. However, imprecision in available planning documents does not allow adequate capture of known proposed development activities (i.e., mapped footprint) for an estuary-scale quantified analysis of future development pressures to be undertaken at this time.

3.5.3 Skeena River Basin

Analyses of historical and future projected changes in summer air temperatures and summer precipitation at six sites selected for assessment across the Skeena River Basin are presented in **Table 16** and **Table 17** respectively.

While no change in air temperature was evident between the historical period (1961-1990) and the current baseline (2000-2010), all three of the climate models evaluated consistently predicted a marked increasing trend in the maximum average monthly air temperatures in the summer (July-September inclusive) at all sites evaluated across the Skeena River Basin (**Table 16**). Projected summer air temperature increases between the comparative baseline (2000-2010) period and a projected 2080 future date ranged from 2.9^{o}C at Lower Skeena (based on the HADCM3 model) to 6.4^{o}C at Upper Babine (based on the HADGEM model).

Projected changes in precipitation that could affect critical low stream flows for salmon (as indicated by the minimum average monthly precipitation in the summer months: July – September inclusive) were not consistent across the climate models evaluated. The CHCM3 and HADCM3 models showed essentially no change in predicted summer precipitation amounts between the current baseline period (2000-2010) and future time projected time periods, except in the Lower Skeena, where the CMCM3 climate model predicted a decline of 21 mm by 2080 and the HADCM3 predicted a decline of 10 mm. Conversely, the HADGEM model predicted a decline in future summer precipitation across all six sites evaluated, ranging from a decrease of 16 mm in the Upper Skeena to a decrease of 38 mm in the Lower Skeena between the 2000-2010 baseline and a projected 2080 future.

Table 16 Maximum average monthly air temperatures (°C) during the summer period (July - Sept.) at six selected sites across the Skeena River Basin as measured historically (1961-1990), for a current baseline (2000-2010), and during projected future periods (2020, 2050, 2080) as predicted by three alternative climate models (CHCM3, HADCM3, and HADGEM) that are considered illustrative choices for examining potential changes in air temperature and precipitation across British Columbia (Murdock and Spittlehouse 2011). Estimates of air temperature were generated using the ClimateBC/WNA database.

Maximum Average Monthly Air Temperature (°C) - Summer

Location	Climate Models	Historical (1961-1990)	Baseline (2000-2010)	Future (2020)	Future (2050)	Future (2080)	Trend
Lower Skeena	CHCM3	19.1	19.5	21.1	21.4	23.3	
	HADCM3	19.1	19.5	20.8	21.5	22.4	
	HADGEM	19.1	19.5	20.7	22.6	24	
Mid Skeena	CHCM3	20.1	20.1	22	22.4	24.3	
	HADCM3	20.1	20.1	21.8	22.6	23.5	
	HADGEM	20.1	20.1	22.2	24.6	26.2	
Upper Skeena Headwater	CHCM3	15.1	15	16.9	17.1	19.1	
	HADCM3	15.1	15	16.9	17.6	18.4	
	HADGEM	15.1	15	17	19.2	20.9	
Upper Babine	CHCM3	19	19.2	20.7	21.5	23.2	
	HADCM3	19	19.2	20.8	21.7	22.6	
	HADGEM	19	19.2	21.2	23.9	25.6	
Terrace	CHCM3	21.7	21.7	23.6	24	25.9	
	HADCM3	21.7	21.7	23.3	24.1	25	
	HADGEM	21.7	21.7	23.5	25.7	27.3	
Topley	CHCM3	20.7	21.1	22.5	23.2	24.9	
	HADCM3	20.7	21.1	22.4	23.3	24.2	
	HADGEM	20.7	21.1	22.9	25.4	27.1	

Table 17 Minimum average monthly precipitation (mm) during the summer period (July - Sept.) at six selected sites across the Skeena River Basin as measured historically (1961-1990), for a current baseline (2000-2010), and during projected future periods (2020, 2050, 2080) as predicted by three alternative climate models (CHCM3, HADCM3, and HADGEM) that are considered illustrative choices for examining potential changes in air temperature and precipitation across British Columbia (Murdock and Spittlehouse 2011). Estimates of precipitation were generated using the ClimateBC/WNA database.

Minimum Average Monthly Precipitation (mm) - Summer

Location	Climate Model	Historical (1961-1990)	Baseline (2000-2010)	Future (2020)	Future (2050)	Future (2080)	Trend
Lower Skeena	CHCM3	102	109	90	85	88	
	HADCM3	102	109	99	92	99	
	HADGEM	102	109	99	75	71	
Mid Skeena	CHCM3	49	49	45	45	47	
	HADCM3	49	49	51	49	49	
	HADGEM	49	49	44	33	28	
Upper Skeena Headwater	CHCM3	75	83	69	74	75	
	HADCM3	75	83	76	77	81	
	HADGEM	75	83	69	58	67	
Upper Babine	CHCM3	47	48	47	42	45	
	HADCM3	47	48	45	48	42	
	HADGEM	47	48	37	34	24	
Terrace	CHCM3	49	51	45	43	45	
	HADCM3	49	51	50	48	49	
	HADGEM	49	51	47	36	31	
Topley	CHCM3	41	43	42	44	46	
	HADCM3	41	43	38	44	38	
	HADGEM	41	43	33	30	25	

4 Summary and Recommendations

Freshwater habitats are known to contribute to the overall diversity and resilience of sockeye salmon (Bisson et al. 2009; Healey 2009). Thus, protecting freshwater habitats is important to the conservation of Skeena lake sockeye CUs. There are significant gaps, however, which hinder the ability to effectively manage habitats for Skeena lake sockeye and the human activities that can impact them.

To improve our understanding about habitat status across Skeena lake sockeye CUs, monitoring of habitat pressure and state/condition indicators needs to be undertaken in a more consistent manner on a regular basis across Skeena rivers, streams, and nursery lakes. 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 Skeena lake sockeye CU habitat report cards 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. While we were able to undertake time series analyses for some key water quantity/quality state indicators for this project (i.e., summer flows, snowpack) the limited distribution of monitoring stations means that such indicators can only realistically be examined at the scale of the whole Skeena River Basin, and are not amenable to comparison of habitat condition at the scale of individual lake sockeye CUs. 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 lake sockeye and other Skeena salmon.

To improve understanding about the effects of stressors on freshwater habitats, there is a need for more precise estimates of the consequences to habitat state/condition of increasing habitat pressures (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 sockeye 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 sockeye salmon.

For improved access to information by stakeholders, better communication tools are needed to relay the status of sockeye salmon and their habitats. The lake sockeye 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 lake sockeye 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 lake sockeye or other 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 lake sockeye 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 (rearing, spawning, 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. 2013) 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 to scoring effects should, however, be considered only a broad first-cut attempt at quantifying cumulative effects across suites of 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 lake sockeye CU ZOI watersheds 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 sockeye habitats, actual risk to sockeye populations is also dependent on CU-specific vulnerabilities/sensitivities to these habitat impacts. Vulnerability indicators for salmon are not identified specifically in Stalberg et al. 2009, but we identified a suite of potential indicators of lake sockeye CU life stage habitat vulnerabilities (measures of CU-associated habitat quantity and quality) as part of this report (building on the vulnerability indicators for sockeye salmon CUs used recently in the Cohen Commission analyses for examining sockeye response to freshwater impacts (Nelitz et al. 2011)). The assembled information on relative vulnerabilities was used in our analyses to assess the relative (ranked) habitat status for each CU and life history stage (based on an integration of cumulative habitat pressures and habitat vulnerabilities); however, this is admittedly only a 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 lake sockeye 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 lake sockeye Conservation Units (CUs) evaluated for this project.

Sockeye CU index	Sockeye CU name	CU rearing lake size (ha)	CU rearing lake juvenile rearing capacity[3] (estimated max. kg/ha)	Average Annual Escapement (# of spawners)[4] (1991 – 2010)
L_20_01	Alastair	8546	8.27	17205
L_20_02	Aldrich	2792	4.20	6015[5]
L_20_03	Dennis	6667	5.30	6015[5]
L_20_04	Ecstall/Lower	2059	no data	no data
L_20_05	Johnston	5245	5.40	8013
L_20_06	Kitsumkalum	193038	2.70	21899
L_20_07	Lakelse	38263	6.00	9921
L_20_08	Mcdonell	19007	4.30	6015[5]
L_21_01	Atna	27555	6.54	40018[6]
L_21_02	Babine	589248	10.00	56113[7]
L_21_02	Babine enhanced[8]	589248	n/a	730402
L_21_03	Bulkley	26650	no data	no data
L_21_04	Club Lake	551	3.60	7739[9]
L_21_05	Gitanyow	17705	17.00	3409
L_21_06	Maxan	23594	no data	no data
L_21_07	Morice	161206	6.00	40018[6]
L_21_08	Nilkitkwa	40144	no data	214161[10]
L_21_09	Stephens	2910	8.70	10823
L_21_10	Swan	10964	2.95	7739[9]
L_21_11	Tahlo/Morrison	43518	8.20	23626[11]
L_22_01	Asitika	2993	7.19	638
L_22_02	Azuklotz	10218	6.60	4037
L_22_03	Bear	28657	5.30	2063
L_22_04	Damshilgwit	6396	2.30	444
L_22_05	Johanson	5397	5.00	no data
L_22_06	Kluatantan	3929	7.19	no data
L_22_07	Kluayaz	16911	7.19	no data
L_22_08	Motase	13170	1.10	424
L_22_09	Sicintine	4496	7.19	no data
L_22_10	Slamgeesh	15604	2.30	no data
L_22_11	Spawning	2713	7.19	no data
L_22_12	Sustut	5020	2.70	no data
L_99_99	Onerka[12]	1393	no data	no data

[3] Based on photosynthetic rate (PR) model: Cox-Rogers et al. 2010 and Cox-Rogers 2012 (Draft)
[4] Skeena lake sockeye CU escapement numbers derived from English 2013
[5] Represents escapement totals for McDonell + Dennis + Aldrich combined
[6] Represents escapement totals for Atna + Morice combined
[7] Includes Babine + Onerka lake (Babine early-run wild)
[8] Pinkut + Fulton
[9] Represents escapement totals for Club + Swan combined
[10] Babine late-run wild
[11] Babine mid-run wild
[12] Onerka is not currently a DFO-designated lake sockeye CU, but DFO has indicated that they will be proposing this lake-rearing sockeye population for discussion as a potential CU. Escapements combined with Babine.

Appendix 2. Location of rearing lakes for 32 lake sockeye Conservation Units (CUs) within the Skeena River Basin (31 CUs currently identified by DFO, plus Onerka Lake (which DFO has indicated that they will be proposing for discussion as a potential CU)).

Appendix 3. 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 – <u>FISH_HABITAT</u> ‘FISH HABITAT – INFERRED’ ‘FISH HABITAT – OBSERVED’ ‘<NULL>’ RoadStreamCrossings – <u>FISH_HABITAT</u> FISH HABITAT – INFERRED FISH HABITAT – OBSERVED <NULL>	Fish habitat arcs and stream crossing points were overlaid with the watersheds layer. Inferred and observed fish habitat was merged into a single ‘fish habitat’ group. A total number of fish habitat crossings per total length of habitat was calculated for each watershed.	Watershed layer identifying the total number of stream crossings per kilometer of fish habitat.	Note the fish habitat and stream crossings are based on modeled data. For more information on the accessible stream length input data contact Craig Mount at the BC Ministry of Environment.
	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	<u>LIC_STATUS</u> ‘CURRENT’ <u>PURPOSE</u> 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 – <u>COVTYPE</u> 120, 121, 122: agriculture 34: urban VRI – <u>BCLCS_LEVEL_5</u> 'RZ', 'RN', 'UR', 'AP': urban 'BU': fire 'GP', 'TZ', 'MI': mining <u>EARLIEST_NONLOGGING_DIST_TYPE</u> 'B*': fire <u>OPENING_IND</u> ‘Y’: forestry <u>OPENING_ID</u> Not null: forestry <u>HARVEST_DATE</u> 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

<table>
<tr><td></td><td></td><td></td><td>H_FIRE_PLY –
<u>FIRE_YEAR</u>
>= 1993: fire

C_FIRE_PLY –
All features: fire

RESULTS –
<u>DISTURBANCE_START_DATE</u>
All openings within last 60 years: forestry

FTEN cutblocks–
<u>DISTURBANCE_START_DATE</u>
All cutblocks within last 60 years: forestry

BTM -
<u>PLU_LABEL</u>
‘MINE’: mining

FTEN road segments –
All features: roads

DRA –
All features: roads
<u>NMBRFLNS</u>
<u>ROAD_CLASS</u>

TA_CROWN_TENURES_SVW –
All current utility tenures: utility

NTS –
<u>ENTITYNAME</u>
“RAILWAY”: rail</td><td>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.</td><td></td><td>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)</td></tr>
<tr><td></td><td>Impervious surfaces</td><td>LCC2000-V (agriculture, urban), VRI (urban), DRA (roads), FTEN (roads), NTS (rail)</td><td>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.</td><td>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 <</td><td>Watershed layer identifying the percent of watershed area covered by impervious surface for each watershed.</td><td></td></tr>
</table>

				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 – <u>STATUS_D</u> 'Developed Prospect', 'Past Producer' <u>COMMODIT_D</u> 'Coal' Aggregate mines from AGGINV04 and North Coast Aggregate Potential gravel pits. Placer mines from MTA_ACQ_TE_polygon – <u>TNRTPDSCRP</u> '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 – <u>STATUS_D</u> '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	<u>DischargeT</u> 'effluent' <u>Status</u> '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.
Skeena Estuary	Protected Areas and current development infrastructure	BC PECP tenures. Wildlife Management Areas; Conservancy Areas; Parks, Ecological Reserves and Protected Areas; Prince Rupert harbour limit (Skeena TAC), Port of Prince Rupert anchorages (Skeena TAC), commercial anchorages (Skeena TAC), Council of BC Yacht Club anchorages (from BCMCA website).		Used for map display only.	Map of protected areas and current pressure activities across the Skeena estuary.	

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

Vulnerability Indicators						
Life Stage	**Indicator**	**Input Data**	**Input Attributes/Features Used**	**Processing**	**Outputs**	**Notes**
Rearing period	Area of nursery lake	DFO sockeye CUs	<u>HECTARES</u>	None required.	Table of CUs with nursery lake area for each CU.	
	Nursery lake productive capacity	DFO designated nursery lakes, DFO - S.Cox-		Productive capacity values (Rmax estimated, kg/ha) for each CU nursery lake were extracted from Cox-Rogers et al. 2010, 2012.	Table of productive capacity values for each CU.	

		Rogers et al. (2010, 2012)				
	Sockeye escapement	Annual escapement estimates, English 2013.	CU_Code SpeciesID "SX" TE column (total estimate)	Calculated average total escapement between 1991 and 2010. Joined calculated averages to CU locations based on CU_Code and description of CU delineations provided in Appendix G of English 2013.	Average escapement estimates between 1991 and 2010 by CU	
Spawning period	Salmonid accessible habitat	MOE Fish Passage Model	FishHabitat – FISH_HABITAT 'FISH HABITAT – INFERRED' 'FISH HABITAT – OBSERVED'	Fish habitat arcs were overlaid with the CU lake ZOIs. The sum of inferred and observed habitat length was calculated for each CU.	Table identifying the total length of accessible stream for each CU.	Note the 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.
	Total spawning length (mainstem, tributary & lake)	Sockeye spawning distribution (provided by Skeena TAC)	SPECIES_NAME 'Sockeye' ACTIVITY 'spawning'	Spawning zones were overlaid with the CU lake ZOIs, and total length of spawning (mainstem, tributary and lake inlet, and lake shore) was calculated for each CU.	Table identifying the total length of spawning for each CU.	
	Tributary/lake inlet spawning length	Sockeye spawning distribution (provided by Skeena TAC)	SPECIES_NAME 'Sockeye' ACTIVITY 'spawning'	Spawning zones were overlaid with the CU lake ZOIs, and total length of spawning (tributary and lake inlet spawning only) was calculated for each CU.	Table identifying the total length of tributary and lake inlet spawning for each CU.	
	Mainstem/lake outlet spawning length	Sockeye spawning distribution (provided by Skeena TAC)	SPECIES_NAME 'Sockeye' ACTIVITY 'spawning'	Spawning zones were overlaid with the CU lake ZOIs, and total length of spawning (mainstem and lake outlet/influenced spawning only) was calculated for each CU.	Table identifying the total length of mainstem spawning for each CU.	
	Length of lake shore spawning areas	Sockeye spawning distribution (provided by Skeena TAC)	SPECIES_NAME 'Sockeye' ACTIVITY 'spawning'	Lake spawning zones represented by polygons were converted to polylines to represent the lake shore length used for spawning. Spawning zones were overlaid with the CU lake ZOIs, and total length of spawning (lake shore spawning only) was calculated for each CU.	Table identifying the total length of lake shore spawning for each CU.	
	Ratio of lake	Sockeye	Mainstem/lake outlet spawning and total	Mainstem/lake outlet spawning length was	Table of ratio values	

	influenced spawning to total spawning	spawning distribution (provided by Skeena TAC)	spawning values – see indicator descriptions for details.	divided by total spawning length to get the ratio of lake influenced spawning to total spawning for each CU lake ZOI.	for each CU.	

Migration period	Migration distance	DFO designated nursery lakes, FWA stream network	FWA streams –
			<u>CWB_WS_CD</u>
			<u>LOCL_WS_CD</u>
			<u>STREAM_ORD</u>
			<u>EDGE_TYPE</u>
				Using the FWA watershed codes, the route downstream from each CU lake could be selected from the stream network. The following selection logic was used:
				
				For a point on the stream network immediately downstream of the lake:
				
				if LOCL_WS_CD & CWB_WS_CD are the same:
				("CWB_WS_CD" LIKE 'aaa-bbbbbb-cccccc-000000%' AND
				"LOCL_WS_CD" LIKE 'aaa-bbbbbb-cccccc-000000%' OR
				"CWB_WS_CD" LIKE 'aaa-bbbbbb-000000%' AND
				"LOCL_WS_CD" < 'aaa-bbbbbb-cccccc' OR
				"CWB_WS_CD" LIKE 'aaa-000000%' AND
				"LOCL_WS_CD" < 'aaa-bbbbbb') AND
				"LOCL_WS_CD" <> '' AND "STREAM_ORD" >= n AND "EDGE_TYPE" IN (1000,1050,1200,1250)
				
				if LOCL_WS_CD & CWB_WS_CD are different:
				("CWB_WS_CD" LIKE 'aaa-bbbbbb-cccccc-000000%' AND
				"LOCL_WS_CD" < 'aaa-bbbbbb-cccccc-[dddddd+1]' OR
				"CWB_WS_CD" LIKE 'aaa-bbbbbb-000000%' AND
				"LOCL_WS_CD" < 'aaa-bbbbbb-cccccc' OR
				"CWB_WS_CD" LIKE 'aaa-000000%' AND
				"LOCL_WS_CD" < 'aaa-bbbbbb') AND
				"LOCL_WS_CD" <> '' AND "STREAM_ORD" >= n AND "EDGE_TYPE" IN (1000,1050,1200,1250)
				
				The resulting stream segments were dissolved into a single line for each CU, and total line length was calculated.
					Table of migration route length for each CU.	The FWA stream network is not without errors, and using the watershed codes to extract the downstream path resulted in a number of small gaps in the route which needed to be manually filled. Some additional stream segments joining on to the main route were also selected when using this logic (where wide rivers are represented by a complex route of constructor lines and secondary channels). These additional segments were manually removed from the migration routes.

	Migration route – length summer flow sensitive	BC MOE ecoregional flow sensitivity mapping (R. Ptolemy, unpubl.), FWA	Flow sensitivity polygons Migration route lines – see migration distance indicator for details.	Flow sensitivity data were overlaid with the CU migration route lines. The sum of line length within only the summer flow sensitive regions for each migration route was calculated.	Table of summer flow sensitive migration length for each CU.	
	Migration route - % summer flow sensitive	BC MOE ecoregional flow sensitivity mapping (R. Ptolemy, unpubl.), FWA	Flow sensitivity polygons Migration route lines – see migration distance indicator for details.	Flow sensitivity data were overlaid with the CU migration route lines. The sum of line length within only the summer flow sensitive regions for each migration route was calculated as a percentage of the total migration route length.	Table of summer flow sensitive migration as a percentage of total migration length for each CU.	
Estuary residence	Estuary area	Skeena TAC suggested Skeena Estuary extent and previously defined boundaries based on salinity profiles and expert opinion.		Manually digitized Skeena Estuary extent based on TAC input and feedback. Estuary area was calculated from the resulting polygon.	Area value.	

Current Condition Indicators						
Spatial scale	**Indicator**	**Input Data**	**Input Attributes/Features Used**	**Processing**	**Outputs**	**Notes**
Skeena River Basin	Snowpack	Snow pack data tables compiled from BC River Forecast Center by Russell Smith (WaterSmith Research)	X/Y coordinates of snow pack monitoring sites Snow Water Equivalent (SWE) fields corresponding to April 1st at each monitoring site	X/Y coordinates from CSV tables were used to create a simple base map Created graphs of annual April 1st SWE across 20 year period (1991 – 2010) for each snow pack monitoring location (each site with at least 10 years of data over that time period)	Map of snow pack station locations in the Skeena River Basin Graphs of annual April 1st SWE at each Skeena monitoring site	
	Glacier extent	1985 & 2005 Skeena glacier extent spatial file from UNBC Skeena region spatial file	Area (km²)	Calculated area of glacier extent per Skeena subdrainage Created summary statistics on past, current glacier extent, and changes in glacier extent over time for each Skeena subdrainage as well as generally across the Skeena River Basin	Map showing glacier loss within Skeena River Basin subdrainages over the 1985 – 2005 time period Summary tables of statistics on Skeena glacial area	

					extent/loss	
	Summer low flows	Water Survey of Canada (WSC) flow station data tables	X/Y coordinates of WSC active flow gauging sites in the Skeena River Basin Flow (m^3/s)	X/Y coordinates from CSV tables were used to create a simple base map Created graphs of the annual minimum average monthly flow for the months July – September across a 20 year period (1991 – 2010) at each WSC location (each site with at least 18 years of data over that time period)	Map of flow monitoring stations Graphs of minimum average monthly flow (July – Sept.) at each Skeena WSC station	
Skeena Estuary	Kelp and eelgrass extents	GIS layer of the current location and extent of marine plants/macroalgae within the Skeena estuary (provided by B. Faggetter, Ocean Ecology)		Used for map display only.	Map of kelp and eelgrass distribution across the Skeena estuary.	
	BORSTAD habitat mapping/rating	Updated GIS layer of Skeena foreshore and intertidal habitat mapping undertaken by BORSTAD Associates Ltd.and updated by WWF (provided by J. Casey, WWF).		Used for map display only.	Map of foreshore and intertidal habitats around Prince Rupert.	

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	Water License Points of Diversion – <u>LIC_STATUS</u> 'ACTIVE_APPL', 'PENDING'	Proposed resource developments were split into 5 indicators and summarized by watershed and by CU for each life stage ZOI (migration, spawning, and rearing), along with a percentage increase based on current values for that indicator. *Proposed mines* – Skeena TAC identified prospect mineral and coal mines (from MINFILE	Summary table of proposed developments in each of the 5 indicators for each CU life stage ZOI.	

		Diversion (proposed), Proposed BC Advance Exploration Sites From the Skeena TAC: Proposed NWBC-Wind, Proposed Pipelines, Proposed Transmission Lines, Proposed Wind & Water Power		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.		
Skeena River Basin	Historical vs. future summer air temperatures	Air temperature tables derived from Climate WNA software	X/Y coordinates of selected site in the Skeena River Basin (sites were selected to be generally geographically representative of terrain variations in the Skeena River Basin) Maximum Monthly Average Air temperature (°C) (between July – Sept.) modeled at different time periods: 1961-1990, 2000-2010, 2020, 2050, and 2080.	X/Y coordinates from CSV tables were used to create a simple base map Air temperature data was modeled using 3 different climate models considered illustrative for BC (CHCM3, HADCM3, and HADGEM)	Map of location where air temperature modeled Graphs of modeled air temperature across different time periods at each selected site in the Skeena River Basin	
	Historical vs. future summer precipitation	Precipitation tables derived from Climate WNA software	Minimum Monthly Average Precipitation (mm) (between July – Sept.) modeled at different time periods: 1961-1990, 2000-2010, 2020, 2050, and 2080.	X/Y coordinates from CSV tables were used to create a simple base map Precipitation data was modeled using 3 different climate models considered illustrative for BC (CHCM3, HADCM3, and HADGEM)	Map of modeled precipitation locations Graphs of modeled precipitation across different time periods at each selected site in the Skeena River Basin	
Skeena Estuary	Proposed development projects in the Skeena	Potential wind power tenures, port development project footprints		Proposed Port development project footprints were digitized from publicly available company reports, maps, graphics and websites.		Port development project footprints are an approximation of

	Estuary			Used for map display only.		the potential development area and should not be used for any other purpose outside of these report cards.
	Climate Change Impacts Scoring (WWF model)	GIS layer for modeled potential climate change impacts (based on exposure and sensitivity) from SST, acidification and/or UV changes for habitats within Skeena estuary (2 km x 2 km grid) (provided by Selina Agbayani, WWF)		Used for map display only.	WWF model outputs: areas of Skeena Estuary with potential impact from SST, acidity and UV changes	Produced using information under License with the World Wildlife Fund Canada © World Wildlife Fund Canada, 2013

Appendix 4. Skeena lake sockeye CU Habitat Report Cards (example for Lakelse CU)

SKEENA SALMON PROGRAM

Skeena Salmon: Lake Sockeye
Conservation Unit (CU)
Lakelse

PACIFIC SALMON FOUNDATION

Version 1.1, July 2013

Introduction

This habitat report card is part of a 2013 project by ESSA Technologies that summarizes pressures on the habitat used by Skeena sockeye CUs during their freshwater life history stages (migration, spawning and rearing), as well as their relative vulnerability to those pressures. For an explanation of the indicators shown here, please see the accompanying *Report Card Summaries*. Full methods and results can be found in the main report, *Skeena Lake Sockeye Conservation Units: Habitat Report Cards* (2013). An online interactive version of this information is available at www.skeenasalmonprogram.ca.

Definitions

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.

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

Vulnerability indicator: Measures of habitat quantity or quality used to represent the intrinsic habitat vulnerability/sensitivity to watershed disturbances for each life-stage.

Zone of influence (ZOI): Areas adjacent to and upstream/upslope of habitats used by salmon CUs that represent the geographic extent for capture/measurement of pressure and vulnerability indicators.

Status: Condition of habitat relative to a defined indicator benchmark.

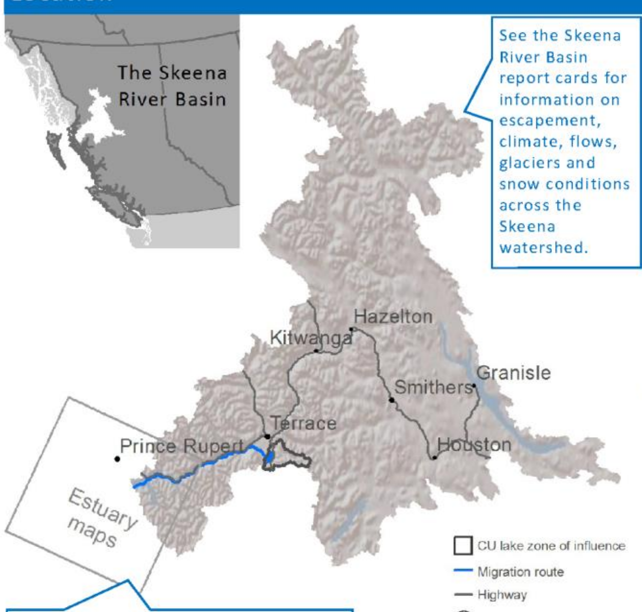
Risk: Risk of adverse effects to salmon habitats within a defined zone of influence. Levels of increasing risk are defined based on the extent/ intensity of impacts relative to defined benchmarks of concern.

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.

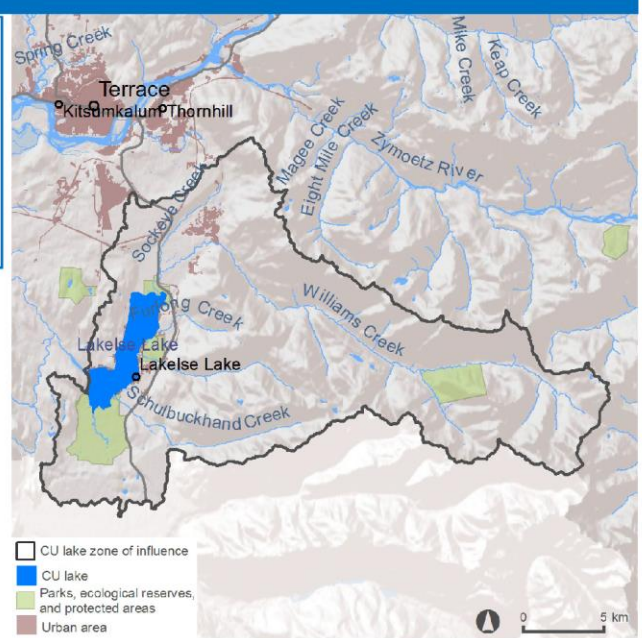
Narrative

* No significant lakeshore spawning. Three main sockeye spawning streams: Williams Creek, Hatchery Creek, Schulbuckhand Creek, with one small population of spawners in a series of small groundwater tributaries along 1st Avenue.
* All three main tributary fans that support the majority of spawners have been heavily modified or channelized. Some systems experience sub gravel flows during low flow conditions.
* Increase in sediment production has provided favorable habitat for heavy growth of Pondweed Elodea Canadensis.
* Snowmelt driven hydrological regime with relatively warm lake water, oligotrophic to slightly mesotrophic with a low Nitrogen:Phosphorous ratio.
* Lakelse sockeye exploitation levels have been low to moderate; however, escapements for the last 20 years have been low relative to historic levels.
* Wide variety of habitat rehabilitation activities over the last 10 years.
* Protection and conservation of ecosystem processes and fish habitat are a high priority.
* Cumulative impacts to fisheries resources from forestry, linear, agriculture and residential developments are rated high.
* Majority of spawning stream drainages have been adversely affected by forestry activities. Increased deciduous growth following deforestation has led to extensive beaver activity.
* Formal Lakelse Lake Sockeye Recovery Plan in place with implementation and monitoring underway including annual adult enumeration, sockeye enhancement, habitat restoration and monitoring.
* Hatchery enhancement of 300,000 sockeye fry from 2006 through 2013.
* Large amount of historical data available as watershed was a fisheries research lake in the 1960's and 1970's.
* Historic highs of over 30,000 spawners.

Location



See the Skeena estuary report card for information on habitat pressures and vulnerabilities to salmon in the estuary.



CU overview of habitat vulnerabilities & pressures

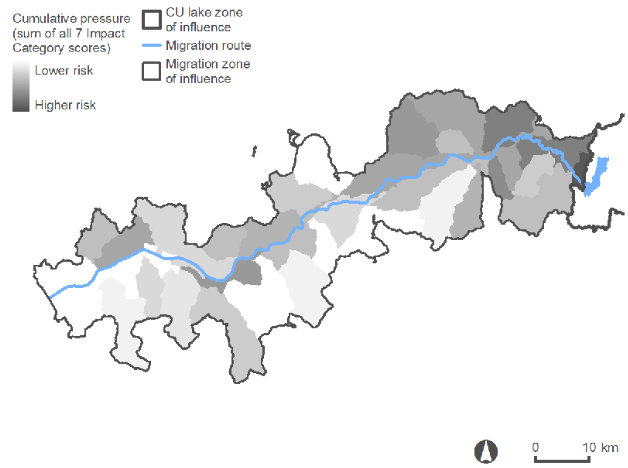
Pressure indicators were grouped into seven relatively independent habitat "impact categories" representing key factors affecting general watershed condition:

- Hydrologic Processes (Forest disturbance; ECA)
- Vegetation Quality (Insect and disease defoliation; Riparian disturbance)
- Surface Erosion (Road development)
- Fish passage/Habitat connectivity (Stream crossing density)
- Water quantity (Water licenses)
- Human development footprint (Total land cover alteration; Impervious surfaces; Linear development; Mining development)
- Water quality (Mining development acid generating; Wastewater discharges)

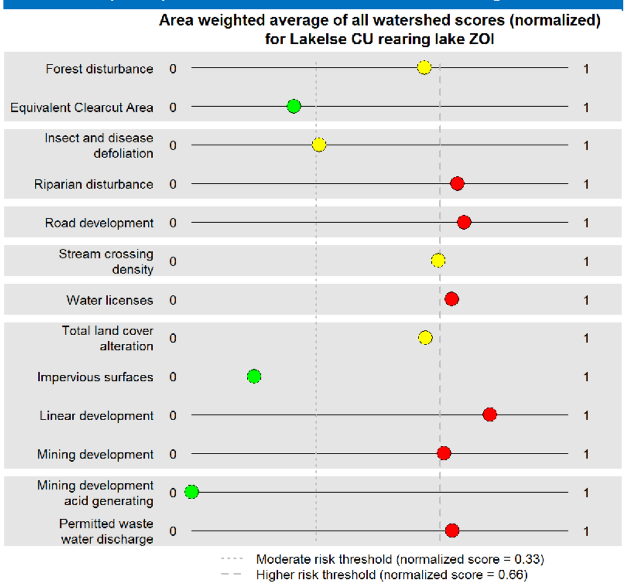
Indicators were also developed reflecting relative vulnerability to habitat pressures within the life stage-specific "zones of influence" defined for each lake sockeye CU:

- Migration (Total migration distance; Length & % of migration route summer flow sensitive)
- Spawning (Total spawning length; Spawning length in tributary, lake or mainstem; Ratio of lake influenced to total spawning length; Length of accessible habitat)
- Rearing (Rearing lake area, Rearing lake productive capacity)

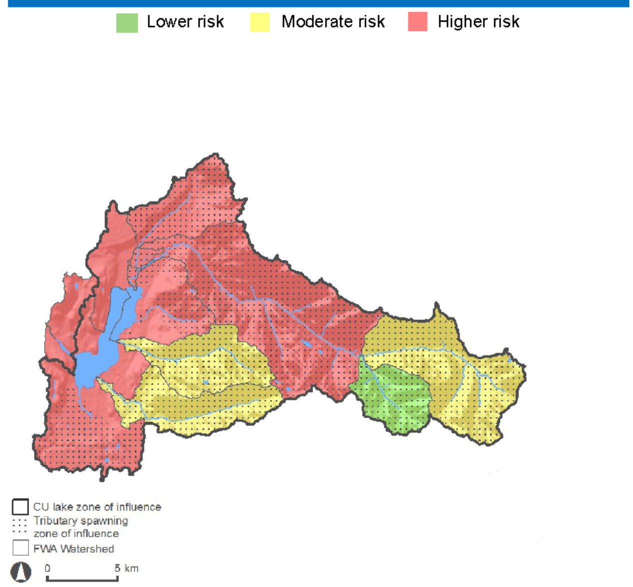
Cumulative pressure—migration



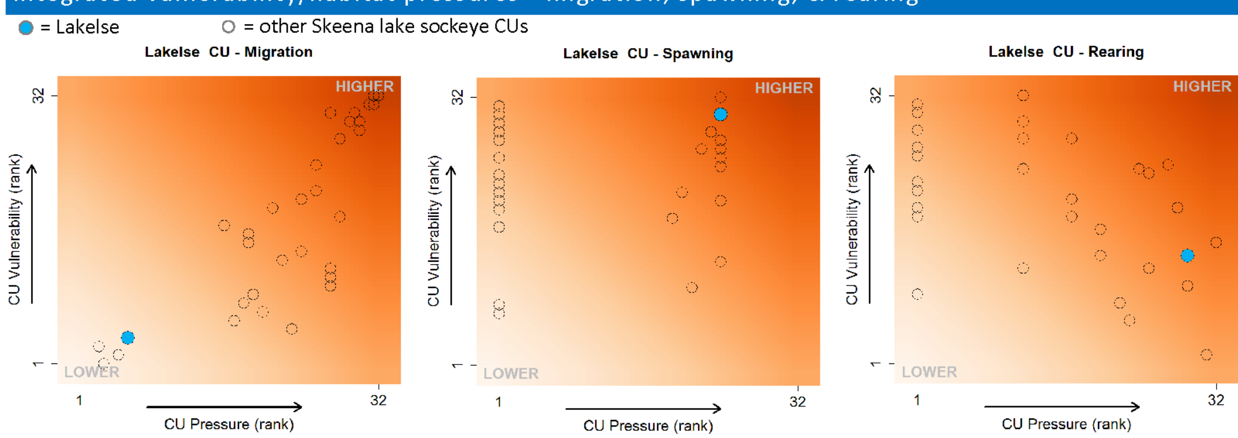
Summary of pressure indicators—rearing



Cumulative pressure—rearing & spawning

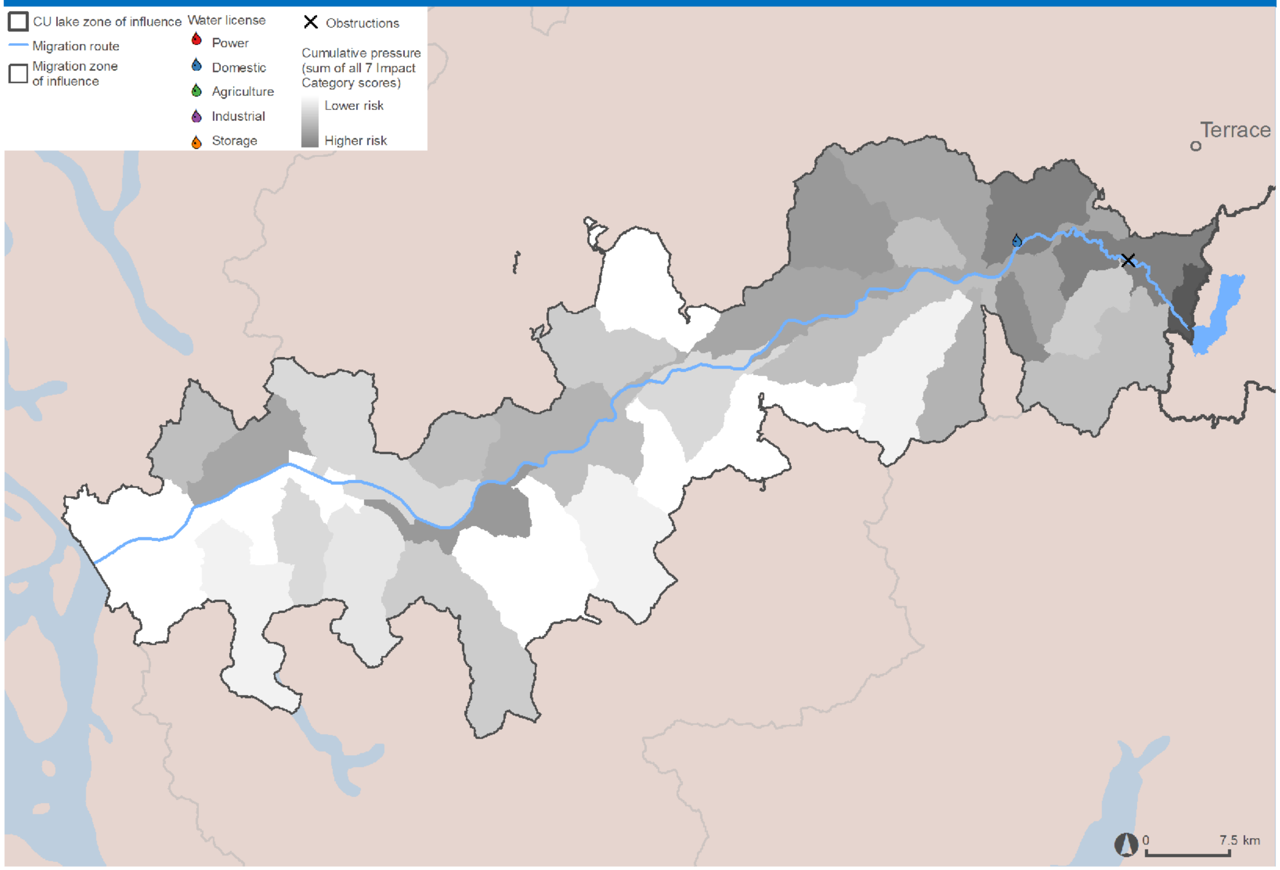


Integrated vulnerability/habitat pressures—migration, spawning, & rearing

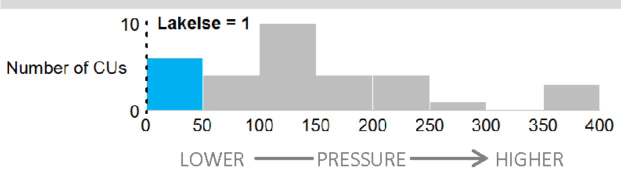


Migration vulnerability & pressure

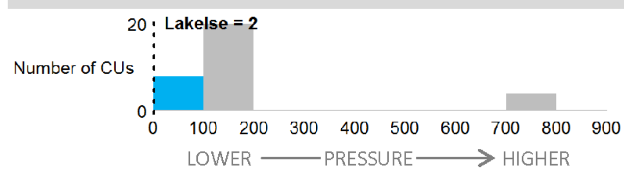
Migration period pressures



Number of obstructions along migration route

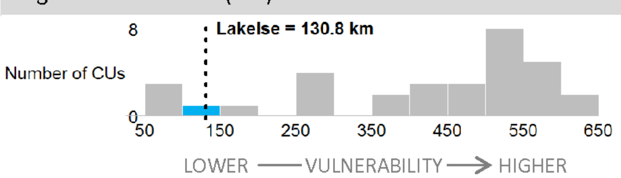


Number of water licenses along migration ZOI

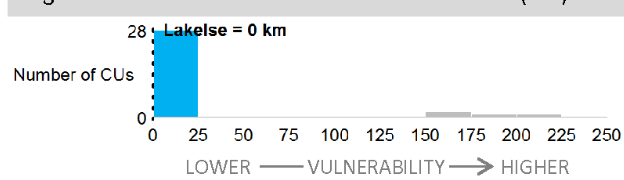


Migration period vulnerability

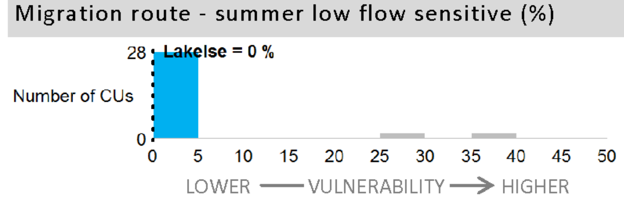
Migration distance (km)



Migration route - summer low flow sensitive (km)



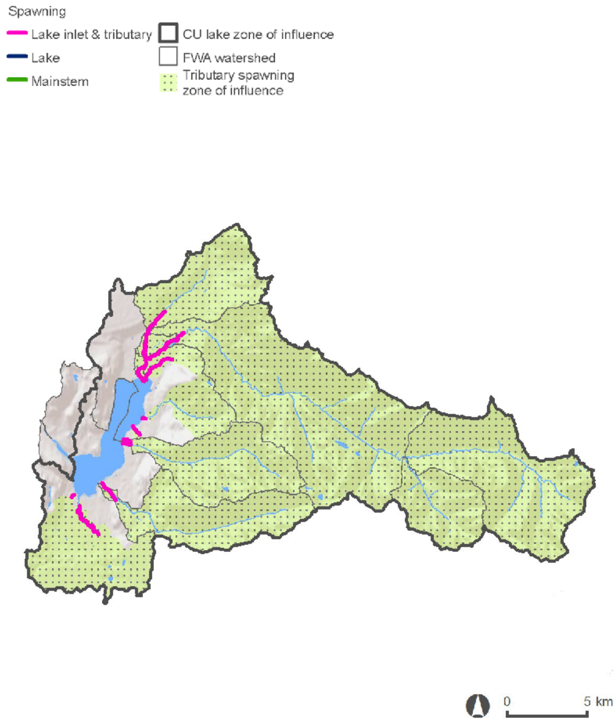
Migration route - summer low flow sensitive (%)



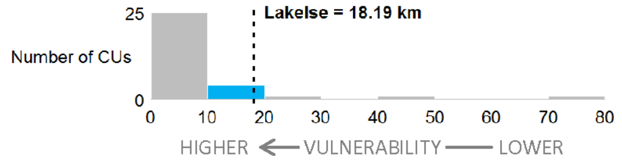
Spawning & rearing vulnerability

Spawning period vulnerability

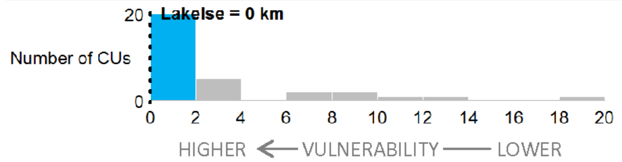
Spawning locations



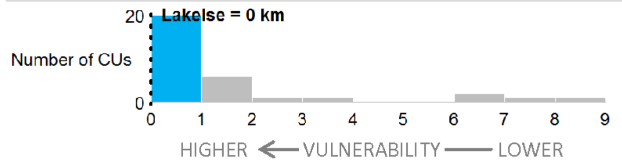
Total (mainstem, trib & lake) spawning length (km)



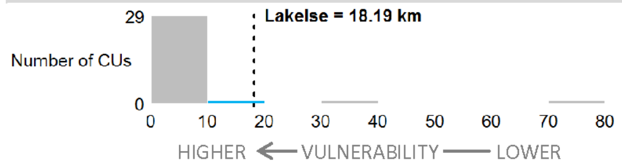
Length of lake shore spawning areas (km)



Mainstem spawning length (km)

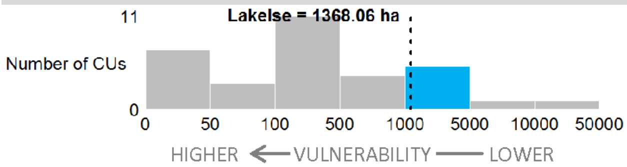


Tributary and lake inlet spawning length (km)

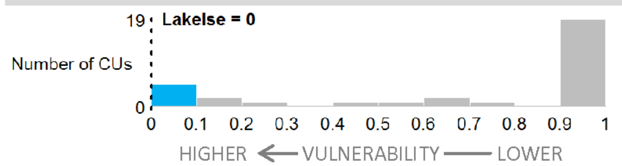


Rearing period vulnerability

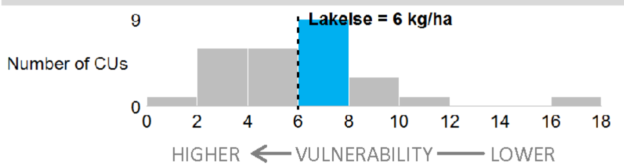
Area of nursery lakes (ha)



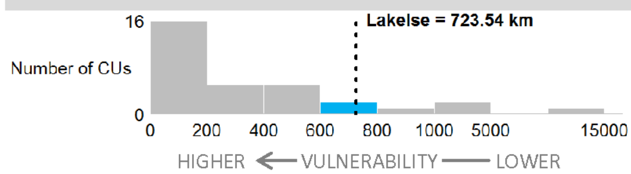
Ratio of lake influenced to total spawning



Nursery lake productive capacity (Rmax est. kg/ha)



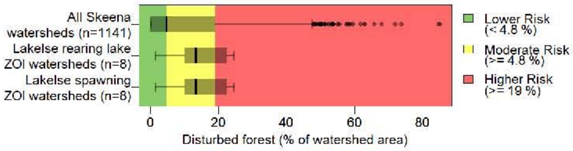
Fish accessible habitat (km)

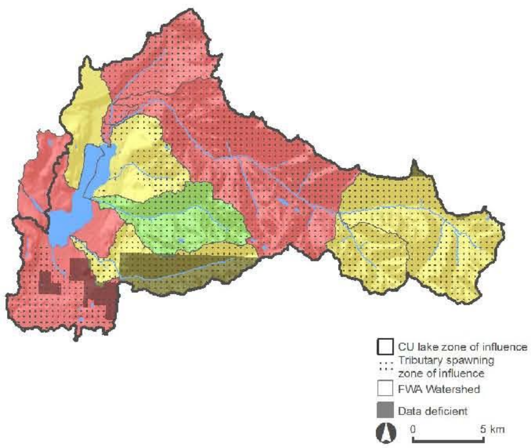


Spawning & rearing pressure

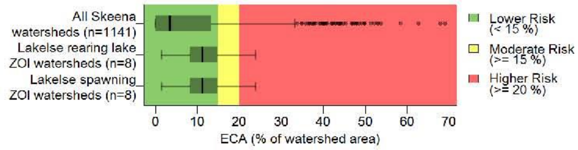
Hydrologic Processes

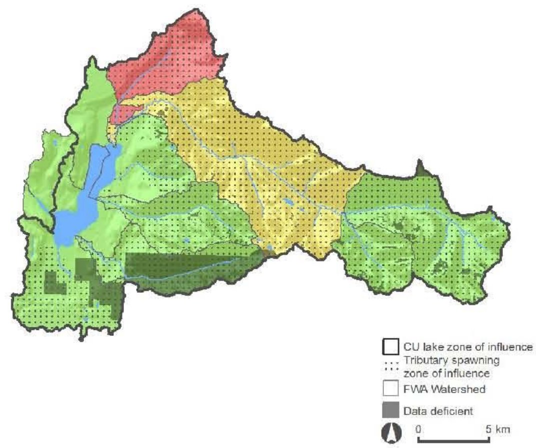
Forest disturbance





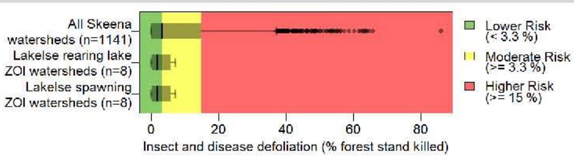
Equivalent Clear-cut Area

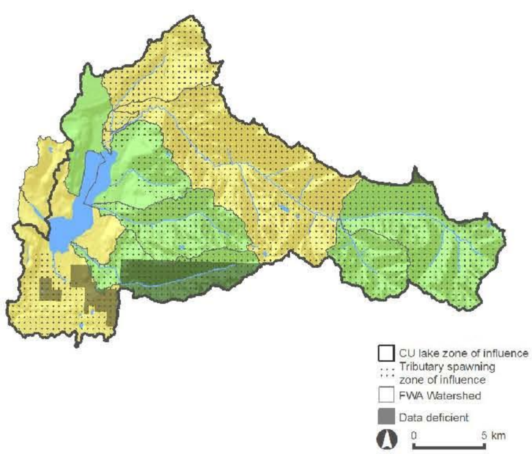




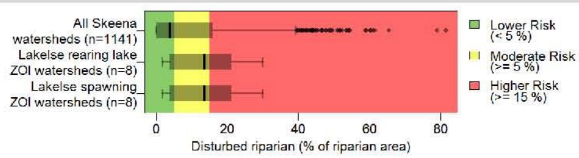
Vegetation Quality

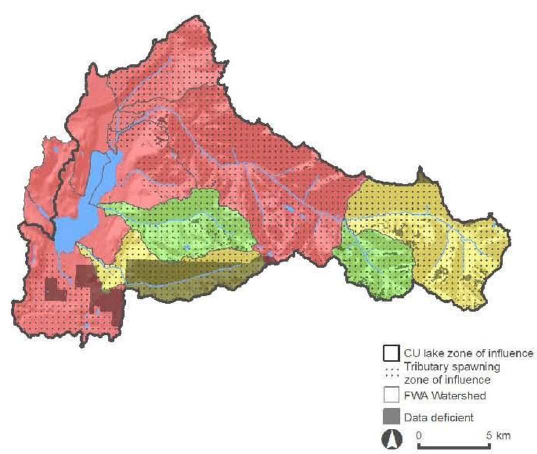
Insect and disease defoliation





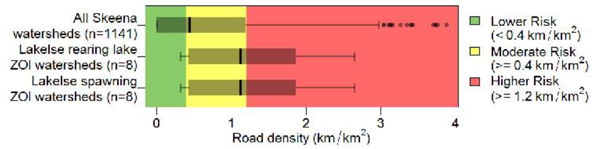
Riparian disturbance

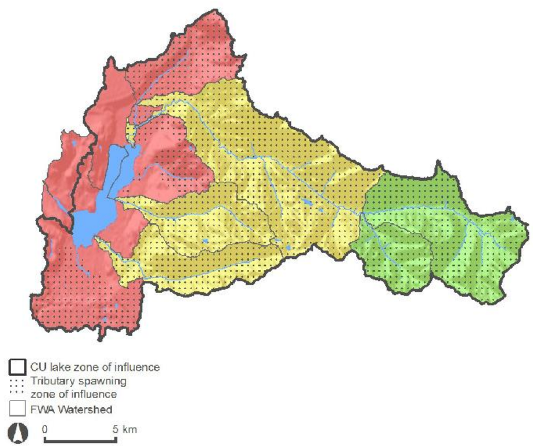




Surface Erosion

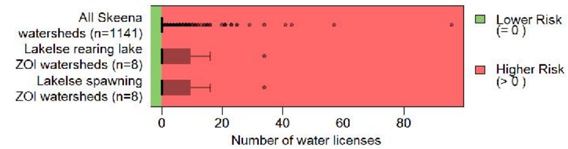
Road development

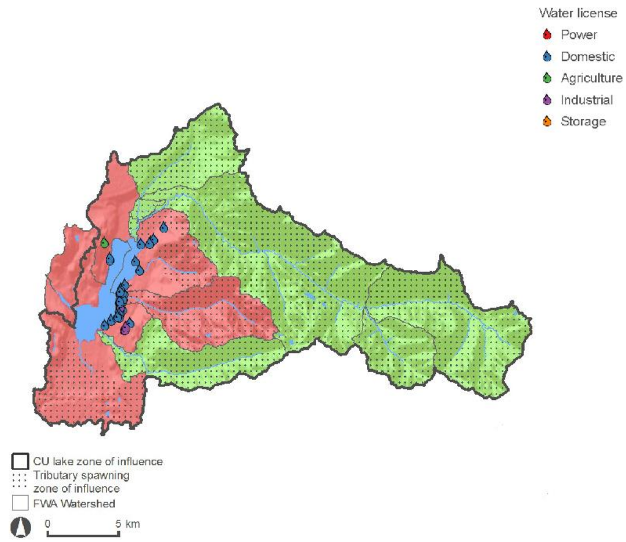




Water Quantity

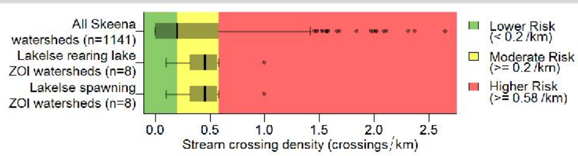
Number of water licenses

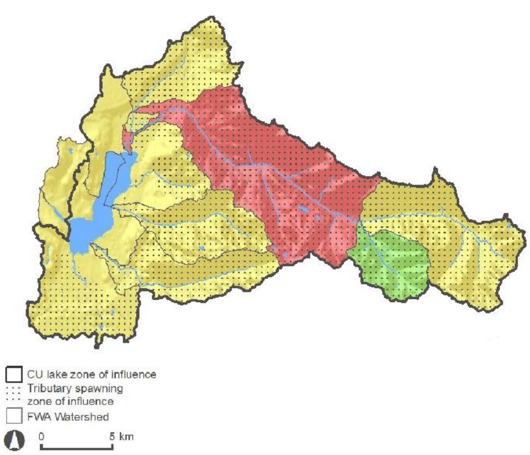




Fish Passage/Habitat Connectivity

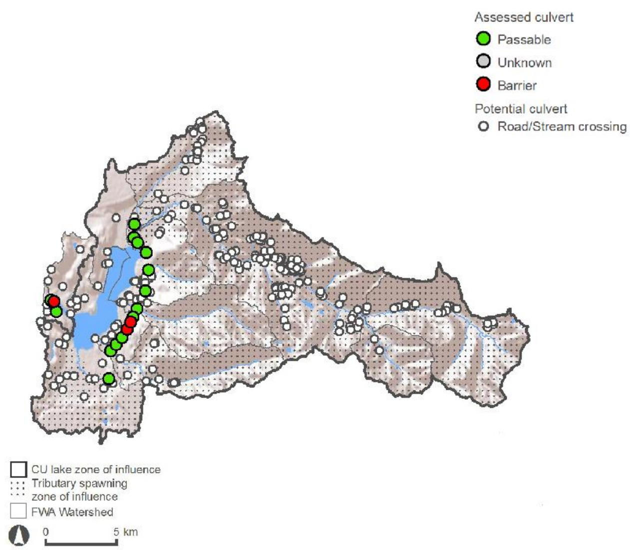
Stream crossing density





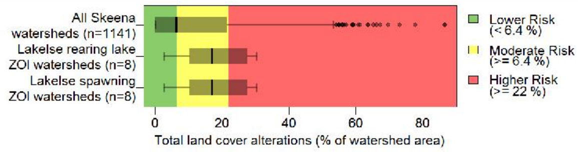
Culvert passability

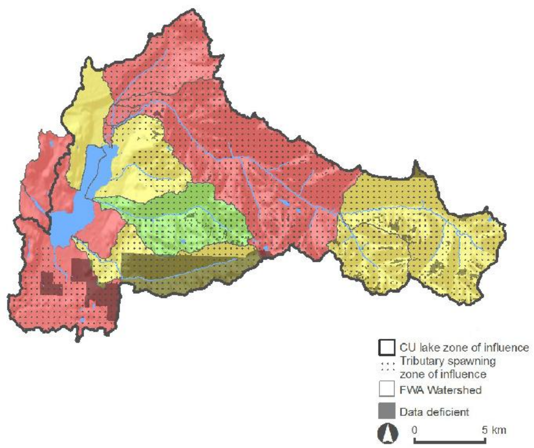
Stream crossings assessed in local Skeena Fish Passage and Culvert Inspection (FPCI) reports.



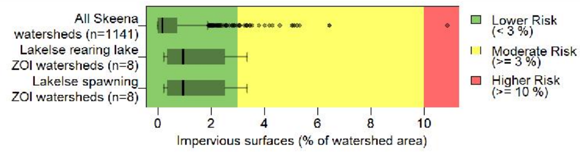
Human Development Footprint

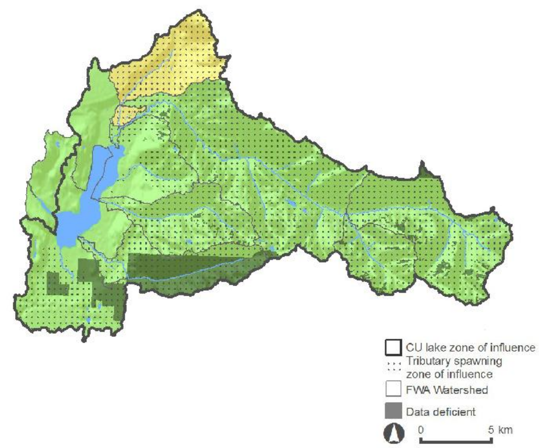
Total land cover alteration



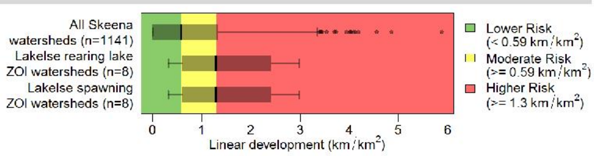


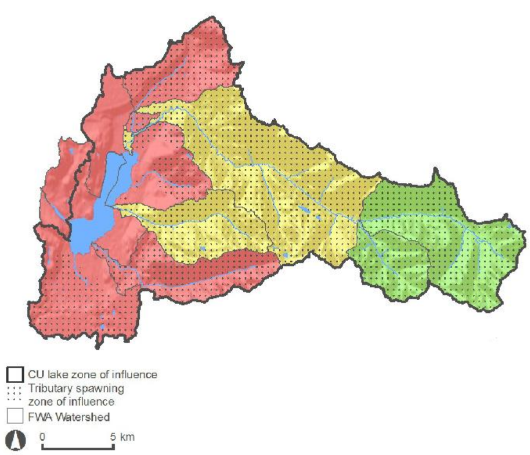
Impervious surfaces



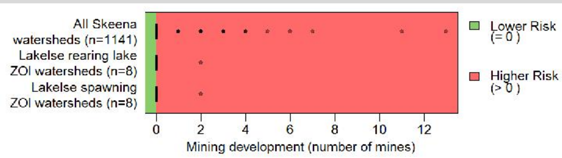


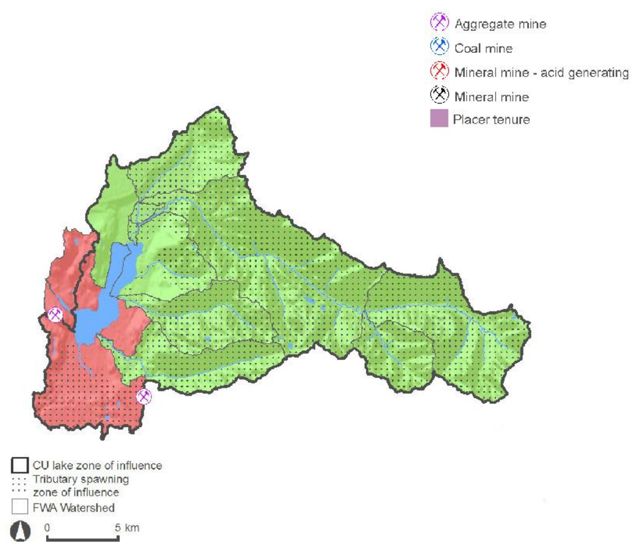
Linear development





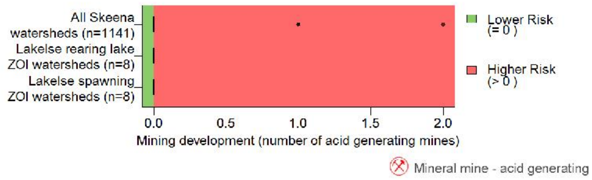
Mining development (total number of mines)

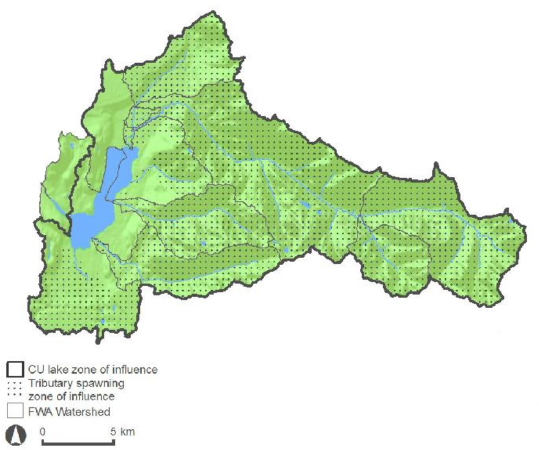




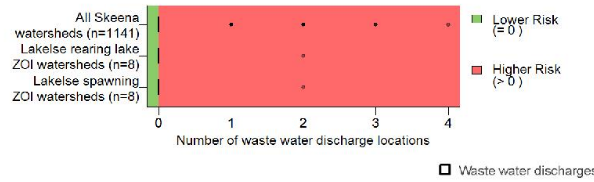
Water Quality

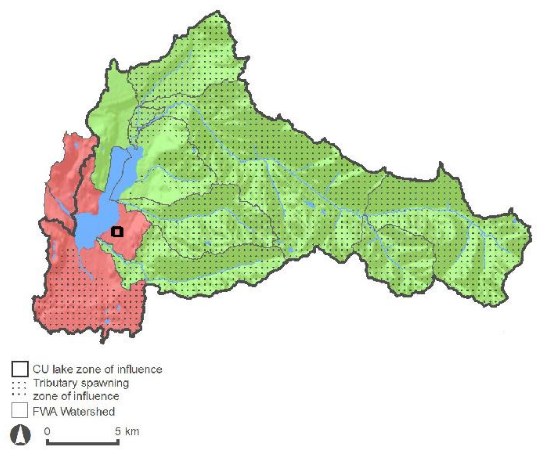
Mining development (acid generating mines)





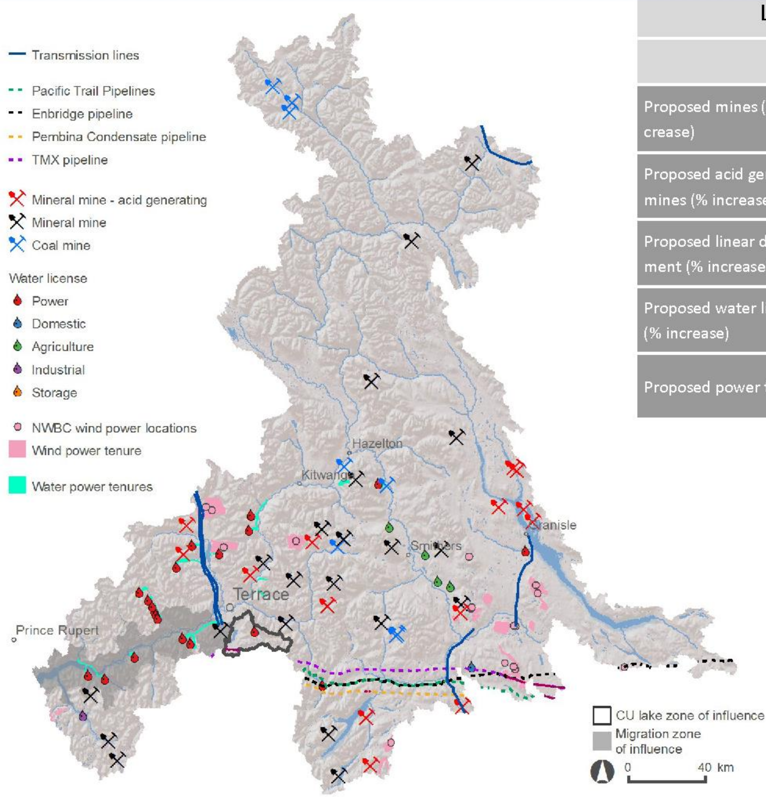
Permitted waste water discharges





Future pressure

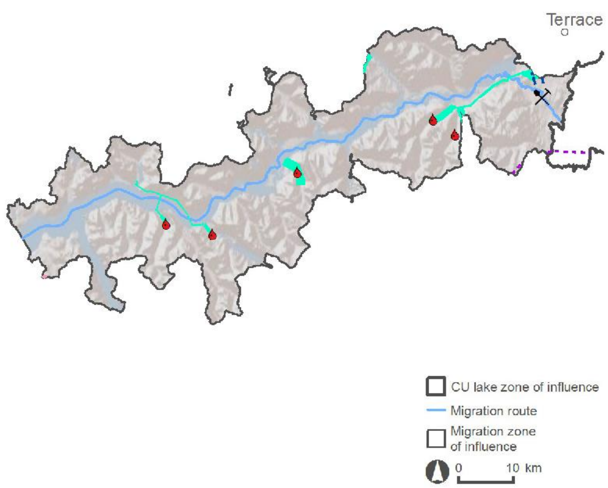
Proposed resource development projects (as of 2010)



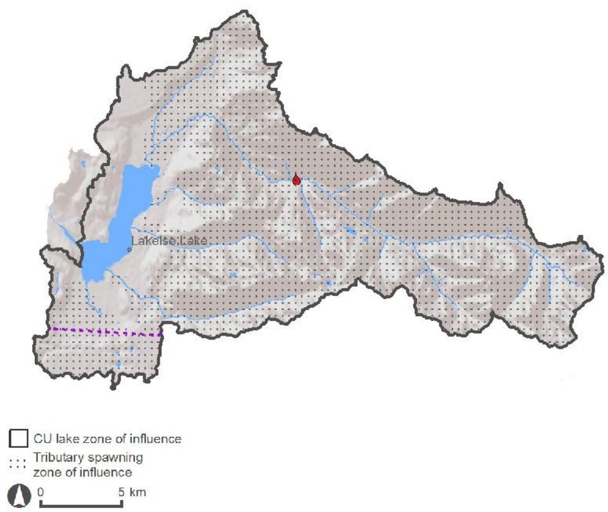
Lakelse Lake Sockeye CU summary

	Migration	Spawning	Rearing
Proposed mines (% increase)	1 (10%)	0 (0%)	0 (0%)
Proposed acid generating mines (% increase)	0 (0%)	0 (0%)	0 (0%)
Proposed linear development (% increase)	0.01 km/km^2 (0.6%)	0.02 km/km^2 (1.1%)	0.02 km/km^2 (1.1%)
Proposed water licenses (% increase)	7 (19%)	2 (4%)	2 (4%)
Proposed power tenures	38.25 km^2	0 km^2	0 km^2

Proposed resource development projects in the CU migration ZOI



Proposed resource development projects in the CU spawning and rearing ZOI



Appendix 5. Skeena lake sockeye CU Habitat Report Card Summary

Skeena Salmon

CU Habitat Report Card Summaries

Version 1.1, August 2013

These CU habitat report cards are intended to allow assessment and comparison of CU habitat 'status' based on a combination of: (1) intrinsic vulnerability of CU freshwater habitats and (2): intensity and extent of human pressures/stressors on those habitats. A full description of indicators and data sources used can be found in the main report (*Skeena Lake Sockeye Conservation Units: Habitat Report Cards*. Porter et al. 2013) available from PSF at: www.skeenasalmonprogram.ca.

Page 1

1. Introduction and Definitions. Brief description of the CU reporting exercise being undertaken for assessing sockeye CU habitats and definitions for key terms that are used throughout the reporting.

2. CU narratives. Short bulleted descriptions of key issues affecting the CU. This includes the principal habitat pressures on CU habitats as determined from the broad-scale analyses undertaken here, as well as more localized habitat impacts affecting the CU as identified by Skeena regional experts.

3. Location (a): Map showing location of the CU rearing lake within the Skeena drainage, and the location of the Skeena drainage within BC. The nursery lake is shaded blue and its defined 'zone of influence' (ZOI) is indicated in black outline. The migration route between the mouth of the Skeena River and the CU rearing lake outlet is indicated by the blue river line.

4. Location (b): More detailed zoomed map of the CU rearing lake showing general features of the area and the defined 'zone of influence' (ZOI) capturing the drainage area upstream from the rearing lake outlet (black outline).

Page 2

CU overview of habitat vulnerabilities & pressures

5. Description of terms. Identification of the GIS-based habitat pressure indicators, habitat pressure 'Impact Categories', and habitat vulnerability indicators developed and used for analyses of sockeye CU habitat status.

6. Cumulative habitat pressures (migration corridor). Map of cumulative habitat pressure scores for watersheds located along the CU migration corridor zone of influence[1]. Given the more diffuse nature of potential impacts along the migration route cumulative pressures scores are assigned to migration corridor watersheds based on the sum of the seven individual Impact Category scores for each watershed (rather than through a categorical rule set across Impact Categories)[2]. Within each watershed each Impact Category is scored as 0 (for a green Impact Category), 1 (for an amber Impact Category) or 2 (for a red Impact Category). The cumulative pressure scores for the migration corridor watersheds can therefore range from 0 to 14 and are colour gradated accordingly. Darker shaded watersheds represent areas along the migration corridor where relatively higher risk habitat impacts may be occurring.

7. CU rearing lake pressures overview 'slider'. Area weighted average of all watershed pressure indicator scores for 1:20K FWA assessment watersheds within or intersecting the CU rearing lake's ZOI. The area weighted average score is normalized for each indicator so that the lower to moderate risk threshold (t_1) occurs at 0.33 (s_m) and the moderate to higher risk threshold (t_2) is at 0.66 (s_h) on a scale of 0 to 1[3]. The greyed areas within the figure represent the separation of the individual indicators into the seven Impact Category groupings.

[1] The zone of influence for the migration corridor is defined as the 1:20K FWA assessment watersheds that either directly adjoin the CU's mainstem migration route (from lake outlet to Skeena River estuary) or that are located within 1 km of the mainstem route

[2] Note that the scoring approach to risk classifications (green, amber, red) for each Impact Category is based on the same defined indicator roll-up rule set that is used for watersheds within spawning and rearing ZOIs.

[3] Where the average score $\bar{s} < t_1$, the normalized score $\bar{s}_n = \bar{s}(0.33/t_1)$; where $\bar{s} \geq t_1$, $\bar{s}_n = s_m + (s_h - s_m)[(\bar{s} - t_1)/(t_2 - t_1)]$.

8. Cumulative habitat pressures (rearing lakes & tributary spawning). Map of cumulative risk from habitat pressures for each watershed found with the ZOIs for CU rearing lakes and tributary spawning areas[4]. The cumulative risk rating is based on the risk scoring of 7 habitat pressure indicator Impact Categories (hydrologic processes, vegetation quality, surface erosion, fish passage/habitat connectivity, water quantity, human development footprint, and water quality). Categorical roll-up rule set for watersheds in rearing & spawning zones of influence: if ≥ 3 impact categories are rated as higher risk, then the watershed's cumulative risk classification = red (higher risk), else if ≥ 5 Impact Categories are rated as (lower risk) then the watershed's cumulative risk classification = green (lower risk), else the watershed's cumulative risk classification = amber (moderate risk).

9. Integrated vulnerability/habitat pressures – migration, spawning & rearing. Figures representing bivariate indices of the relative rankings across Skeena sockeye CUs for scored cumulative habitat pressures and scored vulnerability to these pressures within sockeye CU ZOIs for migration, spawning and rearing. Methods used for selecting scored CU cumulative habitat pressures and vulnerabilities are different for each life stage evaluated (see Porter et. al. 2013a). The larger solid blue circle in each figure represents the ranking of the particular CU relative to the other Skeena sockeye CUs and identifies its ranked position relative to a coloured gradation representing both increasing cumulative habitat pressure and increasing vulnerability to those pressures.

Page 3

Migration vulnerability and pressure

Migration period pressure

10. Migration period pressures. Detailed map of the sockeye CU migration corridor showing cumulative risk scoring, the location of water licenses occurring within migration corridor ZOI watersheds, as well as the locations of identified obstructions along the CU migration route.

11. Number of obstructions. Total number of obstructions identified along the CU migration route. Obstructions can directly impede, delay or even block passage of adult migrating salmon. The figure indicates the total number of identified obstructions along the CU migration route and illustrates the intensity of this pressure (blue bar graph) relative to other sockeye CUs within the Skeena drainage. Data source: Provincial Obstacles to Fish Passage [updated daily – downloaded Dec 2012].

12. Licensed water allocations. Total number of permitted water licenses (for all activities) in watersheds within the migration corridor ZOI. Diverting water for human uses can reduce water flow in streams for fish at critical times, potentially hindering/delaying the passage of migrating adult salmon and/or increasing migration stress. The figure indicates the total number of water licenses within the CU migration route ZOI and illustrates the intensity of this pressure (blue bar graph) relative to other sockeye CUs within the Skeena drainage. Data source: BC POD with Water License Information [updated daily – Downloaded Dec 2012].

Migration period vulnerability

13. Migration distance. Total extent of CU migration, measured as distance between the mouth of the Skeena River and most downstream entrance to the CU nursery lake. Longer migrations increase the risk of exposure to various stressors along the migration route. The figure indicates the total migration distance for the CU and shows the degree of this vulnerability (blue bar graph) relative to other sockeye CUs within the Skeena drainage. Data source: DFO_BC_Sockeye_Lake_CU_V2 [2010], FWA Stream Network [2008].

14. Migration route – summer low flow sensitive (km). The total distance of the CU migration route that is considered prone to experiencing low summer water flows with associated potential for higher water temperatures. Low flow conditions experienced over extended distances can impact fish health and can increase encounters with flow related obstacles/delays to adult fish passage. The figure indicates the total migration distance for the CU that is considered to be within a zone of summer low flow sensitivity and illustrates the degree of this vulnerability (blue bar graph) relative to other sockeye CUs within the Skeena drainage. Data source: BC MOE ecoregional flow sensitivity map [Feb 23 2011].

15. Migration route – summer low flow sensitive (%). The total proportion of the CU migration route that is considered prone to experiencing low summer water flows with associated potential for higher water temperatures. Low flow conditions over extended distances can impact fish health and create obstacles/delays to adult fish passage. The figure indicates the total proportion of the CU migration route that is considered to be within a zone of summer low flow sensitivity and illustrates the degree of this vulnerability (blue bar graph) relative to other sockeye CUs within the Skeena drainage. Data source: [BC MOE ecoregional flow sensitivity mapping [Feb 23 2011].

[4] The zone of influence (ZOI) for the CU rearing lake is defined as encompassing all the 1:20K FWA fundamental watersheds located upstream from the lake outlet to the bounding height of land defining the drainage area. The ZOI for a tributary spawning area is defined as the 1:20K FWA assessment watershed in which spawning is occurring and all FSW watersheds upstream of the spawning watershed to the bounding height of land defining the drainage area.

Page 4

Spawning and rearing vulnerability

Spawning period vulnerability

16. Spawning locations. Map of known spawning sites for lake sockeye (lake, mainstem, and lake inlet/tributary spawning locations) within the defined CU rearing lake ZOI. Data source: Skeena TAC [Dec 2012].

17. Total spawning length. The total length of all sockeye spawning reaches within the CU rearing lake ZOI (lake, mainstem or tributary spawning). Areas of lake spawning are also included and expressed as a linear length. This reflects the total amount of habitat known to be used for spawning by Skeena lake sockeye, with a greater length of spawning habitat indicating a lower CU vulnerability to habitat pressures.The figure indicates the total spawning length within the CU rearing lake ZOI and illustrates the degree of this vulnerability (blue bar graph) relative to other sockeye CUs within the Skeena drainage. Data source: Skeena TAC [Dec 2012].

18. Lakeshore spawning length. The total length of lake shore spawning occurring within the CU rearing lake. Areas of lake shore spawning are expressed as a linear length. This reflects the total amount of lake shore habitat known to be used by Skeena lake sockeye, with a greater length of spawning habitat indicating a lower CU vulnerability to habitat pressures.The figure indicates the lakeshore spawning length within the CU rearing lake and illustrates the degree of this vulnerability (blue bar graph) relative to other sockeye CUs within the Skeena drainage. Data source: Skeena TAC [Dec 2012].

19. Mainstem spawning length. The total length of all mainstem spawning reaches within the CU rearing lake ZOI. This reflects the total amount of mainstem habitat known to be used for spawning by Skeena lake sockeye, with a greater length of spawning habitat indicating a lower CU vulnerability to habitat pressures.The figure indicates the length of mainstem spawning within the CU rearing lake ZOI and illustrates the degree of this vulnerability (blue bar graph) relative to other sockeye CUs within the Skeena drainage. Data source: Skeena TAC [Dec 2012].

20. Tributary/lake inlet spawning length. The total length all trib/lake inlet spawning reaches occurring within the CU rearing lake ZOI. This reflects the total amount of trib/lake inlet habitat known to be used by Skeena lake sockeye, with a greater length of spawning habitat indicating a lower CU vulnerability to habitat pressures.The figure indicates the trib/lake inlet spawning length within the CU rearing lake ZOI and illustrates the degree of this vulnerability (blue bar graph) relative to other sockeye CUs within the Skeena drainage. Data source: Skeena TAC [Dec 2012].

21. Ratio of lake influenced to total spawning. The total length of spawning reaches that are buffered by lake influence (i.e., lake shore or mainstem spawning) relative to the total length of all spawning reaches within the CU rearing lake ZOI. This reflects the effect of lakes to buffer against upstream habitat impacts, such that lake-influenced spawning areas would be considered relatively less vulnerable to disturbances than tributary/lake inlet spawning areas. The figure indicates the lake influenced ratio within the CU rearing lake ZOI and illustrates the degree of this vulnerability (blue bar graph) relative to other sockeye CUs within the Skeena drainage. Data source: Skeena TAC [Dec 2012].

22. Fish accessible habitat. The total length all 1:20K defined stream reaches occurring within the CU rearing lake ZOI that are considered accessible to salmonids. This reflects the total amount of stream habitat that could 'potentially' be available to salmonids for spawning or rearing, with a greater accessible length indicating a lower CU vulnerability to habitat pressures. The figure indicates the accessible habitat length within the CU rearing lake ZOI and illustrates the degree of this vulnerability (blue bar graph) relative to other sockeye CUs within the Skeena drainage. Data source: BC MOE Fish Passage layer [Oct 2011]. Note that this layer is based on a model that defines stream accessibility to salmonids in general and is not specific to sockeye passage abilities/constraints.

Rearing period vulnerability

23. Area of nursery lakes. Total area of the sockeye CU nursery/rearing lake. Larger rearing lakes generally can provide more habitats to support a greater number of juvenile sockeye and should be more resilient to localized habitat impacts. The figure indicates the size of the CU rearing lake and illustrates the degree of this vulnerability (blue bar graph) relative to other sockeye CUs within the Skeena drainage. Data source: DFO_BC_Sockeye_Lake_CU_V2 [2010].

24. Nursery lake productivity. The annual biomass of smolts that could theoretically be produced in the CU nursery lake based on DFO's current photosynthetic rate (PR) model for estimating the intrinsic rearing capacity of Skeena lakes. Productivity (based on the amount of nutrients available) reflects the potential for growth and survival of juvenile sockeye, with more productive lakes presumably more resilient to localized habitat impacts. The figure indicates the estimated productivity of the CU rearing lake and illustrates the degree of this vulnerability (blue bar graph) relative to other sockeye CUs within the Skeena drainage. Data source: DFO - S. Cox-Rogers et al. [2010, 2012].

Page 5

Spawning and rearing pressure

Hydrologic Processes

25. Forest disturbance. Percentage of disturbed forest (recently logged, selectively logged, and recently burned) in each watershed within the CU rearing lake and spawning areas ZOIs. Forest disturbance can impact salmon habitat through general changes to flow patterns and annual water yields. Defined benchmarks of concern (lower, moderate, higher) for forest disturbance are based on the relative distribution of values across all Skeena watersheds. Data source: VRI [updated annually, downloaded Dec 2012], RESULTS [updated daily, downloaded Dec 2012], FTEN [updated daily, downloaded Dec 2012].

26. Equivalent Clear-cut Area (ECA). The percentage of each watershed in the CU rearing lake and spawning areas ZOIs that is considered functionally/hydrologically equivalent to a clear-cut. ECA is a calculated term that reflects the potential cumulative impact on fish habitats of harvesting and second-growth forest regeneration effects on peak flow. Defined benchmarks of concern (lower, moderate, higher) for ECA are science and expert based (MOF 2001; Smith and Redding 2012). Data source: VRI [updated annually, downloaded Dec 2012], RESULTS [updated daily, downloaded Dec 2012], FTEN [updated daily, downloaded Dec 2012], LCC2000-V [2000].

Vegetation Quality

27. Insect & disease defoliation. Percentage of the forest stands in each watershed within the CU rearing lake and spawning areas ZOIs that has been defoliated by recent insect invasion or disease. Defoliation can impact salmon habitats through changes to flows and groundwater supplies from altered precipitation interception and reduced transpiration. Defined benchmarks of concern (lower, moderate, higher) for insect and disease defoliation are based on the relative distribution of values across all Skeena watersheds. Data source: VRI [updated annually, downloaded Dec 2012].

28. Riparian disturbance. Percentage of the riparian zone (defined by a 30m buffer around all water bodies) in each watershed within the CU rearing lake and spawning areas ZOIs that has been altered by land use activities. Disturbance to the riparian zone can alter stream shading, water temperature, organic matter inputs and bank stability. Defined benchmarks of concern (lower, moderate, higher) for riparian disturbance are science and expert based (Stalberg et al. 2009, Tripp and Bird (2004). Data source: VRI [updated annually, downloaded Dec 2012].

Page 6

Surface Erosion

Water Quantity

29. Road development. The density of all roads in each watershed within the CU rearing lake and spawning areas ZOIs. Extensive road development can interrupt overland flow and increase fine sediment generation, impacting downstream spawning and rearing habitats. Defined benchmarks of concern (lower, moderate, higher) for road density are science and expert based (MOF 1995a &b, Stalberg et al. 2009 & Porter et al. 2013a). Data source: DRA [updated monthly, downloaded Dec 2012], FTEN [updated daily, downloaded Dec 2012].

30. Water licenses. The total number of permitted water licenses (all types) for points of diversion in each watershed within the CU rearing lake and spawning areas ZOIs. Diverted water can potentially reduce flows in streams, thereby limiting fish access to or use of habitats and/or changing hydrological processes. The defined benchmark of concern (lower & higher) for water licenses is a binary measure based simply on presence/absence of the pressure in the watershed. Data source: BC Points of Diversion with Water License Information [updated daily, downloaded Dec 2012].

Fish Passage/Habitat Connectivity

31. Stream crossing density. Number of crossings per km of defined fish habitat in each watershed within the CU rearing lake and spawning areas ZOIs. Obstructions at stream crossings can impact salmon habitat conditions and hinder migration of fish or block access to useable habitats. Defined benchmarks of concern (lower, moderate, higher) for stream crossing density are based on the relative distribution of values across all Skeena watersheds. Data source: BC MOE Fish Passage layer [Oct 2011], FWA Stream Network [2008], DRA [updated monthly, downloaded Dec 2012].

32. Culvert passability. Fish passage classifications (passable - green, barrier - red, unknown - grey) for stream crossings that have been surveyed using provincial PSCIS culvert assessment protocols within the CU rearing lake and spawning areas ZOIs. Stream crossings on DRA defined roads that have not yet been surveyed are indicated by white circles. Data source: BC MOE PSCIS layer [Oct 2011], Skeena TAC [March 2013].

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Human Development Footprint

33. Total land cover alteration. Land alteration (agriculture, residential/agriculture mix, recently burned, recently logged, selectively logged, mining, recreation, and urban) as a percentage of watershed area for each watershed within the CU rearing lake and spawning areas ZOIs. Land cover alteration reflects a suite of potential changes to hydrological processes and sediment generation, with potential downstream impacts on spawning and rearing habitats. Defined benchmarks of concern (lower, moderate, higher) for land cover alteration are based on the relative distribution of values across all Skeena watersheds. Data source: LCC2000-V [2000], VRI [updated annually, downloaded Dec 2012], DRA [updated monthly, downloaded Dec 2012], FTEN [updated daily, downloaded Dec 2012], RESULTS [updated daily, downloaded Dec 2012], NTS [1998], Crown Tenure [updated daily, downloaded Dec 2012], Current Fire Perimeters [updated daily, downloaded Dec 2012], Historical Fire Perimeters [updated monthly, downloaded Dec 2012], BTM [1992].

34. Impervious surfaces. Percentage of each watershed within the CU rearing lake and spawning areas ZOIs that is considered impervious: a calculated term that reflects the area covered by hard man-made surfaces (e.g. asphalt, concrete, brick, etc.). Extensive impervious surfaces from urban/rural development in a watershed can impact rainwaters infiltration and groundwater recharge, and lead to stream habitat degradation through changes in geomorphology and hydrology. Impervious surfaces are also associated with increased loading of nutrients and contaminants in developed areas. Defined benchmarks of concern for impervious surfaces (lower, moderate, higher) are science and expert based (Paul and Meyer 2000; Smith 2005). Note that impervious surface co-efficients (ISC) for land surface types used for this exercise were not Skeena drainage specific but were instead generalized from those used in other jurisdictions. Data source: LCC2000-V [2000], VRI [updated annually, downloaded Dec 2012], DRA [updated monthly, downloaded Dec 2012], FTEN [updated daily, downloaded Dec 2012], NTS [1998].

35. Linear development. Density of all linear construction (e.g. roads, utility corridors, pipelines, right of ways, railways, etc.) in each watershed within the CU rearing lake and spawning areas ZOIs. Linear development is a general indicator of potential human impacts on fish habitats. Defined benchmarks of concern (lower, moderate, higher) for linear development are based on the relative distribution of values across all Skeena watersheds. Data source: DRA [updated monthly, downloaded Dec 2012], FTEN [updated daily, downloaded Dec 2012], NTS [1998].

36. Mining development (all mines). Total number of mines in each watershed within the CU rearing lake and spawning areas ZOIs. The general footprint of a mine and its associated processes of mining can change geomorphology and the hydrological processes of nearby water bodies. Mining can also generate deposition of fine sediments which can affect salmon survival and prey densities. The defined benchmark of concern (lower & higher) for mines is a binary measure based simply on presence/absence of the pressure in the watershed. Data source: BCGOV MEM & PR databases [updated regularly, accessed Dec 2012].

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Water Quality

37. Mining development (acid generating mines). Total number of acid generating mines in each watershed within the CU rearing lake and spawning areas ZOIs. Acid generating mines have increased risk for potential outflow of acidic water, heavy metals and other contaminants, with associated harm to fish habitats. The defined benchmark of concern (lower & higher) for acid generating mines is a binary measure based on presence/absence of the pressure in the watershed. Data source: BCGOV MEM & PR databases [updated regularly, accessed Dec 2012], Skeena TAC identification of acid generating mines [2012].

38. Permitted wastewater discharges. Total number of permitted wastewater discharge sites in each watershed within the CU rearing lake and spawning areas ZOIs. High levels of wastewater discharge have the potential to impact water quality through excessive nutrient enrichment or chemical contamination. The defined benchmark of concern (lower & higher) for wastewater discharge sites is a binary measure based simply on presence/absence of the pressure in the watershed. Data source: MOE Wastewater Discharge and Permits database [updated regularly, downloaded Dec 2012].

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Proposed resource development projects

39. Skeena overview map of the locations of new resource development projects proposed within the Skeena drainage (across a range of activities). Data source: Skeena TAC, extracted from multiple sources [2012].

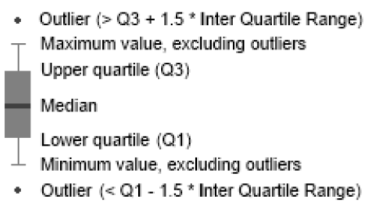
40. CU summary of resource development projects. The total number or extent of resource development related projects that are known to be proposed for future development within watersheds affecting the CU (i.e., within migration, spawning and/or rearing ZOIs) and the potential percentage increase in these pressures (if any) over the current baselines. Data source: Skeena TAC, extracted from multiple sources [2012].

41. Map of CU migration ZOI resource development projects. Detailed map showing locations of new resource development projects that have been proposed in watersheds within the CU migration ZOI. Data source: Skeena TAC, extracted from multiple sources [2012].

42. Map of CU spawning & rearing ZOIs resource development projects. Detailed map showing locations of new resource development projects that have been proposed in watersheds within the CU spawning and/or rearing ZOIs. Data source: Skeena TAC, extracted from multiple sources [2012].

Additional notes

Key to interpreting pressure indicator box plots:



Data deficient areas. Mapped areas delineated as "data deficient" are those that have incomplete coverage for the core VRI or LCC2000 GIS data used for generation of some habitat indicators. These areas are mapped explicitly to identify any watersheds that have some level of relative uncertainty around a particular habitat indicator value. These areas however have been supplemented (i.e., patched) with GIS data from alternate sources, sometimes at a coarser resolution, to allow indicator generation/scoring or else are areas lacking only minor elements of a larger suite of data components with limited influence on the final derived habitat indicator values.

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